Department of Mechanical Engineering

Energy Systems Research Unit

Sustainable Project:

Implementing Renewable Energy Technologies in NHS Dumfries and Galloway

By

Dirichi Nnaemeka Chukwu

A Thesis submitted in partial fulfilment of the requirements for the degree of MSc in Energy Systems and the Environment

December, 2007

COPYRIGHT DECLARATION

ACKNOWLEDGEMENT

I am highly indebted to God almighty for his special grace, strength and protection towards me.

My appreciation goes to all whom has contributed to the success of this master's degree course.

I wish to thank my supervisor and course director Dr Paul Strachan for his unending support, to Dr Andrew Grant for his patience and encouragement during my first semester, and to all the staff and student of the sustainable engineering in the University of Strathclyde for making my stay in Glasgow interesting.

Eva Milroy at the Graduates for Business programme, Scottish Enterprise Dumfries and Galloway for giving me information, support and advice, Mr Ian Bryden for providing this project and the necessary information on NHS Dumfries and Galloway.

And to my family, relatives, true friends and countless others who have lent their support in diverse ways, I am grateful.

DEDICATION

To my loving parents; Chief and Lolo Martins Onyemache Chukwu KSM, for all they are to me.

ABSTRACT

The objective of this work is to investigate the possibility of installing renewable energy technologies within a typical hospital environment and demonstrate a method whereby the hospital energy demand can be reduced. The study looks at the current practice of renewable energy integration in hospitals with particular focus on the UK Health Sector. A review of the framework set out by building regulations, British and European standards and other environmental regulation was undertaken. These were the guidelines of the methodology used in this study.

The thesis presents a case study on Annan hospital which is under NHS Dumfries and Galloway Trust. The literature review covers the energy sources and usage, saving potential and energy efficiency awareness in a hospital. It looks at the energy efficiency strategies, taking into account the systems used to run a typical hospital building. The building envelope and building services were considered with respect to energy efficiency. As part of the methodology used in this study, an energy management matrix was produced, followed by a simple energy audit to assess the overall building energy performance and management status. The study focuses on the energy demand reduction measures that should be applied in any hospital building before looking at ways to offset the remaining energy demand.

Different options of renewable energy technologies such as wind turbine, solar photovoltaic, biomass and ground source heat pump (GSHP) that can be applied in the case study were analysed using energy model software called RETScreen. This study recommends the use of ground source heat pumps as an alternative energy supply for heating and domestic hot water in Annan hospital due to its noiseless and non-combustion operation, less transportation involved and availability of land area. And from an economic viewpoint, it has a positive Net Present Value.

Table of Contents

Table of Figures

Tables

1 Introduction

Hospitals are institutions for the care of the sick or injured. Hospital buildings are normally occupied 24 hours per day, all year round. Hospital buildings use energy in many different ways, so have high potential for energy savings. Hospital buildings are usually large thus careful control of their internal climate is necessary. Hospitals are prone to high heat generation; this combined with good building insulation reduces the cooling effect of the external temperature on indoor temperature and air quality. This in turn increases indoor temperature and thus reduces heating requirements.

Nevertheless, since hospitals encounter numerous emergency cases daily, there is need for constant power supply, thus demand on electricity is often high. Healthcare facilities are designed to meet the requirement of the patient, to provide a good working environment for all hospital staff, visitors and other users. Provision of a conducive recovery and working environment for patients and staff is necessary as it will result to significant economic benefits through customer and employee satisfaction, such working environment can only be achieved with constant power supply. This contributes to high energy demand typical with the health sector.

Implementing energy conservation measures (ECM) in hospital buildings during construction and operation can reduce the health risks associated with pollution and climate change, protect the environment and save money via energy demand reduction. Normally, hospital buildings are designed for long term use and are often utilised far longer than anticipated by its builders. The actual active lifetime of a hospital building is frequently greater than 40 years (7), though a lot of retrofitting and renovation often takes place during its life time and these present an opportunity for implementing or improving energy efficiency measures. However, energy efficiency measures can be incorporated into the design of new buildings. For instance, buildings can be designed to use natural light and ventilation reducing the need for electrical lighting and air conditioning, which accounts for over 50% of the primary energy use in a typical hospital (2, 7).

Capital investments in energy saving design and controls can be recovered through lower operating costs.

Most countries are evolving methods for encouraging or enforcing national energy efficiency in buildings. The European Union, for example, has issued a Directive for Energy Performance in buildings (EPBD) which obliges member states to have appropriate regulation and systems in place to ensure that the overall objective of saving fuel and energy are met. The United Kingdom and the Republic of Ireland have chosen to use their building codes and regulation to help control energy use and carbon emissions [(32)].

Buildings generate 46% of the UK's carbon dioxide emissions [(2, 7, 76)], the main gas contributing to climate change. In England, energy use by the health sector produces about 3.47 million tonnes of carbon dioxide a year [(69)]. Estimates show that admissions to hospitals linked to air pollution costs the NHS between £17-60 million a year [(69)], thus the need to reduce air pollution.

Overall performance indices (environmental and cost) provide a single measure of building performance, and can be expressed in terms of carbon dioxide (CO_2) emissions or energy cost. Overall energy indices are useful for comparing a stock of buildings or for assessing the performance of buildings with electric heating or combined heat and power (CHP) [(81)].

Apart from implementing energy efficiency measures, implementing renewable energy technology is a way of further reducing CO_2 emissions. However, in order to implement a renewable energy supply option for a building, separate fossil fuel and electricity performance indices are more useful to assist in deciding a course of action. Thus the very high energy consumption potential of the health care sector makes renewable energy technology an attractive option for this sector.

1.1 Project Aim

The primary aim of the project is to develop a procedure for assessing energy efficiency and renewable energy options for the health care sector. In order to actualise these the NHS Dumfries and Galloway are very interested in carrying out a feasibility study looking at the introduction of renewable energy systems into its community hospitals and health centres and Annan hospital was used in this study as a case study.

1.2 Project Objective

The aim of this research was realised by achieving the following objectives in Annan hospital:

- Test the effectiveness of the proposed procedure for assessing energy efficiency and renewable energy options in the health care sector
- To determine the current energy demand and CO_2 emissions in Annan hospital
- To determine possible energy demand reduction measures
- To determine a suitable renewable energy technology option for Annan hospital

1.3 Report Description

Chapter 1 sets out the problem of large energy consumption and CO_2 emissions typical with the health sector and its impact on climate change, thus establishing the need for implementing energy efficient measures and renewable energy.

Chapter 2 of this report is the literature review and it expounds on typical energy consumption in the health sector, available renewable energy technologies in the UK, statutory requirements and other factors that drive the implementation of renewable energy technologies in buildings. This chapter also goes further to review some case studies of successful renewable energy projects within the health sector.

Chapter 3 touches on different methods for monitoring and controlling a building's energy performance; it also describes different methods that can be used to evaluate the economic benefits of energy efficiency or renewable energy projects.

Chapter 4 proposes a method for assessing energy efficiency and renewable energy options for the health care sector and details all the methods utilised to achieve the aims and objectives of this research. This chapter also goes further to give a brief description of RETScreen, the software used in assessing the most suitable renewable options for the hospitals of NHS Dumfries and Galloway

Chapter 5 tests the proposed procedure on the case study (Annan hospital) and reports the findings of the energy audit and RETScreen analysis and proffers recommendations for energy reduction and the most suitable renewable energy option.

Chapter 6 gives a brief description of the environmental concerns and benefits associated with renewable energy projects. Finally the report is concluded in chapter 7.

2 Literature Review

2.1 Introduction

Energy is a critical requirement for hospital management. With increased pressures on services; extra reliance on computers; more air-conditioning coupled with inefficient and ageing buildings, energy consumption is always increasing. At the same time, the cost and unreliable supply of fossil fuels coupled with the increased requirements of current legislations hospitals are compelled to look towards an alternative energy plan.

In a January report issued by DTI [(24)], average energy prices in 2006 increased by 30% from the third quarter of 2005. Although a new NHS Purchasing and Supply Agency framework for purchasing electricity was agreed from October 2004 for three years - shielding the NHS from further rises in electricity prices. With this the NHS was able to reduce electricity consumption by 29 percent as well as consumption of gas by approximately 46 percent [(54)].

Since 1990 there has been a significant switch in the fuel mix for electricity generation as shown in Table 1. The main changes that have taken place include a general rise in nuclear capability for the first half of the decade, a considerable rise in the use of gas in combined cycle gas turbines, and a consequential fall in the amount of coal used [(23)].
Oil has fallen from 11% to under 2% in the same period. In the future, the nuclear component is set to fall as the ageing stations are closed, and by 2025, it is likely that the nuclear capability will be under 1200 MW unless new stations are built. In Scotland the fuel mix has always been different with just under 54% of electricity generated from non fossil fuels. The current nuclear generation in Scotland is around 44%, while hydro produces around 10% [(65)].

Also, there has been a requirement since April 1st 2002 for a specific proportion of electricity to be generated from new renewable sources [(34)]. This proportion is set to increase steadily up to 10.4% by 2010. Currently there is insufficient renewable generation available to satisfy these requirements, and consequently suppliers must pay the so-called buy-out charge if they fail to obtain sufficient renewable energy. This means that the full reductions seen in the wholesale price of green energy are unlikely to be seen by the consumers, and as the Renewable Obligation are set to increase, the consequence of the buy-out may cause the prices to consumer to rise and any further price reductions from NETA (The New Electricity Trading Arrangements) may be limited. The health sector being such a major consumer of energy, can cut down expenses accrued from buy-out charges and green electricity tariffs by implementing renewable energy.

Energy Source	**Electricity**	**Average for UK (for comparison)**
Coal	47.0%	35.2%
Natural Gas	42.7%	36.8%
Nuclear	2.9%	20.9%
Renewable	6.6%	4.2%
Other	0.8%	2.9%
Total	100.00%	100.00%
Environmental Impact		
CO_2 Emissions	0.58 kg per kWh	0.26 kg per kWh
High level Nuclear Waste	0.0004 g per kWh	0.0120 g per kWh

Table 1: Scottish Power Fuel Mix Breakdown: April 2005 - March 2006 [68]

2.2 Energy Use and Savings Potential

As already established, the health sector is very much dependent on power for its operation. Figure 1 shows a typical break down of energy use in the health sector. Conventionally speaking the higher the energy consumed by an appliance, equipment or service, then the higher the potentials for energy savings. As observable from Figure 1, a bulk of energy consumption in the health sector comes from space heating, hot water production and lighting, thus offering opportunities for energy savings. This trio represents about 70% of energy consumption in health sector [2, 5]. For instance in hospitals, lighting is general the largest consumer of the electricity in a hospital, accounting for about for about 40% of the total consumption [40] thus offering an opportunity for energy saving. The energy used for lighting depends on the efficiency of the lamp, and their hours of use. Daylighting is the most important element in creating a low-energy building in many climates.

Reducing lighting loads decreases the electrical energy required for operating lighting systems and reduces building cooling loads. However, many commercial building owners are sceptical about daylighting strategies because of the perceived risk associated with what is considered a new concept. Also, architects and engineers find it difficult to optimize the daylighting system so as to minimize the sum of heating, cooling, lighting, and ventilation energy costs [25]. Furthermore the use of energy efficient lightings and lighting controls offer excellent means of cutting back on energy consumption via lighting. Control of lighting is normally by local switches and these should be provided in sufficient number to allow variation in lighting options e.g. reduced levels of luminance when circumstances permit, and to encourage energy conservation [26].

Building envelopes and thermal insulation offer means for reducing energy consumption associated with space heating. Regulations for thermal insulation, ventilation, lighting and indoor temperature levels ensure that every house in the UK is somewhat energy efficient [59, 66].

In addition to lighting, hot water demands are continuous and in significant quantity, hot water consumption ranges between 100 to 200litres/bed per day. With about 2.5kg of dry laundry per bed per day, hospital laundries, which often use hot water/ steam, are very big energy consumers. Typically, they account for 10-15% of a hospital's total energy consumption of around 2000kWh/bed [11, 83]. Considerable energy saving can be achieved in the production, distribution, utilisation, and final recovery of this steam.

In addition to the need for lighting, space heating and hot water generation, 24 hours a day, hospitals demand extensive energy for ventilation; running equipments; sterilization; laundry and food preparation. Such activities are major contributors to the 45 million gigajoules (GJ) of energy consumed annually by the NHS – a figure equivalent to supplying energy to about 525,000 domestic homes a year [69].

This represents 20% of the UK's entire public-sector buildings outputs, the current figure of 3.74m tonnes of CO_2 emissions per year, and rising, and the Department of

Health has declared that it must be reduced [25]. The Department's current targets are a 15% reduction in CO_2 emissions over the next three years, with carbon neutrality by 2012, and efforts to help the NHS achieve this figure are becoming increasingly concentrated. But sustainability is about more than carbon emissions. The newly established NHS alliance for building sustainability [54], expects future NHS buildings to be; carbon neutral or using a substantial proportion of renewable energy; using waste as a resource (reduce, reuse, recover, and recycle); transport friendly; water efficient; and promoting good land use [69].

A building's heating, ventilation, and air conditioning system (HVAC) creates interior comfort by compensating for climatic conditions. Heating, ventilating, and air-conditioning (HVAC systems) account for 39% of the energy used in commercial buildings in the United States [20]. Consequently, almost any business or government agency has the potential to realize significant savings by improving its control of HVAC operations and improving the efficiency of the system it uses.

The use of high performance HVAC equipment can result in considerable energy, emissions, and cost savings (10-40%). Whole building design coupled with an "extended comfort zone" can produce much greater savings (40%-70%) [66]. Ventilation in particular constitutes about 20-30 % of the total energy consumed in buildings today [66]. For most buildings, efficiency can only be achieved if the energy used for ventilation is reduced; this however may lead to reduced ventilation rates and increased levels of air pollution in buildings from people and their activities, and thus result in poorer indoor air quality, which contradicts the ventilation energy requirements of the EU Directive 2002/91/EC. The obvious solution for this apparently opposing requirement would be to reduce the pollution sources indoors [19]. However ventilation within hospitals is absolutely necessary to reduce transmission of airborne pathogens, given the vulnerability of patients' immune systems.

On the other hand, with hospital equipments, correlation with energy consumption is difficult, given the variety of equipment and its distribution, but is less important than might be expected [2,38]. There are firm requirement throughout the hospital for equipment, instrument and materials to be sterilised, because of the potentially widespread contamination risks. With only a few percent of a hospital's total energy consumption, sterilisation is not very energy-intensive. Annual energy consumption is in the order of 500kWh/bed [11]. The power required is low, around 1kW for decentralised equipment, so opportunities for energy saving are limited, likewise for other medical equipments.

In conclusion, the key to achieving energy efficiency in the health sector is promoting energy efficiency awareness amongst staff and users of health care facilities. For instance Guy's and St. Thomas Hospital launched an ambitious campaign to reduce energy consumptions by 10 percent over the next three years. If the project is achieved, it will reduce energy and water costs by £150,000 [53]. By raising awareness of the impact of small but important action such as turning off lights and computers the trust (Hospital) hopes to save more than 3,000 tonnes of CO_2 over three years. Also Southampton University Hospitals NHS Trust has entered into a long-term carbon awareness campaign, for staff, patients and the public, with a national consultancy [69].

Other measures being undertaken include replacement of an inefficient chilled water system; remedial works and upgrades of insulation levels to steam pipe work; lighting-control improvements; the possible installation of a biomass boiler system; reduced ventilation through unoccupied theatres; use of inverter technology for pumps and fans; and reduction in the site's high voltage level.

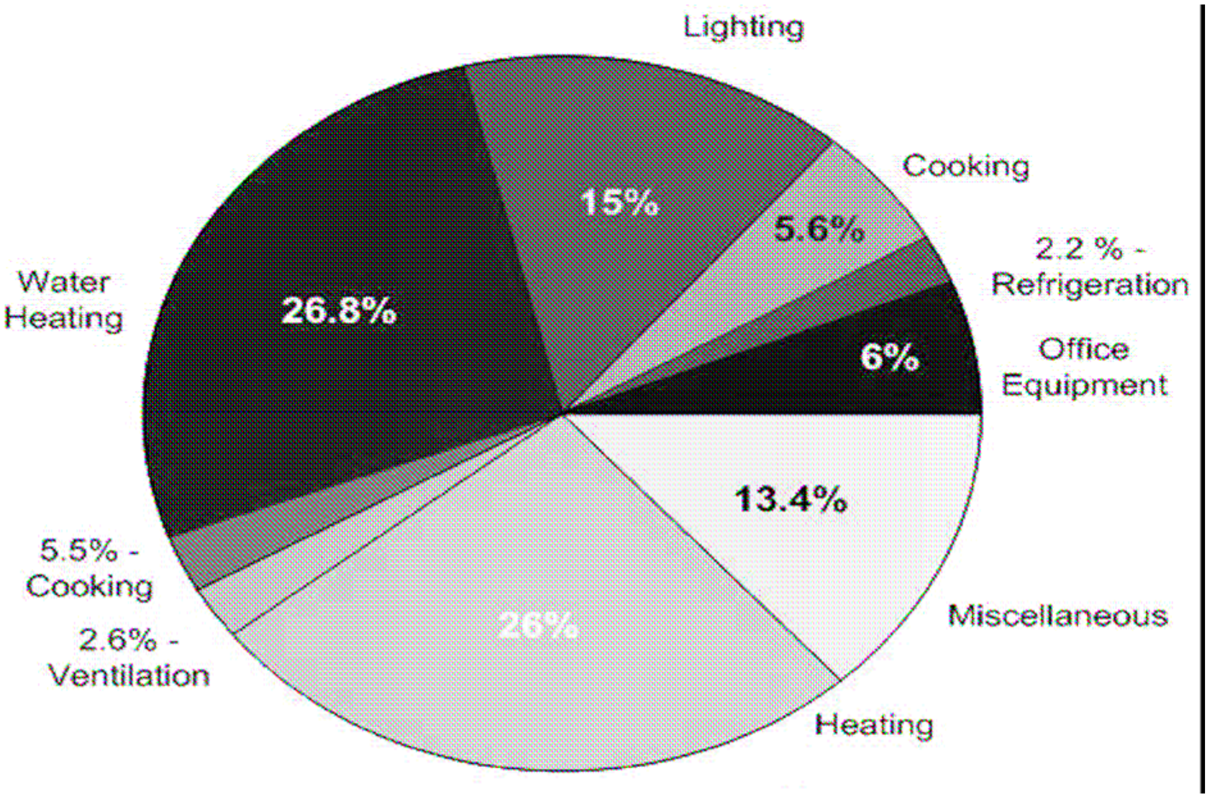

Figure 1: Energy use in hospitals [(2)]

2.3 Renewable Energy

Renewable energy is energy produced from sources which can be replenished or replaced [(8)]. Scotland has a wide range of renewable energy resources that can be used to meet its electricity and heating needs. The appropriate development of these resources will increase the diversity and security of UK‘s energy supply, as well as play a key role in reducing greenhouse gas pollution.

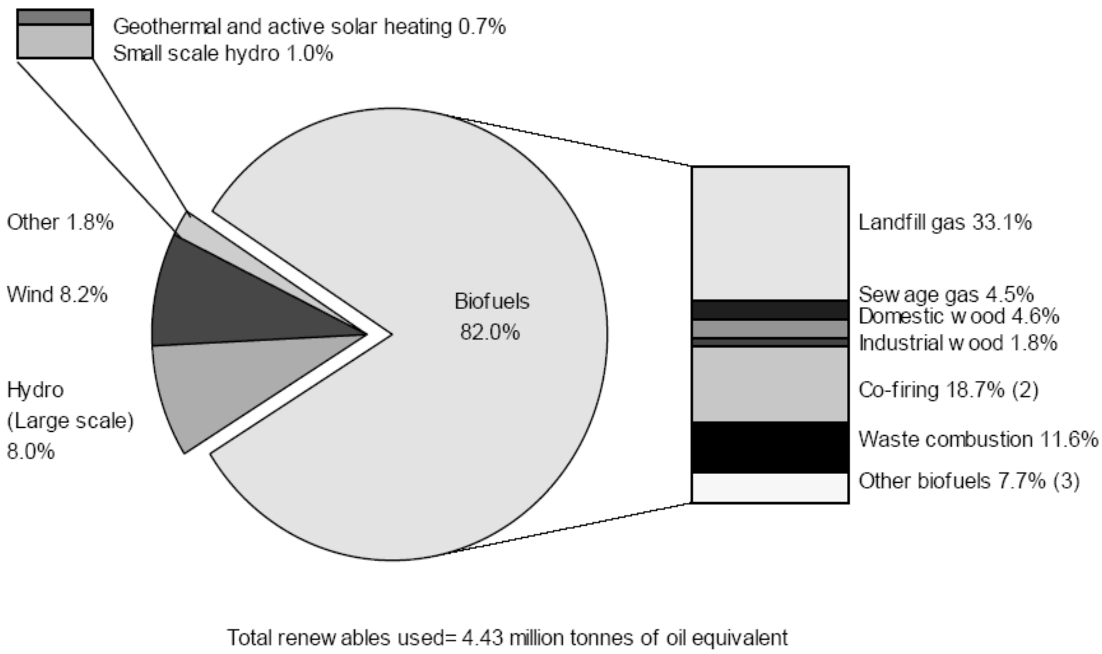

Figure 2: Chart showing the total renewable energy sources used in UK [17]

In recent years increased concern about the environment, and in particular the environmental impacts of conventional energy systems e.g. global warming, acid rain, etc has revitalised interest in renewable energy. With little or no net emissions of polluting gases, renewable energy sources are seen as part of the solution to these problems [8, 32] However, renewable energy technologies normally have high initial capital cost but with low operating and maintenance costs.

There are many renewable energy technology options available; an account of some of these is given below:

2.3.1 Wind Energy

Wind turbine is used to harness the kinetic energy from the wind by converting it to electrical energy. However the use of wind turbine is very much dependent on the geographical factor whereby the speed of the wind in a place might affect the feasibility of having wind turbines in a community.

Figure 3: UK Wind Resource [30]

Wind turbines are of various sizes and capacities. For domestic use, typical wind turbine capacity varies from 2kW to 6kW depending on the location and size of the house.

The cost also varies with the capacity but very often the initial capital may go up depending on the feasibility, planning and installation cost. This is because higher prices for wind generation can partially ameliorate planning constraints by enabling development in less visually intrusive, lower lying areas, despite less favourable wind regimes.

Figure 4: Wind Turbine Installed in a High School Premises [4]

2.3.2 Solar Photovoltaic

Solar energy, active and passive is sometimes used for hot water production, to reduce the need for other types of space heating and of course to reduce the need for artificial lighting. Passive solar energy needs careful consideration, as this type of system should be integrated with the building design to minimise the need for artificial light. Solar photovoltaic (PV) converts solar energy into electrical energy and hence, the amount of energy generated will be very much dependent on the amount of solar radiation that falls on the PV material. Solar PV connection can be either grid-connected or stand-alone system. Photovoltaic systems use daylight to power ordinary electrical equipment, for example, household appliances, computers and lighting.

The orientation of the solar PV plays a vital role in determining the annual energy yields, whereby south facing solar PV is always considered as the optimal position. However, the optimal inclination angle varies from one place to another. Proper positioning of PV can help to maximize the output of solar PV. Solar photovoltaic PV offers the ability to generate electricity in a clean, quiet and renewable way. It makes use of the abundant energy from the sun, to generate electricity without the production of harmful carbon dioxide (CO_2) emissions, one of the main gases affecting climate change and its operation is virtually silent.

2.3.3 Biomass

Biomass is a product of organic materials which can be obtained directly from plants or indirectly from processed materials. Biomass can be burnt to extract the heat energy which can be used for heating purposes. Even though the combustion of biomass emits carbon dioxide, this is balanced by the amount of carbon dioxide absorbed by the plants during their life.

For small health centres, the capacity of biomass heater ranges from 6-12kW, while biomass boiler are generally larger than 15kW. In some cases, biomass is also used to generate electricity via biomass Combined Heat and Power (CHP).

The Renewable Obligation of Scotland (ROS) is currently drafted to promote the increased use of biomass in generating electricity. Power from dedicated biomass plants is eligible for ROCs, but there are also provisions within the legislation which allow for the co-firing of biomass material in fossil fuel plants, with ROCs awarded to the proportion of the output attributable to the biomass element of the fuel mix [10].

Currently, eligibility under the GB Obligations is limited to electricity produced from the biomass fraction of mixed wastes using the advanced conversion technologies of pyrolysis, gasification or anaerobic digestion [25].

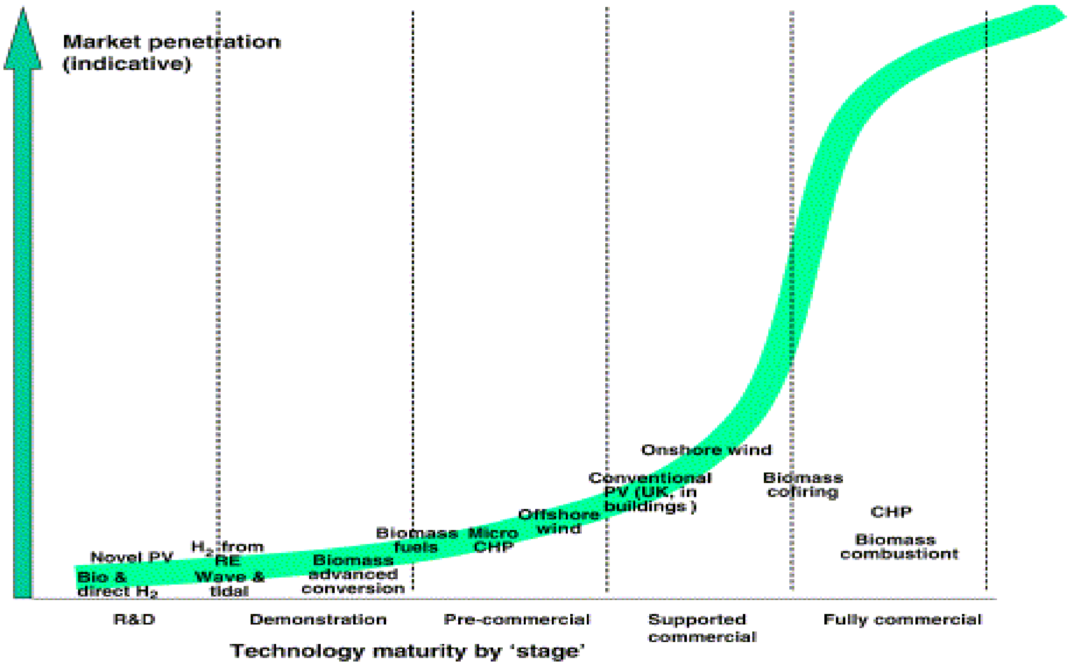

Figure 5: Graph showing the Biomass market in UK [32]

For heat and electricity production, there are active projects, mainly using combustion. This is a commercial technology, in which the UK is the leading technology players, and the technology and market risk are relatively low. Policy support has been and is directed at biomass combustion systems, but has tended to favour potentially more efficient and cleaner advanced technologies such as gasification and pyrolysis.

2.3.4 Ground source heat pumps

Ground source heat pumps use the earth as a heat source in the winter and a heat "sink" in the summer. Much of the upper 3.1m of the Earth's surface maintains a nearly constant temperature between 10 °C and 16 °C. A ground source heat pump consists of a closed-loop piping network buried near the building and connected to a heat exchanger and ductwork going into the building.

In the winter, heat from the relatively warmer ground is pulled into the building by the heat exchanger, and in the summer, hot air from the building is pulled into the relatively cooler ground by the heat exchanger. Some heat pump systems also include a secondary heat exchanger that allows heat from summer air to be used for heating water in the hot water tank [(32)].

Ground source heat pumps are ideally used to cater for heating demand during winter whereby they collect, concentrate and distribute geothermal heat. They are a well established technology, having been used across the world for many decades.

GSHPs have three components - the ground source or loop that collects the heat, a heat pump that concentrates the heat, and a heat distribution system. There are a number of ways of collecting the heat from the ground: these include deep looped pipes buried 80 - 150 cm down, a mixture of water and environmentally friendly anti-freeze circulating through the pipes is then used to absorb thermal energy from the earth [(32)]. This method is regularly used because it does not involve any additional construction costs and is installed in almost any garden as long as it has an area that is almost the same as the heated floor

Ground source heat pumps (GSHP) have several advantages compared to other renewable technologies. In comparison to biomass for example, GSHPs do not produce smoke or air pollution and the energy source is on site, removing the need to transport the fuel source. GSHPs also utilise ground temperatures that, unlike wind or wave power, are much less susceptible to changing weather conditions. In addition, GSHPs are unobtrusive, producing a modest or no visual impact or noise pollution, thereby avoiding the planning problems often associated with wind power. Perhaps most importantly GSHPs are a low carbon technology relative to fossil fuel heating systems and can contribute to a significant reduction in Scotland's CO_2 emissions [(45)].

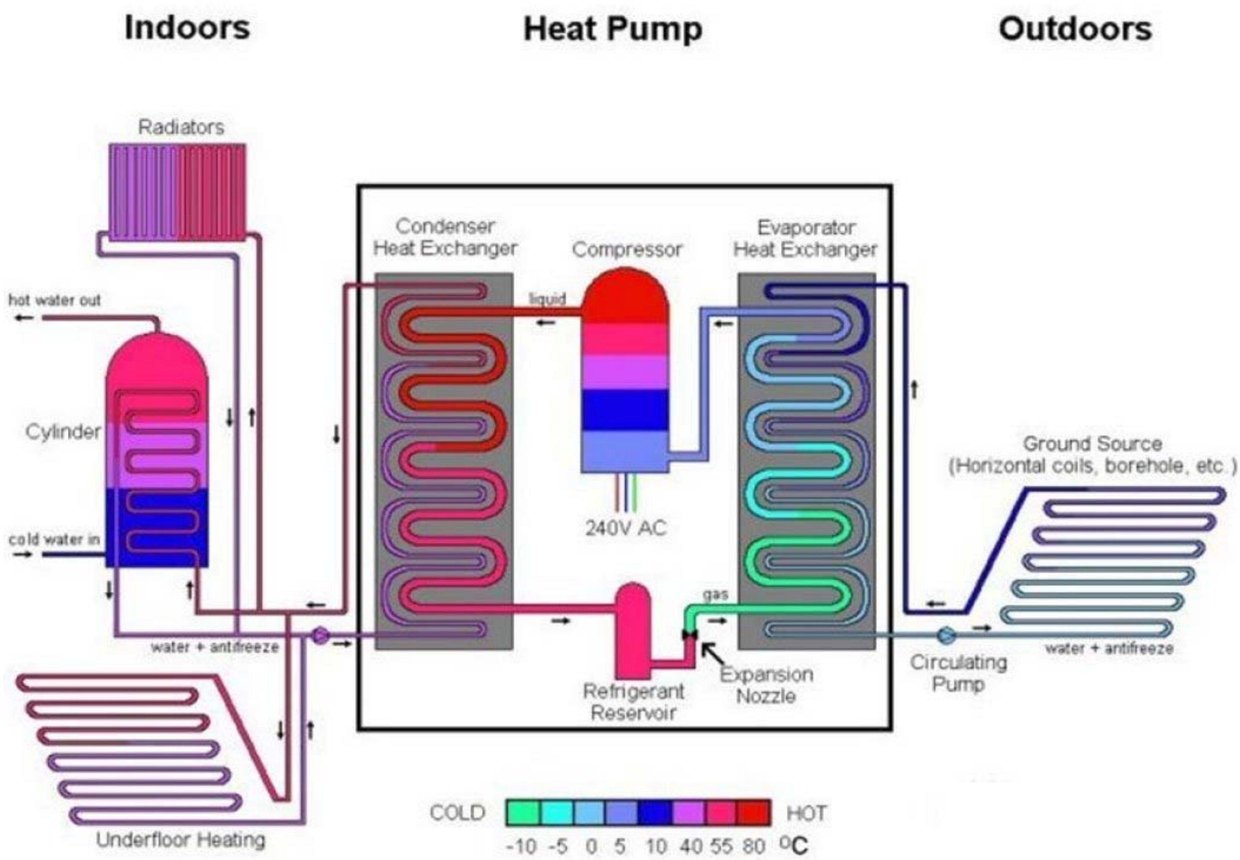

Figure 6: Ground source heat pumps schematic [34]

2.4 Renewable energy in hospitals

Renewable energy is now becoming a more desirable, and achievable solution to current energy problems. One of the main challenges to investing in renewable energy for hospitals and other public sector organisations has been the lack of disposable income and a low priority remit for sustainable energy. The success of projects such as that at Bronllys Hospital, Powys, the first UK NHS hospital to generate electricity from sunlight , built with the help of European Regional Development Fund and the PV Programme, has encouraged hospital management to investigate supports available to develop viable renewable energy technology [7].

Currently, wind power is the favoured option in terms of on-site renewable generation.

The 40 metre high 660kW wind turbine used in Antrim area hospital saves £90,000 a year in energy cost to the benefit of the patients and the environment [71]

2.4.1 Drivers and Barriers of Implementing Renewable Energy Technology

There are many drivers and deterrents influencing the choice of implementing renewable energy technologies.

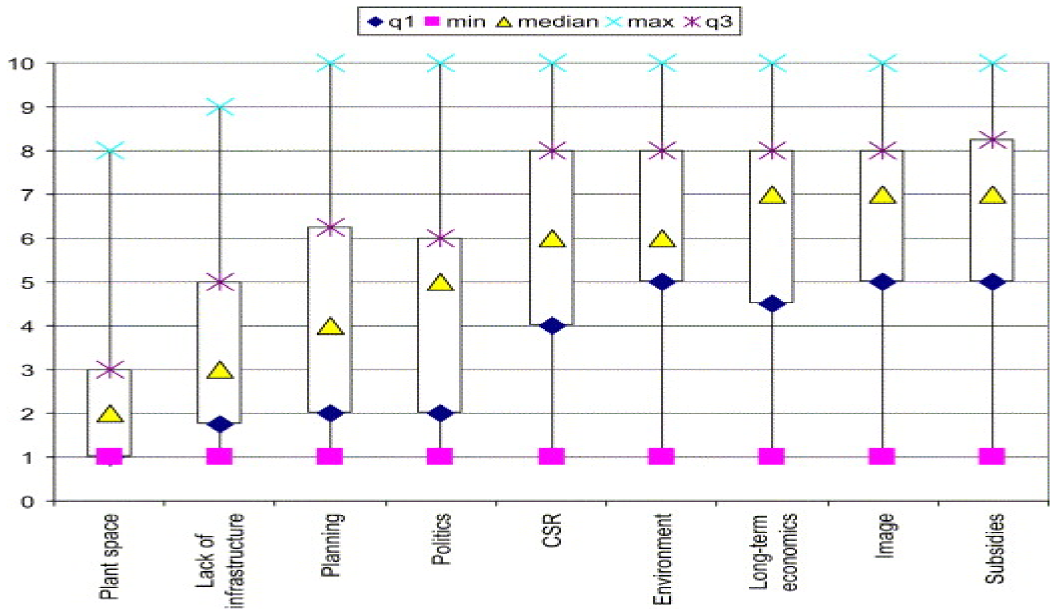

Figure 7: Driver for Implementing Renewable Energy [10]

A survey of stakeholders conducted by Cooke et al [10] revealed that major drivers of implementing renewable energy technologies within a business include; financial benefits (in the form of access to subsidies, grants and cost reduction), corporate social responsibility, image protection and political influence through legislations and regulations. While common barriers include Implementation cost, lack of knowledge of the renewable energy technology, planning constraints, complexity and maintenance. Figure 7 and Figure 8 give details of the outcome of this survey.

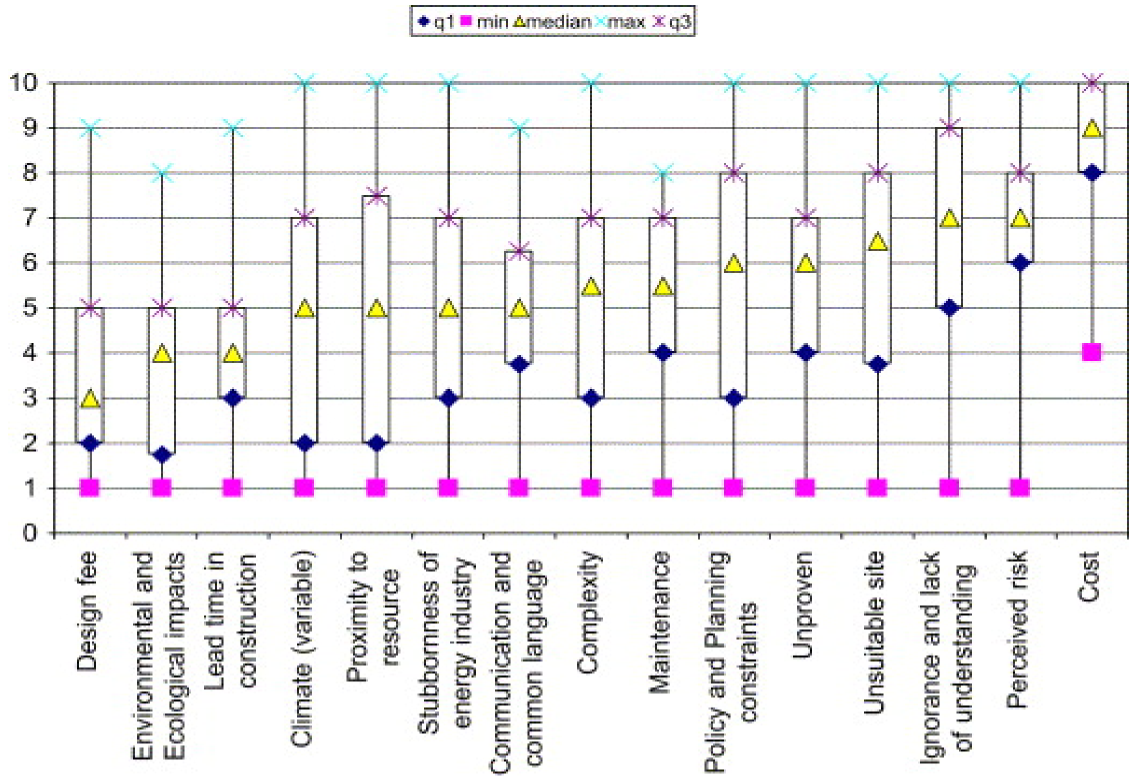

Figure 8: Barriers against Implementing Renewable Energy Technologies [10]

2.4.2 Fiscal and Statutory Frameworks Driving the Implementation of Renewable Energy Technologies

There is work in progress by the Scottish Executive to further the sustainable development of new buildings (both domestic and non-domestic). It is the policy of the Scottish Executive to continue to embed the principles of sustainable development in building regulations, planning policy and procurement guidance, rather than expecting developers to adopt voluntary codes of practice [67]. Further improvement on the current regulations with regard to the sustainability of new buildings is expected through forthcoming changes. Amendments to the Building Regulations have been issued for consultation and came into force since May 2007. The topics that will impact on building energy efficiency are most notably; energy performance, low and zero carbon technologies including renewable sources and energy metering. It is also expected that a consultation will be issued on the implementation of the Energy Performance of Buildings Directive 2002/91/EU.

The Energy Performance of Buildings Directive of the European Parliament and Council came into force in January 2003 (Directive 2002/91/EC) [22]. The purpose of the Directive is to increase awareness of energy use in buildings and force building owners to invest in energy efficiency measures. It is estimated that there are "160 million buildings in the European Union consuming over 40% of Europe's energy [6]." Europe is committed globally to reducing carbon emissions under the Kyoto Protocol and this measure is intended to contribute towards the proposed reduction. Due to the capital intensive nature of renewable energy technologies, there are legislations enforcing their implementation.

However there are several Government policies developed in the EU to encourage the implementation of renewable energy technologies, especially in future building projects.

The main reference document in which European policies for the renewable energy sector are defined is the White Paper on renewable energy, which was adopted in November 1997 [32]. This not only established the ambitious target of 12% for the contribution of renewable sources of energy to the European Union's gross inland energy consumption in the year 2010, it also required the Commission to report every two years on the progress, which is achieved towards this objective. Also the Green Electricity Directive adopted on 27 September 2001 sets a legal framework for the future development of the renewable electricity (RES-E) markets in the EU. The Member States are now obliged to establish national targets for the future consumption of RES-E [38].

A combination of factors such as pressures from the EU and public support for innovation in new and renewable energy has gradually been gaining a higher profile in the UK since 1990, and is central to the UK government's Energy White Paper [24], published in February 2003.

The UK's first market support scheme for renewable energy (though initially focused on nuclear power) was the Non-Fossil Fuel Obligation (NFFO), which offered renewable energy developers the opportunity to bid for contracts to sell electricity at a fixed premium price for a fixed term, funded by a levy on conventional generation. Though, it was superseded by the renewables obligation (RO) in April 2002, and the RO is to remain in place until 2026. The RO places an obligation on electricity suppliers to make an annually increasing proportion of their generation from renewable sources, initially reaching 10% by 2010, then increased to 15% in 2015 and currently remaining at that level (15%) until 2026. A key feature is the institution of a trading scheme in accredited renewable generation, Renewables Obligation Certificates (ROCs). Suppliers can thus either meet their obligation by direct sourcing (qualifying for ROCs), by buying an equivalent level of ROCs, or can instead choose to pay a 'buy-out' price of 3p/kWh. Funds raised from payment of the 'buy-out' price are recycled to suppliers who have met their obligation through ROCs, creating an extra incentive.

The European Environment Agency recognises that it has a special responsibility, as the only European Union body dedicated exclusively to providing information for protecting the environment, to show leadership in its own environmental management and performance.

On the positive side, the Agency believes that the information it provides has an important beneficial impact on Europe's environment by giving policymakers a sound basis for action and raising public awareness to protect the environment [28]. The Agency also provides information to help monitor that the renewable energy targets are met by all member states of the EU.

2.5 Related Cases of renewable energy technologies in UK hospitals

2.5.1 NHS Energy Facts and Figures [69]

- £412m: NHS expenditure on energy per annum
- 3.47m tonnes per year: total CO_2 emissions from NHS buildings
- 45m Gigajoules: energy consumption by NHS buildings per annum
- 11%: the rise in CO_2 emissions from 1999 to 20052
- 60%: the amount of the UK's CO_2 emissions that buildings and construction generate, including 10% alone from the production of construction materials
- 151m tonnes pa: of total UK waste, from materials production and construction
- 22%: NHS buildings constructed prior to 1948
- £100m: Funding over next three years to help NHS improve energy efficiency
- 2012: Carbon neutrality required across NHS estates.

2.5.2 Gateway Surgical Centre, Newham- Case study [54]

The Gateway Surgical Centre (GSC) was constructed in Newham university hospital NHS trust just over three years ago due to the need for a separate surgical unit for day-case and short-stay patients. The 65-bed unit offers 50% single rooms, and some significant energy-saving features. Floor-to-ceiling windows maximise natural light and ventilation throughout the building. Solar panels and wind turbines provide power for external car park lighting, and heat recovery is achieved through a run-around coil throughout the ventilation system. Rainwater is collected and stored in underground storage tanks and reused for toilet flushing. A pneumatic tube was installed between the GSC and the main hospital building, so specimens can be transported in just two minutes, rather than shuttled by van between buildings. Furthermore, excavation waste was re-used on site, and more than 2000 plants and trees have been planted around the building.
The cost of individual sustainability elements ranged from just under £7,000 for lamp columns with wind and solar components (£6,681) to £58,000 for the rainwater harvest system. This project has saved £150 per year by powering the car-park lighting using solar panels and wind turbines and £760 per year is saved due to the 22,000-litre grey water tank.

2.5.3 Riverside Building, Lewisham NHS Trust-Case study[56]

Lewisham NHS Trust was committed to procuring a building of outstanding design, on a tight site between a busy main road and a previously derelict watercourse, and overlooking Ladywell Fields. Medical director and design champion, Robin Stott, incorporated the sustainability element up front into his brief for the inpatient block, which incorporates 419 elderly and inpatient beds (a mixture of single bedrooms and four-bed units), along with operating theatres, an endoscopy suite, admissions unit and a critical care unit. The PFI consortia were aware that submissions would be judged by their sustainability performance. The resulting seven-storey, 52,800m^2 building is mainly naturally ventilated with air conditioning restricted to critical areas, such as operating theatres. Through the installation of 110m^2 of photovoltaic on the roof (72 panels), an impressive 10,300kWh per annum are generated, with a peak output of 13.7kW. Building low-energy designs should help the trust achieve its target of reducing energy consumption to its target of 49Gj/100m^3/pa, which is 23% less than the amount consumed by old hospital buildings.

Furthermore, by regenerating the watercourse, the project promotes biodiversity in the local environment. The hospital, working with The Prince's Foundation, the London borough of Lewisham and Transport for London, helped secure a £1m grant for improvements to Ladywell Fields. Not only did this create a secure route across the park to Ladywell station, improving access to Lewisham High Street, but re-landscaping enabled it to become a recreational facility for patients, staff and the local community. The photovoltaic system cost £79,846, which was paid for by a grant from the Energy Savings Trust.

2.5.4 Antrim Area Hospital Northern Ireland- a case study [71]

Antrim Area Hospital is an acute trust of 350 beds and is part of Antrim United Hospitals Trust. Spurred on by the public sector building energy reduction target, the Hospital investigated installing a wind turbine on site to provide energy.

Following a feasibility study, a wind study and an environmental impact assessment (EIA), planning permission for the project was given. From idea to conception, installation took 3 years and has been fully operational since 7th February 2005.

The 40 metre high 660 kW Vestas V47 wind turbine is the largest at any hospital in the UK. It will generate an average of 1.2 million units of electricity per annum, which is used as base load replacement. It has the potential to provide enough electricity for the hospital during the night, and two-thirds of the power needed during the day, which would otherwise cost £90,000 a year. Even in low wind conditions the turbine is cost effective and the money that would have been spent on power is freed up for improved services for patients.

The turbine cost £497,000, of which 80% was a grant from the Government Central Energy Efficiency Fund. Without a grant it would take five years for the initial cost to be repaid (at 2005 energy prices). As well as cutting Antrim Area Hospital's energy bill, the project has also reaped the following benefits:

- Reduced power generation waste
- Reduced air pollution and climate change
- No impact on biodiversity
- Easy land reclamation

Figure 9: 660kW wind turbine installed in Antrim Area Hospital [71]

2.5.5 Stokmarknes hospital, Norway [63] – a case study

In 1987, the Stokmarknes hospital, located in Norway, installed a heat pump using sea water as the heat source. The hospital has a relatively high heating need varying from 100kW to 800kW throughout the year. The heat pump has a maximum capacity of 400kW and can meet half of the design heat demand, while an oil boiler is used to meet peak demands. The heat pump covers 88% of the whole annual heating need of the hospital (2,500MWh), relying on an inexhaustible supply of low temperature heat from the sea. Since the heat pump uses only 840MWh per year and the additional heat demand is covered by the equivalent of 425MWh of oil, this means that the energy saving is as much as 1,235MWh per year (nearly 50% of total heat demand). The annual energy saving equals a cost saving of nearly €31,743. With a total investment cost of €213,316 (1987 prices), the payback period was seven years compared to an alternative electric system, nine years compared to an alternative oil system (calculated with an electricity price of €0.02/kWh). Energy savings have also reduced annual emissions of CO_2 by 800 tonnes and SO_2 by 5.5 tonnes. [72]

3 Monitoring and Controlling Building Energy Performance

Many countries have introduced measures that encourage or enforce the efficient use of energy. One reason to conserve fuel and energy is that the earth's total reserves of convenient fossil fuels such as oil and gas are limited. Another motive for the restricting use of fuel is the environmental concern of emitting carbon dioxide and other greenhouse gases produced when fuels are used for transportation, electricity generation [46].

The main concern of the building energy performance standard is to improve energy performance. This chapter explore different methods of assessing building energy performance.

3.1 Building Energy Management System

When assessing and evaluating considered or implemented energy efficiency measures, it may become evident that proper management and control cannot be maintained without a central computerised energy management and control system (EMCS).

The Building Management System provides control and monitoring of many of the hospital's heating and ventilation systems. It enables efficient control of building environments and helps to reduce energy consumption. Energy management can be regarded as a programme within a hospital's corporate energy strategy, i.e. as an energy management programme. Different tools can be used to implement this programme. Control of the system is carried out via a graphic interface from the estate management building. Normally, details of metered energy use are archived, providing an historical record of energy costs; reports can be generated to provide detailed information of a building's energy use and alarms are automatically generated and monitored around the clock.

Over the years, the Building Control Systems have helped to deliver buildings which are safe, healthy and accessible for everyone who lives and works in and around them [12]. Generally the system should have sufficient zone, time and temperature controls to ensure that the heating system only provides the desired temperature when the building is occupied [26].

3.2 Energy Audit

Good energy management starts with an energy audit. An energy audit is necessary to identify where energy is consumed and how much energy is consumed in an existing facility, building or structure. Information gathered from the energy audit can be used to introduce energy conservation measures (ECM) or appropriate energy-saving technologies, such as electronic control systems, in the form of retrofits. Energy auditing evaluates the efficiency of all building components and systems that impact energy use. An audit usually provides a basis from which an action plan for reducing energy costs can be developed.

Some of the most important information that should be gathered in an energy audit includes (40, 44):

- Building characteristics(size ,age, type, design of structure etc)
- Main energy uses
- Location of departments, type of activity and corresponding hours of operation
- Types of energy systems and equipment
- Energy consumption data for all energy systems equipment and hospital areas.
- Energy demands, by type of fuel including peak demands
- Description of energy measures already implemented
- Recommendation of appropriate measure to be implemented.

The audit process begins at the utility meters where the sources of energy coming into a building or facility are measured. Energy flows – inputs and outputs – for each fuel are then identified and quantified into distinct functions or specific uses, and then the function and performance of all building components and systems are evaluated measured (42). The energy audit report should contain documentation of the use and occupancy of the audited buildings, as well as an assessment of the condition of the buildings and the associated systems and equipment. The report also should include recommendations on how to increase energy efficiency through improvements in operation and maintenance (O&M) and installation of energy-saving technologies and energy conservation measures (ECM).

The efficiency of each of the functions is assessed, and energy and cost-savings opportunities are identified. At the end of the process, an energy audit report is prepared (75,76).

Improving energy efficiency and conservation are fundamental to achieving environmental sustainability. They are the first step to take in actualizing reduction in greenhouse gas emissions and other forms of air pollution such as acid rain and smog.

3.3 Energy benchmarking

Energy Benchmarks provide a baseline value by which to compare actual performance of building energy use. Comparing energy consumption against established benchmarks for a hospital building type will provide a first indication of how well a similar hospital building is performing and identify what scope there is for improvement [51].

3.4 Energy Management Matrix

An energy management matrix does not directly assess the energy performance of a building, but rather it provides an insight into a company's or an estate management department to energy matters. It can be used to identify important energy savings activities that can improve the energy efficiency of a Hospital or Company, thus improving the building's energy performance at the long run.

As shown on Table 2 each column of the Matrix deals with each of the energy management issues: energy management policy; organising; staff motivation; tracking, monitoring and reporting systems; staff awareness/training and promotion; and investment [60]. The ascending rows, from 0 to 4, indicate greater levels of sophistication (or action taken). The management objective should be to move up through these levels towards current 'best practice' and, in doing so, to develop balance across every column. These elements of the energy management matrix are discussed below:

Policy

A formal written energy policy acts as:

• A public statement of the organisation's commitment to energy conservation and environmental protection and as

• A working paper to assist in the development of the organisation's energy management measures

A policy document normally contains the following sections: declaration of commitment, objectives, action plan, resources, accountability and review procedure.

Organisation

Energy management is the responsibility of the whole organisation as everyone uses energy to complete their work tasks. The four most common options where energy management could be located in organisation are in the: technical department; human resources department; accounting/finance department or outside consultants. Each option has various benefits and pitfalls associated with it. The Hospital Management must determine which option best complements its organisation's hierarchical structure.

Motivation

Motivating people to take an active part in energy efficiency measures such as switching off unnecessary lights is a challenging task but not as difficult as they may have first thought.

Training will not be successful unless people want to change their behaviour and are motivated to learn how to reduce their energy usage by working smarter and not harder. Updating staff about the organisations energy performance will help create a sense of involvement and boost employee commitment to the energy management system.

Information Systems

Accurate information is invaluable for effective energy management. When developing an information management system for an energy management system, the following issues must be considered:

•Who or those that will use the information obtained and involve them in making accurate needs assessment

• Ensure that data input and analysis are as straightforward as possible and meet the information systems requirements

Level	Environmental Policy	Organisation	Motivation & Training	Information Systems	Marketing	Investment
4	Active commitment of top management	Environmental management fully integrated into general management	All staff trained and motivated to address issues	Comprehensive system - effective data capture and management reporting	Extensive marketing on basis of environmental management performance	Positive discrimination in favour of "green schemes"
3	Formal policy - but no commitment form top	Clear delegation and accountability	Most relevant personnel are motivated / trained	Data capture and retention for most areas	Regular publicity campaigns	Same appraisal used as for any other investment
2	Unadopted policy	Some delegation bur authority unclear	Motivation and training are patchy	Legally required data is retained	Some degree of in house promotion / awareness raising	Investment with short term pay back only
1	Unwritten guidelines	Informal responsibility	Some staff awareness	Patchy data retention	Informal contacts to promote environmental management	Only low cost measures taken
0	No policy	No delegation of environmental management	No awareness of need to address issues	No information kept	No marketing or promotion of environmental management	No investment in environmental management

Table 2: Energy Management Matrix Chart [60]

Marketing

Promoting energy management is an important component of any energy policy and will enable the following to occur:

• Raise the awareness of the importance of energy efficiency for both environmental and financial considerations.

• Market the energy management services within the hospital. [So staffs know what they do and can ask for guidance.]

• Highlights the benefits associated with energy efficiency measures to senior management

Investment

Organisations will generally commit to energy efficiency investment if it is made aware of the following:

- The amount of the energy wasted annually and the financial losses resulting from it.
- The technical and simple energy efficiency measures available to reduce energy wastage
- The predicted rate of return on any investment option.

3.5 Economic Analysis Methods for Energy Projects

As recommended by the energy management matrix, economic evaluation must be conducted for each of the energy-efficiency projects identified in the energy audit. A number of the economic methods described below are available for this purpose. A more detailed discussion of financing and analysis of energy-efficiency investments may be found in the various references/tools developed by the Energy Star program such as Financing Energy Projects [57].

Simple Payback (SPB) – SPB measures how long it takes to recover an initial investment in a cost-saving measure. For example, a £500 investment that saves £100 per year has an SPB of £500/£100/year = 5.0 years. Although widely used to support decisions, SPB fails to consider the time value of money and to properly consider the impact of cash flows [84].

Discounted Payback (DPB) – The time value of money issue can be resolved by discounting future cash flows to their present value and determining the DPB period, or the length of time it takes for the cumulative present value of savings to equal the investment cost.

Return on Investment (ROI) – Sometimes referred to as the simple rate of return or the investor's rate of return, the ROI is the reciprocal of the SPB expressed as a percentage. ROI expresses the percentage of the investment cost that will be returned annually by savings. For the previous example, ROI = £100/£500 = 0.2 = 20%.

Internal Rate of Return (IRR) – This method calculates the discount rate that makes the present value of the costs equal to the present value of the revenues (or savings). A project is worthwhile according to this measure when the IRR is greater than the rate of interest at which the money was borrowed to finance the project, or is greater than the rate that could be obtained from alternative investment opportunities, whichever of the two rates is higher.

Net Present Value (NPV) – This method also employs discounting. The NPV is obtained by discounting both costs and revenues (or savings) at a specified rate, and then subtracting the resulting present value of the costs stream from the present value of the revenue (or savings) stream. A project is worthwhile according to this measure if the NPV is positive [(84)].

Life-Cycle Cost Analysis (LCCA) – An economic method of project evaluation in which all costs over the life of a project are considered to be important. The life-cycle cost (LCC) is the total cost of owning, operating, maintaining, and eventually disposing of the project over a given period, with all costs adjusted or discounted to reflect the time value of money [(52)]. LCCA is appropriate for considerations of new construction alternatives as well as renovation or retrofit project alternatives.

Savings-to-Investment Ratio (SIR) – This method calculates the benefit to- cost ratio of the present value of the savings over the study period (related to the life of the project) to the present value of the investment-related costs. SIR is useful as a reliable means of ranking independent projects for purposes of allocating limited investment capital. When faced with a large number of energy/cost saving projects, each of which is cost-effective but where funding limits the number of projects that can be implemented, ranking by highest-to lowest. SIR will ensure the greatest return for investment of the available capital.

4 Methodology

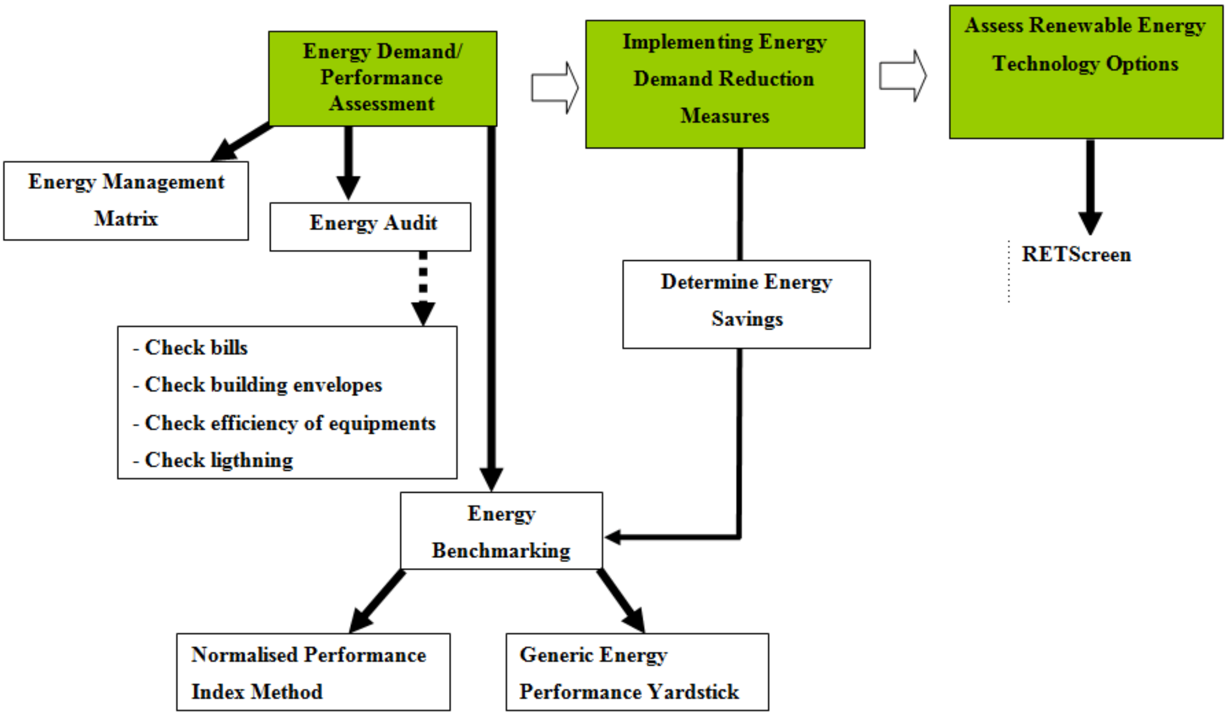

Figure 10: Procedure for Assessing Energy Efficiency and Renewable Energy Options for the Health Care Sector

The main aim of this study is to develop a procedure for assessing energy efficiency and renewable energy options for the health care sector. This procedure is intended to be generic for use in most organisations. However, in this study, this methodology will be tested on a particular health care sector build- Annan hospital. Figure 10 represents a flowchart of this procedure. The procedure defines three main steps for assessing energy efficiency and renewable energy options and these main steps include:

- Energy demand and performance assessment
- Implementing energy demand reduction
- Assessing renewable energy option

4.1 Energy Demand and Performance Assessment

This is the first step defined by the proposed procedure. This step is often achieved by developing an energy management matrix performing an energy audit and energy benchmarking.

4.1.1 Energy Management Matrix

A description of energy management matrix is give in the literature review, as already mentioned, an energy management matrix does not directly assess the energy performance of a building, but rather it provides an insight into a company's or an estate management department's energy matters. It can be used to identify important energy savings activities that can improve the energy efficiency.

4.1.2 Energy Audit

According to the proposed procedure, the energy audit involves:

- Analysing the energy bills: this is important to determine the average energy consumption of the building in question. Also an analysis of the energy bills can help to determine the energy signature of the building. Analysing the energy bills simply involve plotting a graph to identify trends in the energy consumption. In other words by analysing the energy bills, sources of energy waste and potential savings can be identified.
- Checking building envelopes will also help identify source of heat loss, the performance of the building envelopes can be assessed by gathering information concerning the age of the building and the thermal design of the building, these information can be gotten from the estate department.
- Checking efficiency of equipments: inefficient equipment often tend to consume more energy than normal.
- Check lightning: as already established in the literature review, lights are major consumers of energy in hospitals, thus it is necessary to explore means of reducing lightning demand.

4.1.3 Energy Benchmarking

The energy consumption yardstick and the normalised performance index (NPI) have been used in this study for assessing the energy performance of the case study building. The NPI is a preferred method compared to the energy consumption yardstick, as the NPI assess energy performance based on building specific energy estimates, rather than on generic building energy estimates. However other forms of benchmarks for assessing building energy performance exist.

4.2 Implementing Energy Demand Reduction Measures

This stage of the proposed procedure involves implementing energy conservation measures (ECM) within the building. The sort of ECM implemented will depend upon the result of the energy audit. For instance if the energy audit reveals lightning to be the major cause of energy wastage, then implementing efficient lightning will be a top agenda for energy management.

Hospitals have an option of choosing low-cost/ short term energy conservation measures and high-cost /long term energy conservation measures.

Low-cost ECM projects for hospitals include:

- Increasing energy efficiency awareness
- Installing energy saving lamps and electronic ballasts
- Installing occupancy sensors in private offices and selected public spaces
- Replacing computers with ENERGY STAR® qualified ones and activating the power-saving sleep mode on LCD monitors
- Monitoring the run times of the air handler units and scheduling them off when floors are not occupied.
- Replacing inefficient motors with high efficiency motors

High-cost ECM projects for hospitals include:

- installed high-efficiency boilers and chillers
- Replacing the HVAC system
- Retrofitting the building envelope though funding may be available for installing insulation depending the country
- Installing renewable energy supply systems

After ECM's have been implemented, the performance of the building should be re-assed to establish energy savings.

4.3 Implementing renewable energy technology options for demand offset

This is the last stage of the proposed procedure, and it involves assessment of the current renewable energy technology options in the UK. It also involves assessing which renewable energy technologies are readily available in the locality, where the renewable project is to be established. Also an assessment of the ability of the geographic conditions of the locality to support the optimal functioning of each renewable energy option is carried out. RETScreen is recommended by the proposed procedure, as RETScreen is able to carry out all these assessments. Also RETScreen goes further to assess the economic feasibility of the renewable energy project, the achievable reduction in GHG from implementing any particular renewable energy option.

4.3.1 Software Description: RETScreen

The RETScreen International Clean Energy Project Analysis Software can be used worldwide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions, financial viability and risk for various types of proposed energy efficient and renewable energy technologies (RETs). The software has been developed to overcome the barriers to renewable or clean energy technology implementation feasibility study stage. It provides a proven methodology for comparing conventional and clean energy technologies. All clean energy technology models in the RETScreen Software are similar and follow a standard approach to facilitate decision-making – with reliable results. RETScreen is developed in Microsoft Excel environment and uses a five step standard analysis procedure for each model. The five standard project analysis procedures are;

- **Energy Model**: Specifies parameters describing the location of the energy project, the type of system used in the base case, the technology for the proposed case, the loads and the renewable energy resource (for RETs).

- **Cost Analysis**: Performs a pre-feasibility or a feasibility study by inputting the initial, annual, and periodic costs for the proposed case system.

- **Greenhouse Gas Analysis (GHG):** Helps determine the annual reduction in the emission of greenhouse gases stemming from using the proposed technology in place of the base case technology.

- **Financial Analysis:** Specifies financial parameters related to the avoided cost of energy, production credits, GHG emission reduction credits, incentives, inflation, discount rate, debt, and taxes. From this, RETScreen calculates a variety of financial indicators (e.g. net preset value, etc.) to evaluate the viability of the project.

- **Sensitivity & Risk Analysis:** Assists in determining how uncertainties in the estimation of various key parameters may affect the financial viability of the project.

Each model also includes integrated product, cost and weather databases and a detailed online user manual, all of which help to dramatically reduce the time and costs associated with preparing pre-feasibility studies [62].

For example, the RETScreen Wind Energy Project Model software can be used world-wide to evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for central-grid, isolated-grid and off-grid wind energy projects, ranging in size from large scale multi-turbine wind farms to small scale single-turbine wind-diesel hybrid systems. Version 3.0 upgrades of the software include a Metric/Imperial unit switch; updated product data; an enhanced GHG model to account for emerging rules under the Kyoto Protocol; a Sensitivity & Risk Analysis worksheet; and the ability for users to now evaluate wind projects using wind power density data (in addition to wind speed data).

5 The Case Study

5.1 Introduction: Background of Annan Hospital health centre

Annan hospital, which is one of the small hospitals under NHS Dumfries and Galloway, was used as the actual case study for this research. Annan hospital was chosen as a case study because its small capacity ensured the manageability of the project. The hospital building is located in Annan, 25 miles from the main hospital. It has floor area of 2160m^2. It was built in 1987 by the
Dumfries and Galloway primary care NHS trust. Temperature in summer conditions is 24^{o}C and relative humidity 45% in the occupied area and winter conditions is 22^{o}C and 60 %. Thermal conditions in unoccupied areas in summer are 25^{o}C and in winter 12^{o}C. With regard to outdoor air ventilation, the air flow for each space of the health building will differ depending on its use, maximum airflow being in operating theatres or physical therapy room and the minimum in the waiting room.

Figure 11: Annan Hospital

The building normally has a maximum of 18 patients at a time and a minimum of 6 patients with 18 medical staff, two to three domestic staff and one administrator. The medical staff operate on three shifts with the early shifts of the day (7am-12pm) having up to 10 medical staff. The kitchen operates from 7am to 7pm. The energy sources in the hospital are electricity from the grid through Scottish Power and gas supply from EDF energy for space heating and domestic hot water supply.

The electricity is used for lighting and powering of all the appliances in the building. It also has a 148kVA backup generator for emergency purposes. There is some insulation present in the building as the windows are double glazed and the loft is insulated. The presence of cavity walls could not be assessed.

5.2 Objectives of the Case Study

The objectives of this case study were to:

- Test the effectiveness of the proposed procedure for assessing energy efficiency and renewable energy options in the health care sector
- To determine the current energy demand and CO_2 emissions in Annan hospital
- To determine possible energy demand reduction measures
- To determine a suitable renewable energy technology option for Annan hospital

The proposed procedure shown in figure 10 was used to realise the objectives of this case study.

5.3 Energy Demand and Performance Assessment of Annan Hospital

The assessment of the energy performance and demand in Annan hospital was conducted by developing an energy management matrix, conducting an energy audit and benchmarking to assess performance. Below a detail of the outcome of these is given:

5.3.1 Energy Management Matrix- Annan Hospital

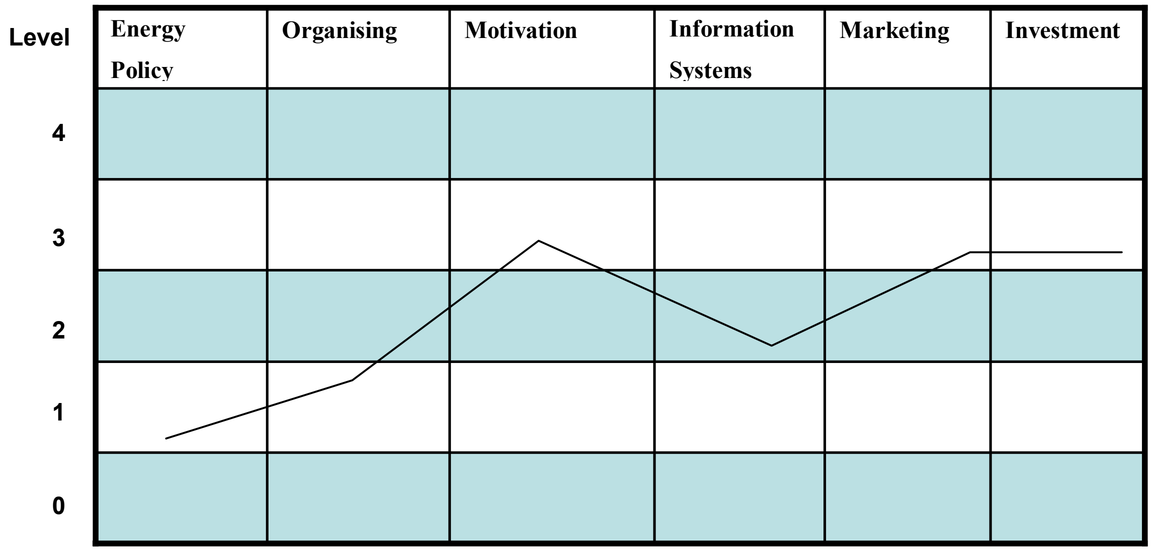

Table 3: Annan Hospital Energy Management Matrix

The Energy management matrix as shown in Table 3 reflects how Annan hospital stands in their energy management profile. This analysis is obtained from the interview that was conducted with head of the estate department of NHS Dumfries and Galloway and two other staff.

The graph shows an unbalanced matrix where:

- There is an un-adopted energy policy set by energy manager
- Energy manager in post but line management and authority are unclear. This shows a minimal form of organization for the energy management programme of Annan hospital.
- Energy committee used as main channel together with direct contact with major users, this show that there is a form of communicating about the energy management programme of Annan hospital.
- Monitoring and targeting of reports based on supply meter data reflecting an information system. Energy unit has ad hoc involvement in budget setting.
- Programs of staff awareness and publicity campaigns present
- Same payback criteria employed as with all other investment decisions.

The Energy policy area contains the lowest trough and motivation the highest peak. However, achieving a balanced energy management matrix will require the hospital stepping up the energy policy, Organizing, motivation, information systems, marketing, investment, to the same level (preferably level three) with reference to the energy management matrix chart in Table 2 of the literature review. Thus there is an opportunity for improving the energy management system of Annan hospital especially by improving the energy policy and restructuring the management of the energy management system in terms of defining roles and responsibilities.

Good energy management in NHS Dumfries and Galloway has the potential to encompass all the issues as discussed in the literature review of this project report: ensuring security of supply, choosing fuel which minimizes emission, promoting a healthy environment locally and internationally. Energy management can be incorporated into existing management systems to provide an integrated approach to energy sustainability. It is strongly recommended that, where practicable, energy management or environment management systems (such as ISO 14001) be implemented.

It is observable from Table 3, that developing an energy management matrix best describes an organisations approach to energy management and will help identify areas for improvements.

5.3.2 The Energy Audit

The energy bills of the Annan Hospital were used to estimate the global energy requirements during winter and summer operation. As part of the energy audit the building envelope was inspected and heat loss arising from the building was estimated. Also electrical fittings such as boilers, hot water systems, HVAC and lightning were inspected. Equipments used for treatment were not inspected as this may pose potential health hazard to patients.

Energy Bill Analysis:

- Average annual Energy consumption in Annan hospital:

- **Electricity consumption**: 217,003kWh
- **Carbon emission from electricity consumption**:
  217,003x 0.43 = 93,311.3kg CO_2/kWh
- **Gas consumption**: 998,052kWh

- **Carbon emission from gas use:**
  998,052 x 0.206= 20,559.8 kg CO_2/kWh
- **Average Annual Energy Cost**: £ 37,887.83
- **Average Annual Total Carbon emission**: 113,871.1kg CO_2/kWh

(Emission factors are based on DEFRA's [13] figures, long term marginal factor used for calculating CO_2 emissions from electricity and natural gas use).

- **Sankey Diagram for Annan Hospital**

The energy flow in Annan hospital as shown in figure 12 represents how the overall energy is used in the building. The site survey and energy bills collected from the building during this study, revealed the source of energy input into the building such as amount of electricity from the grid and the quantity of gas supplied.

In Annan hospital, 20% of the total energy input is electricity from the grid, taking care of the power and lighting. These include lamps, part of the hot water system and major equipment used in the building. Gas has 80% of the total energy input in the building, of which majority is used for space heating. According to a BRECSU [3] report, space heating typically accounts for 75% of the gas consumption in commercial buildings. Gas is also used for the hot water system and catering services.
In a more detailed analysis of the building's energy use, a summary of the metered energy use can be categorized showing the actual amount of gas and electricity that goes to each system (heating, air condition and ventilation, hot water system, power and lighting, process plant etc) in the building.
As no metered data was available from the hospital the figures in the Sankey diagram were estimated.

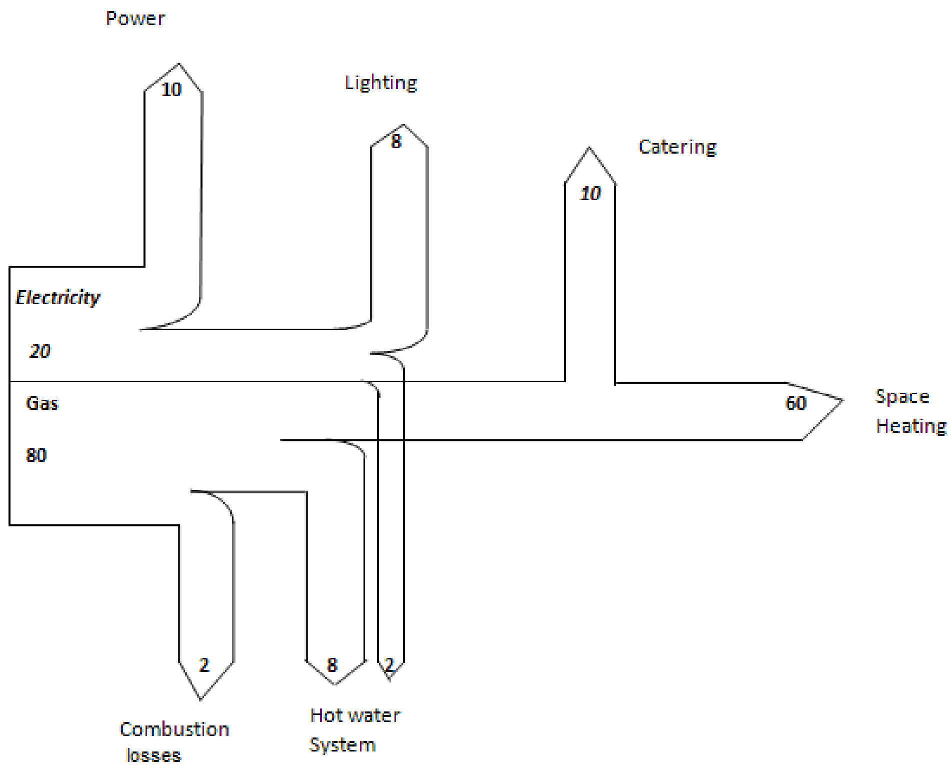

Figure 12: Sankey Diagram of Annual Energy Consumption

Graphical Analysis of Energy Bills

From figure 13, which details gas consumption in Annan hospital for the 2005/2006 financial year, there is an observable rise in temperature during the winter months (October 2005 to April 2006), after which a fall is noticed during the summer notes. Thus the energy signature of the gas consumption is evident and shows that majority of gas consumption is utilised for space heating. The same trend is also observable from figure 14 which details the gas consumption for 2006/2007. (See Appendix one for source data)

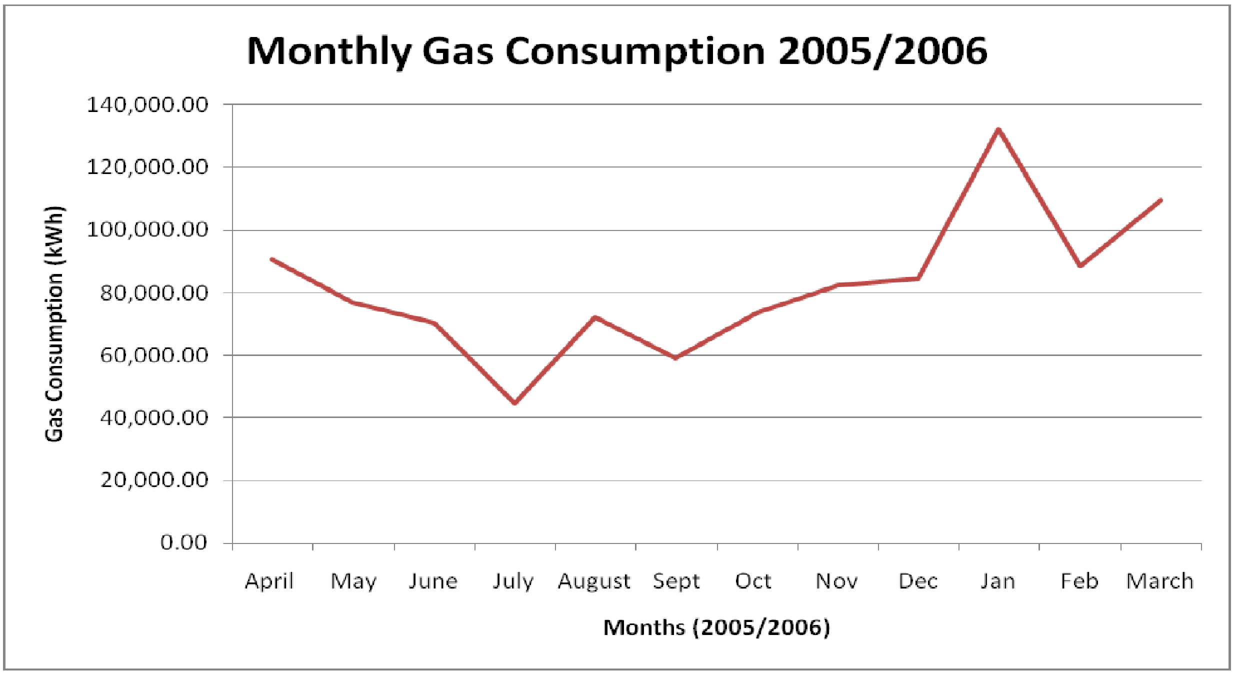

Figure 13: Annan Hospital Monthly Gas Consumption 2005/2006

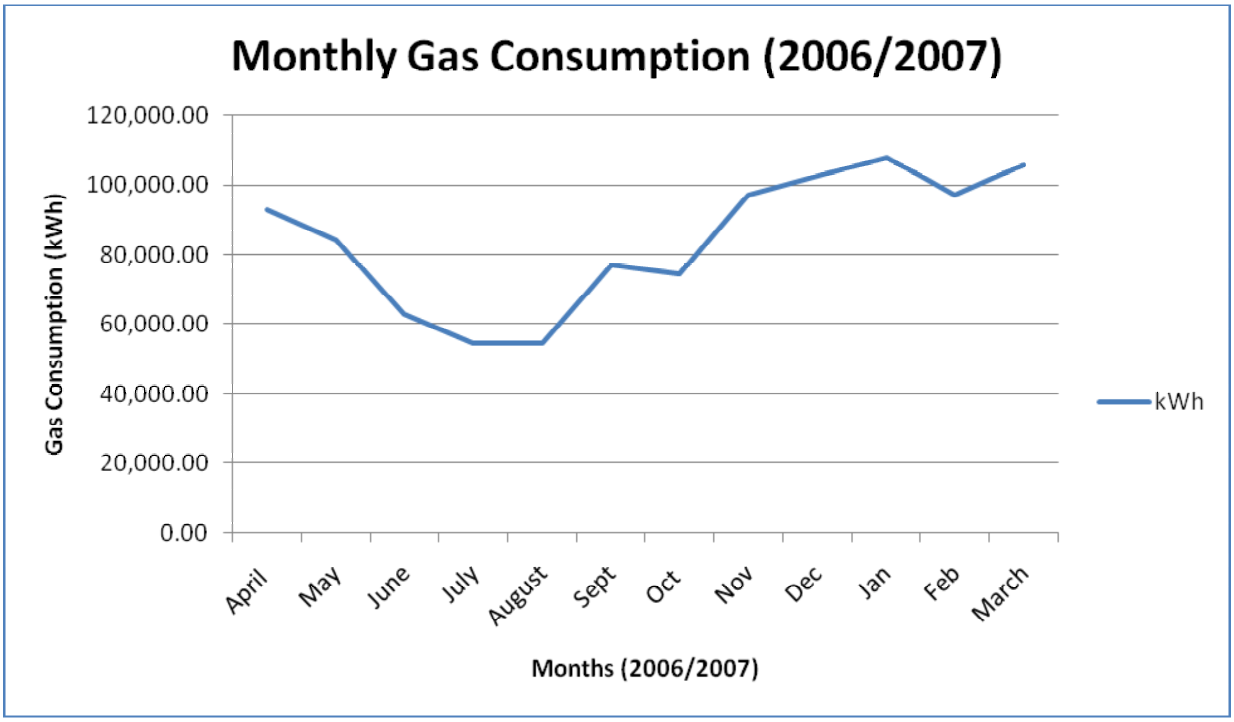

Figure 14: Annan Hospital Monthly Gas Consumption 2006/2007

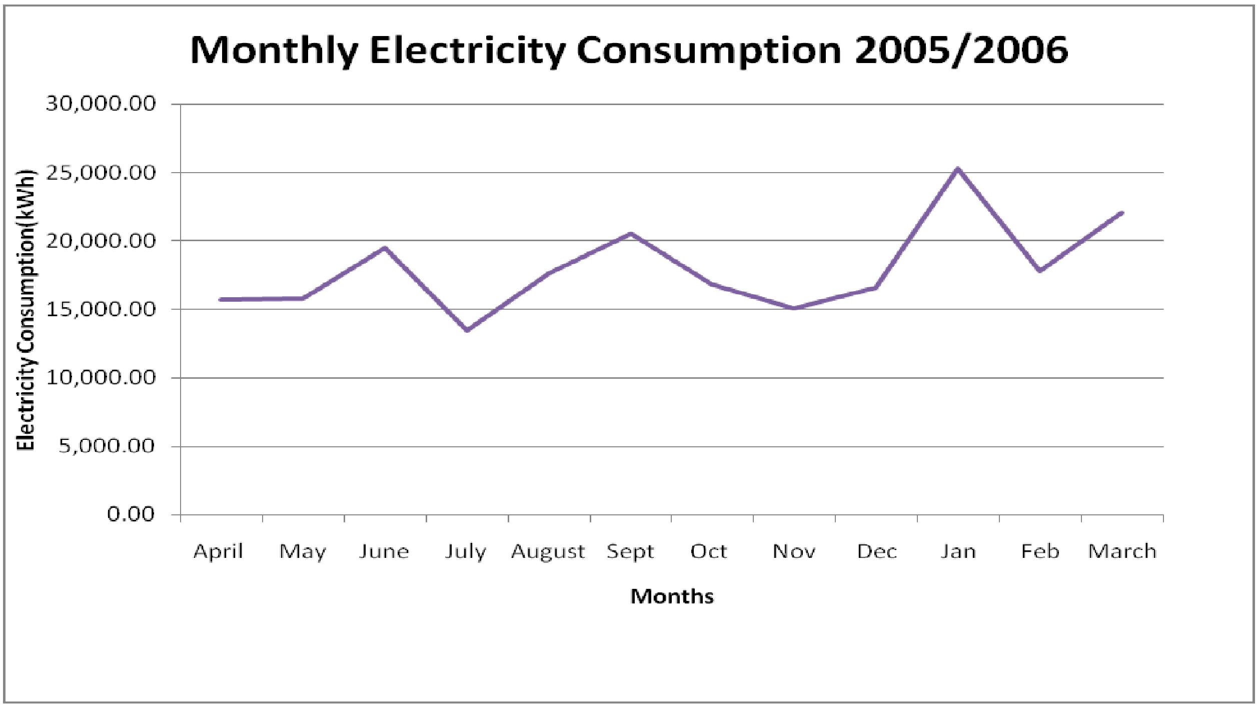

Figure 15: Annan Hospital Monthly Electricity Consumption 2005/2006

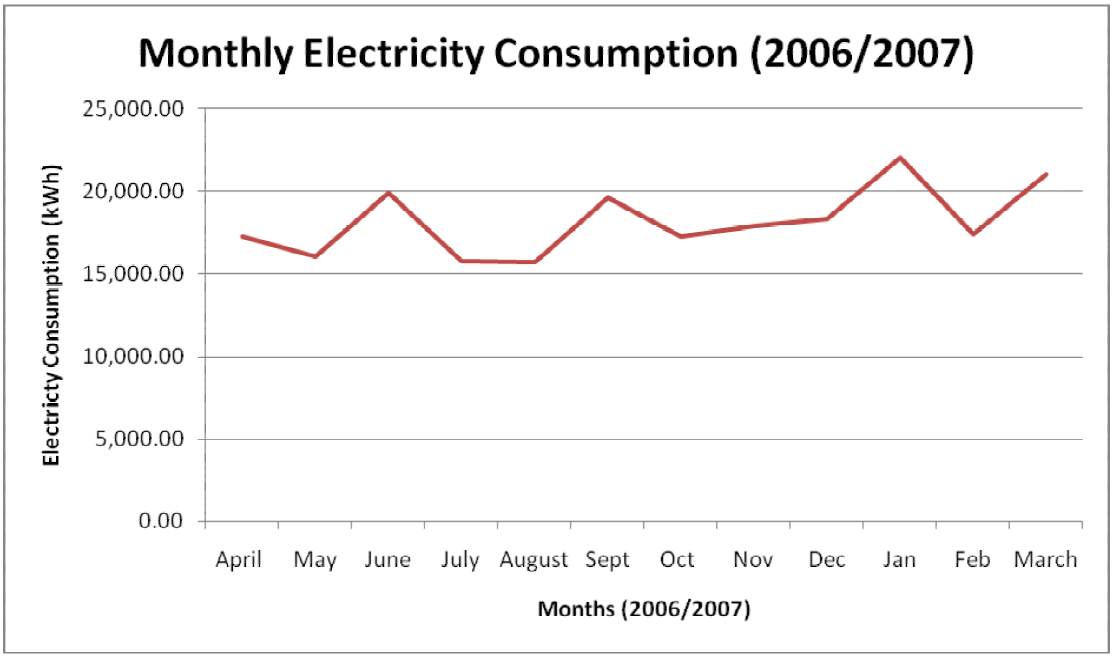

Figure 16: Annan Hospital Monthly Electricity Consumption 2006/2007

From fig 15 and 16, it is observable that there is no apparent trend for the electricity consumption in Annan hospital, as the graphs shows an irregular fluctuation in electricity consumption, thus the energy signature for electricity consumption can not be determined.

The reasons for this irregular fluctuation in electricity consumption may be as a result of rising and declining equipment load due to monthly surges or decline of patient intake, then again it may also be due to increased lightning need or cooling requirements during summer.

5.3.3 Checking Efficiency of Electrical Fittings

- **Boilers**

The boilers are gas fired and have low and high fire facilities. With this system there are four boilers which are step controlled to maintain a boiler return temperature. The controlling sensor is located in the flow return. Each boiler has a circulating pump associated with it and if the boiler is shut off for any reason the circulating pump will continue to run to allow dissipation of heat within the boiler (timer setting in panel) Boiler control is only enabled when following conditions are satisfied when

- Pressurisation unit is fully operational i.e. No Fault.
- Main heating pumps or domestic hot water primary pumps are running.

Figure 17: Gas fired unit boilers in Annan hospital

- **Domestic Hot Water System**

Domestic hot water (DHW) system is controlled by a 2 port control valve. A thermostat located on the DHW calorifier operates this valve's opening or closing depending on the demand. Should no demand be required then the DHW primary pumps are switched off (changeover facilities- as for Main heating pumps). Should temperature exceed the high limit setting of the thermostat, then valve is closed and pumps are switched off. This condition requires that the thermostat is manually reset.

A DHW circulating pump is time clock controlled by an on/off switch.

Figure 18: Domestic Hot Water calorifier in Annan Hospital

- **Lighting**

- Lights are generally left on continuously in the hallways restrooms and all common areas.
- No occupancy or ambient light sensors were found.
- Overhead lighting is utilized to provide the required lighting levels without taking into account the available ambient light.

- **HVAC System**

Heating, Ventilation and Air conditioning (HVAC) is provided by combination of air handler chilled water air –conditioning with heating and cooling coils and rooftop mounted heating and cooling units. The exiting HVAC pneumatic controls in Annan hospital are in fair operating conditions and need to be upgraded. The source of chilled water for much of the hospital cooling system is providing via a few centrally located chillier units. Heating is provided by gas fired heating systems in combination with four gas fired unit boilers. Throughout the hospital, the mechanical systems run continuously. There were several different HVAC systems observed during the walk-through audit. These systems ranged from the make-up air unit serving the kitchen area to central station Air Handler with Variable Volume zone control in the rooftop.

The current HVAC system for the building draws 100% outside air and air is routinely conditioned two times prior to being discharge into a patient room or work station. Air is passed through a cooling coil, typically set to discharge air at 24 degrees C. During the audit, inadequate change of air filter was observed, thus requiring the heating, ventilation and cooling system to expend more energy to condition the in-coming air to desired areas in the hospital. HVAC units run continuously in the return air re-circulation mode and do not take advantage of free cooling opportunities such as the use of economizers to pull fresh air outside the facility during the cool periods of the day or night operating hours.

5.3.4 Inspecting the Building envelope

There is wall cavity insulation, loft insulation and double glazed some windows in place.

The opening and closing of these windows is used to control air temperature throughout the year, resulting in large energy loses from the heating, ventilation and cooling system. Floors are pure concrete with various floor coverings. Hallways utilize linoleum while offices use carpet.

Annan Hospital Insulation	Level
Loft insulation	(150mm)Medium
Pipe lagging	Medium
Cavity wall insulation	High

Table 4: Insulation Level in Annan hospital

The Annan hospital building has been modelled with a total area of 12m^2 per room (note there are a total of 75 rooms in the hospital). The walls are constructed with 50mm polyurethane foam insulation with a total U value of 0.92W/m^2 K. The windows are double glazed construction with a U-value of 2.6W/m^2 K. The ceiling has an overall U-value of 0.34W/m^2 K. Design outside air temperature is considered as -5^{o}C as per CIBSE for the Glasgow area or paisley since there is no actual data for Dumfries and Galloway. The heating load was calculated as if no casual gains were available. The inside temperature is taken as 20°C (this temperature is based on the indoor thermometer in Annan hospital, observed during site survey) for the hospital buildings. The height of the room is taken as 2.7m. Based on this information the heat load from the building was calculated as shown on Table 5.

Building Element	**Area (m^2)**	**Temperature Difference °C**	**U Value W/m^2 K**	**Design heat loss (Watts)**
External wall	16	25	0.92	368
Window	2	25	2.6	130
Internal wall	7.5	Nil	N/A	N/A
Internal wall	10	-2	1.7	-34
Floors	12	-3	1.36	-49
Ceiling	12	25	0.34	102
			Total	**517**
Ventilation load				
Air change /h	**Room Volume (m^3)**	**Temperature Difference °C**	**Vent factor W/m^2 K**	**Design heat loss (Watts)**
2	30	25	0.33	495
			Total design heat loss	**1012**

Table 5: Heat Load Calculation per Room in Annan Hospital

5.4 Energy Bench Marking for Annan Hospital

Currently, the total average energy consumed annually by the Annan hospital building is 781.0 GJ for electrical and 3592.7 GJ for gas, for a total of 4373.2 GJ at a cost of £37887. Gas costs make up 71% of the total utility costs for the facility and 80% of the consumption. Electrical costs make up 28.3% of the total utility costs and 20% of the consumption.

	Average Annual billed units (kWh)	**Annual GJ**	**Treated Volume m^3**	**Annual GJ/100m^3**
Gas	998,052	3592.7	5832	62
Electricity	216,961	781.0	5832	13.4
Average Total Energy Consumption	1215013			

Table 6: Energy Performance Index of Annan Hospital

Performance Assessment

	Low consumption (Less than)	Medium Consumption (Between)	High consumption (Greater than)
	Yardsticks in GJ/100m²		Yardsticks in GJ/100m²
Small acute hospital (<25,000m³)			
Fossil fuels	54		72
Electricity	6.0		8.0
Large acute hospital (>25,000m³)			
Fossil fuels	62		70
Electricity	8.0		10.0
Long stay hospital			
Fossil fuels	55		63
Electricity	5.5		7.0
Nursing/residential care home			
Fossil fuels	54		68
Electricity	6.0		7.5

Figure 19: Energy Consumption Yardstick (benchmark criteria) [13]

The data in Table 6 represents the energy performance index of Annan hospital with a volume of 5832m^3.Based on these data Annan obtained the following result for energy consumption performance when compared with a standard performance assessment of a typical small acute hospital with less than 25,000m^3 size as shown in Figure 19.

- Annual gas consumption of 62GJ per 100 cubic metres, this shows that the hospital building with this size (5832m^3) has medium gas consumption.
- Annual electricity consumption of 13.4GJ per 100 cubic metres, this reflects low electricity consumption for its size when compared.

	Consumption (kWh)
Natural Gas	**998,052**
Electricity	**217,003**
Total energy use for the year	**1,215,055**
Space heating energy use	**kWh**
Annual space heating energy use (A)	**698636**
Annual non-space heating energy use (B)	**1,215,055 – 698636 = 516419**
Adjusting Space heating to account for weather	
Degree days for the energy data year	**2393**(11)
Weather correction factor (C)	**2462*/ 2393= 1.03**
Adjusting the space heating energy to standard condition	
698636 x 1.03 (A x C)	**719,595kWh (D)**
Adjusting the space heating to account for exposure	
719595 X 0.9* (Dx0.9)	**647635kWh (E)**
Normalised annual energy use	
516419 + 647635 (B + E)	**1164054kWh(F)**
Normalised performance indices(kWh/m^2)	
Floor area(m^2) (G)	**2160m^2**
1164054/2160 (F/G)	**538kWh/m^2**

Table 7: Normalised Performance Indicator (NPI) Calculation

*Note: With reference to the BRECSU's building energy solutions guide[3]:

- Energy used by space heating is assumed to be 75% of the total energy use.
- 2462 represents the nominal value for calculating weather correction factor
- 0.9 represents the exposure factor of the hospital building

(Normalised annual energy use= Annual non-spacing heating + Adjusted space heating)

Table 7 above, shows the normalised performance index (NPI) calculation; this presents an alternate method for assessing building energy performance. The NPI calculation shows the typical energy consumption of a buildings when the location of the building and the weather correction factor are taken into consideration. With reference to table 6, it is observable that the total average energy consumption, before normalisation, of Annan hospital is 563kWh/m^2 (1,215,013 kWh), however as seen on table 7, on normalising the energy use of the hospital, energy consumption becomes 538kWh/m^2 (1164054kWh). This value indicates that Annan hospital can further reduce its energy consumption.

5.5 Implementing Energy Demand Reduction Measures in Annan Hospital

Based on the findings of the energy audit, this section proffers specific recommendations to improve energy management in Annan hospital.

The recommended energy demand reduction measures include:

- **Increased insulation**: As seen in table 4 Annan hospital currently has a loft insulation of level of 150mm, this should be increased to at least 250mm, this will enable Annan hospital meet the requirements of current building regulation, which states that the minimum loft insulation should be at least 200m. Some sources such as E.on recommend a loft insulation level as high as 270mm. Improving the insulation level is a straightforward method to reduce energy losses in a building. Most modern hospital buildings will have adequate insulation in the cavity walls, loft space, under floors and on hot water tanks/distribution pipe-work since it is a requirement of the building regulations.

- **Energy efficient Lightning:**

- Appropriate light sensor should be installed to control light distribution in offices, hallways etc.
- Light controllers should be installed throughout the hospital. Lighting Controls can offer increased flexibility to lighting use by ensuring lighting is only utilised when needed. Lighting levels can also be adjusted manually to suit the task. Lighting control is exercised through a variety of switches or dimmers such as time switches, occupancy sensors or a photocell (light sensor). These systems will allow the lighting systems to go into the equivalent of a night setback similar to night setback scenario for the HVAC systems.

- Installing low energy lighting can be a way of reducing the energy consumption by 15%. It should be noted that the latest building regulations (2004, Part L) aim that artificial lighting must "be capable of being controlled to achieve maximum energy efficiency" [(4).] Furthermore these regulations compel replacement lighting systems to be considered as if the building is new. Table 8 gives a variety of energy efficient lightning options.

Lamp Type	Typical Application	Efficiency (Lumen/Watt)	Lifespan (hrs)
Tungsten Filament	Standard bulb (non energy efficient)	8-12	1,000
Tungsten Halogen	Display lighting	12-24	2,000-4,000
Compact Fluorescent	Typical saving light bulb	50-85	5,000-10,000
Tubular Fluorescent	Office	65-140	5,000-15,000
High Pressure Sodium	External lighting	70-100	14,000-30,000

Table 8: A variety of low energy lighting options [(6,11)]

- **Improved Efficiency of Electrical Fittings and Equipments:**
- Installing energy saving electrical fitting.
- Installing a direct digital Control system (DDCS) that links all building operating systems together for demand side management, night setback, and more dependable occupant comfort. Installing a DDCS will reduce the drift, maintenance and recalibration problems common with HVAC pneumatic control system.
- A preventive maintenance routine should be initiated to scheduled items and maintain equipment operating as designed with minimum energy expanded.
- Introducing highly efficient boiler for space heating and domestic hot water system can help reduce energy demand. Since hospitals are under public

building the overall operation and maintenance level of the HVAC system are checked for efficiency [78].

- There should be a regular change of air filters of the HVAC system to ensure energy efficiency.

Other recommendations geared towards reducing energy demand include:

- **Increasing Awareness level:** Awareness and education can play a key role in empowering building occupants to take responsibility for their energy use. The awareness level on energy efficiency of the occupants of the hospital building (staff patients and visitors) can reduce the building energy consumption. Behaviour change toward energy use will make the hospital staffs serve as a secondary control system within the building. Furthermore facilities managers can make savings through a well thought out energy policy i.e. defined heating seasons, correct seasonal settings, policy on auxiliary heating etc. [42, 59, 65]

- **Implementing smart metering**

The UK Government is committed to seeking measures to achieve carbon savings of 0.2 MtC by 2010 through better metering and billing. It believes that one way this could be achieved is if all new and replacement meters are 'smart'[78, 79, 80]

Smart meters allow energy suppliers to communicate directly with their customers, removing the need for meter readings and ensuring entirely accurate bills with no estimates. They tell people about their energy use through either linked display units or other ways, such as through the internet or television. They could offer gas and electricity customers: more accurate bills; information that could help them use less energy and encourage energy efficiency; lower costs through reduced peak consumption, Increased security of supply: by ensuring more sustainable energy consumption and thus leading to the preservation of fossil fuel reserves. Smart metering is also environmentally friendly because it will ensure reduced carbon emissions.

5.6 Determining Energy Savings

After the general recommendation, these two energy conservation measure (ECM) analysis were performed to produce a likely energy savings to be made in Annan hospital's energy consumption.

Analysis I – Improving building insulation

As part of the analysis performed on the case study (Annan hospital), the insulation in the building envelope was increased from what is assumed to be its current situation. This improvement is supposed to give a likely saving on the space heating and the overall gas consumption.

As observable from Table 4, the heat load of Annan hospital, at its currently existing insulation level, is 1012W. With reference to Table 5, if insulation level is improved for the external walls; windows and ceiling (loft), as recommended in sections 5.4 above, by installing insulation materials of lower U-value as shown the heat load/loss improves to 791.64W. The improved U-value figures for windows, external walls and loft on Table 9 were chosen because these values are recommended as best practice values by the Approved document L1B-for refurbishment[5].

Building Element	Area (m^2)	Temperature Difference ^oC	U Value $W/m^2 K$	Design heat loss (Watts)
External wall	16	25	0.55	220
Window	2	25	2.2	110
Internal wall	7.5	Nil	N/A	N/A
Internal wall	10	-2	1.62	-32.4
Floors	12	-3	1.36	-48.96
Ceiling	12	25	0.16	48
			Total	**296.64**
Ventilation load				
Air change /h	**Room Volume (m^3)**	**Temperature Difference ^oC**	**Vent factor $W/m^2 K$**	**Design heat loss (Watts)**
2	30	25	0.33	495
			Total design heat loss	**791.64**

Table 9: Heat Load Calculation per Room after Improving Insulation

The calculations below show the energy savings achievable by reducing heat loss from 1047W (as shown in table 5) to 791.64W.

Total Existing Heat loss in Annan hospital= 1012W x 75 rooms = 75900W = 75.9kW

Total Improved heat loss = 791.64W x 75rooms= 59373W =59.37kW

Energy savings from heat loss = 75.9kW – 59.3kW = 16.6kW.

% energy savings = 22%

Thus a 22% savings is achievable from improving the insulation level as recommended as above. Assuming, such an increase in insulation was actually performed in Annan Hospital, the building will experience a likely saving of about 22 percent. With reference to the 2006/2007 energy bills, this will reduce gas consumption from 1,011,914.20kWh to 844,949 kWh. Figure 20 shows the effects of the improved insulation on gas consumption (see appendix 2 for details).

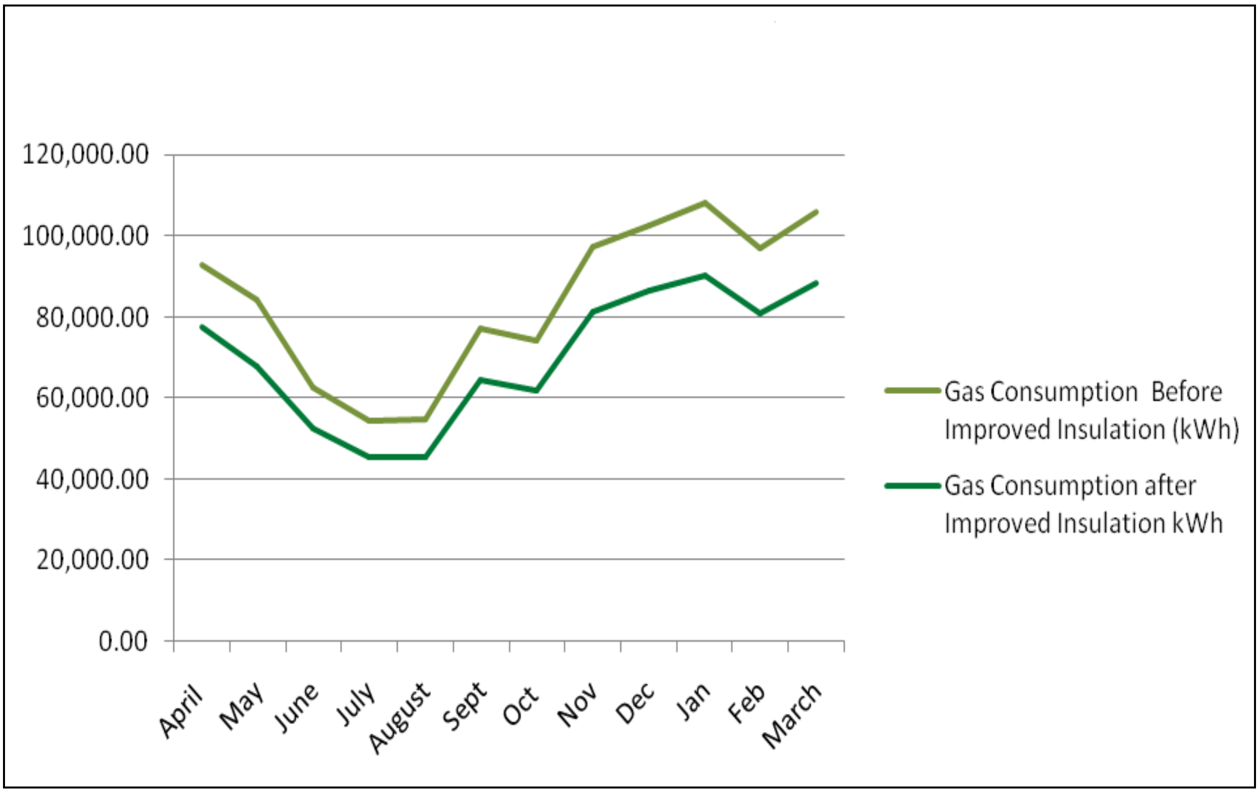

Figure 20: Effects of Improved Insulation on Gas Consumption in Annan Hospital

Analysis II - Energy saving from efficient lighting

This analysis was based on the fact that lighting in has huge impact on the electricity consumption since most lighting fixtures in the building are always switched on. Efficient lighting fixtures were assumed to be installed in the hospital to replace the existing ones. As a result of this analysis, the study aim to realise a huge savings in the electricity demand in the hospital

Efficient Lighting

Considering replacement 200 compact fluorescent rated at 60W, 2500 hrs of lifespan with compact fluorescent lamps rated at 18W, 15000 hrs with operating conditions of 18hrs per day on average. Energy cost at £0.093 per kWh [27].

Annual Energy Savings

Annual operating hours = 6570 hrs

With 60W, 60 x 6570= 394.2kWh

200 x 394.2kWh= 78.8MWh

Wattage Difference = 60- 18 = 42 W

Savings = 42 x 6570 = 275.9 kWh per lamp

Energy saving for 200 lamps: 55,100 kWh = 55.1MWh

Percentage energy saving = 69.9%

Thus a 69.9% saving is achievable from replacing 200 lighting fittings

Cost Savings:

Energy cost (£/kWh) x Energy savings = 0.093 x 394.2kWh

= £36.66 per lamp

Cost savings for 200 lamps: 13.39 x 200 = £7332.12

Thus the total annual cost saving for substituting 200 lamps would be **£7332.12**

From the energy bill, Annan hospital uses **215,933kWh** of electricity (using 2006/07 energy bill) which includes lighting. With a likely saving of **55,100kWh** on lighting for 200 lamps, 25.5% of the hospital electricity demand can be achieved.

However, the demand analysis that was performed gave us 22 percent reduction in gas demand for space heating and 26 percent reduction on electricity demand for lighting. Both percentages were applied to the 2006/2007 energy bill. Table 10shows the summary of the energy demand before and after demand reduction analysis. Also in figures 20 and 21 are reflecting the effect of the reduction in gas and electricity consumption.

	Before improved insulation and efficient lighting	After improved insulation and efficient lighting
Electricity consumption (kWh)	218,073	161,373
carbon emission from electricity consumption ($kgCO_2/kWh$)	93,773	69,390.5
Gas consumption (kWh)	1,011,914	844,949
carbon emission from gas consumption ($kgCO_2/kWh$)	208,454	174,059
Annual Total Carbon emission ($kgCO_2/kWh$)	302,227	243,449
Annual Total energy consumption (kWh)	1,229,987	1,006,322

Table 10: Summary of the Effects of ECM on Energy Demand in Annan Hospital

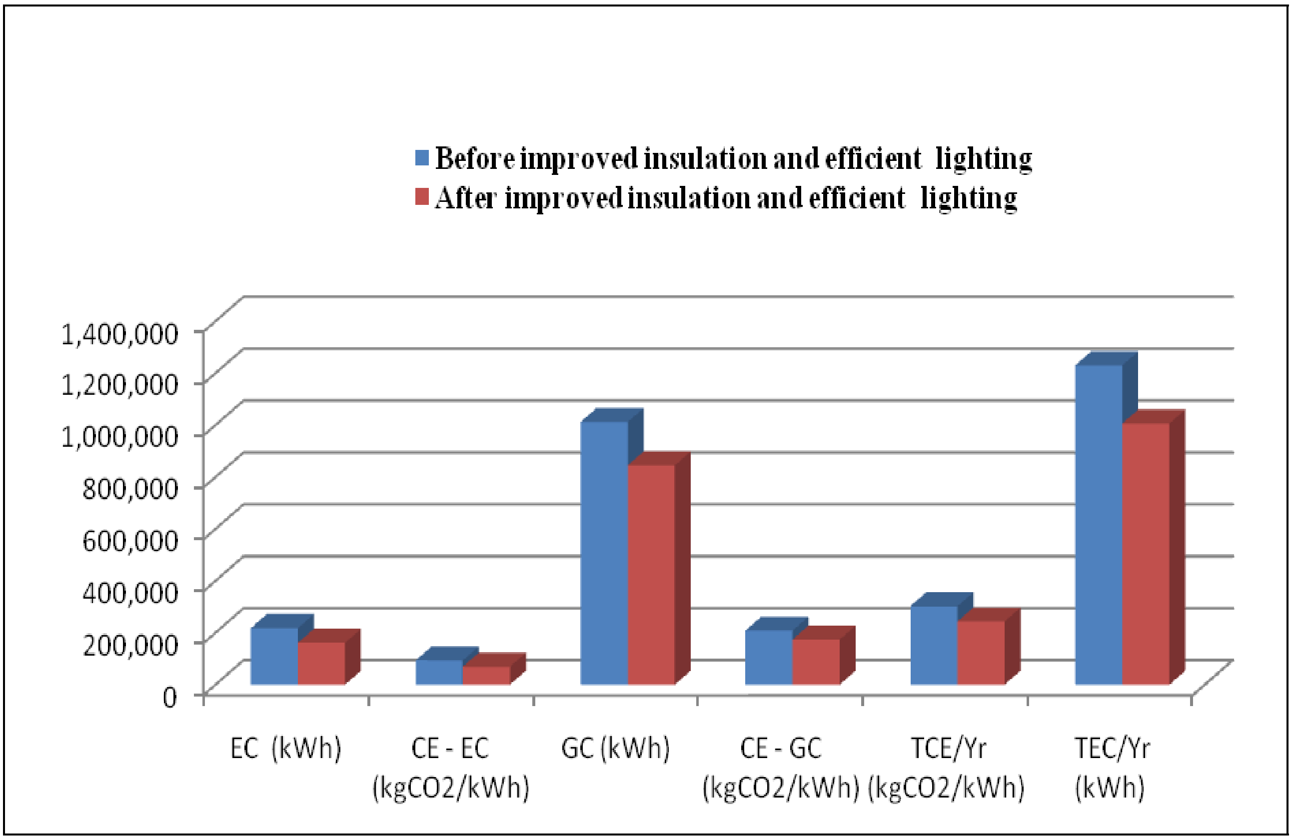

Figure 21: Summary of the Effects of ECM on Energy Demand in Annan Hospital

Key:

ECMs: Energy Conservation Measures

EC: Electricity Consumption

CE - EC: Carbon emissions from EC

GC-: Gas Consumption

CE- GC: Carbon emissions from GC

TCE/Yr: Annual Total carbon emissions

TEC/Yr: Annual Total Electricity Consumption

5.7 Outcome of the RETScreen Renewable Energy Analysis

To offset the above remaining demands that will be left when all reduction measures are in place, This study was focused on four micro generation technologies which are Biomass, ground source heat pump, solar PV and wind turbine, this choice was made for the following reasons:

- Biomass has the capacity to generate large amount of energy and also has huge potential due to the availability of the resource (wood chips) in Dumfries& Galloway.

- Ground source heat pump has been used in one of the hospital mentioned in literature review, which makes it a tested and acceptable RE technologies within a hospital building.
- Wind and Solar energy are common RE technologies that can be applied anywhere in the UK once the wind speed and the solar radiation of the location are determined.

Due to lack of data on the daily energy demand profile, the study used the monthly energy demand profile derived from the energy bill to help in the design stage of the renewable energy supply.

For electricity and heating demand, the RETScreen software was used for demand supply analysis. These analysis were performed on different scenarios. The three scenarios are:

- Simulation I -using the current monthly energy demand profile (before improved insulation and efficient lighting)
- Simulation II -based on the assumption that the hospital energy demand may increase up 30 percent of the amount obtainable at present (Building expansion, increase in services etc).
- Simulation III -using the reduced monthly energy demand profile (after improved insulation and efficient lighting).

For heating demand in the Hospital, demand supply analysis was carried out involving ground source heat pump and biomass. For Electricity demand, wind turbine and solar PV were involved.

RETScreen parameters for demand supply analysis
Latitude =55.91N
Longitude = 04.53W
Average mean wind speed = 5.1m/s
Average mean temperature (Maximum and Minimum) ^{o}C =9.625 ^{o}C
Average total global radiation (kJ/m^2) =278470.58kJ/m^2

The main focus of this study is on simulation I results. Simulation II and III serves as a guideline if the current demand changes (higher or lower).

Simulation 1 was performed from the current energy demand of Annan hospital building for year 2006/07. At present the grid electricity consumption is 218,073 kWh and gas consumption is 1,011,914 kWh. This was used in the analysis performed in Table 11 to get the best renewable energy option that can serve as an alternative energy supply to the hospital energy demand.

Simulation 1			
Technology	**Energy generated (kWh)**	**Capacity (kW)**	**Carbon saving $kgCO_2/kWh$**
Wind	**29,912**	**17**	**7,777**
Photovoltaic-PV	**5,153**	**15 (42units of 1770AH @240V Batteries)**	**20,514**
Biomass	**864,000**	**250 (388 tonnes of woodchips)**	**7,750**
Ground source Heat Pump (GSHP)	**52,907**	**68.8**	**32,690**

Table 11: Result from the Simulation 1(Annual Energy Production of the RE technologies)

5.8 Result Summary

With the aid of software (RETScreen), analysis based on different type of renewable energy sources present the following

- **Wind turbine**

From Table 11, it shows that installing a 17kW capacity of wind turbine in the hospital at an average wind speed of 5m/s will produce 29,912kWh of energy annually that can be used as an alternative to the conventional grid supply of electricity to the building. This will reduced the electricity demand from the grid by 13% .Although the wind speed normally drops below average, storing the energy in the battery can help maintain reasonable constant supply.

- **Solar PV**

The deployment of a 15kW rated power solar photovoltaic capacity plus inverters is expected to generate an estimated 5,153 kWh a year. The rooftop system normally helps to insulate the building and still provide 2.4 % of the electricity required annually in the building.

- **Biomass**

The result shows that almost 86% of the heating requirement of the hospital can be provided by a biomass system. In this energy model 864,000 kWh was estimated from a 250kW biomass plant a year. The carbon emission saved is small due to the combustion process involved.

- **Ground Source Heat Pump**

68.8kW Ground Source heat pump capacity can produce 52,907kWh of heating energy. This capacity can be increased to meet high heating and hot water demand because of the vertical closed loop system type used this energy model. The total borehole length is 428 meters. With this capacity, it can produce 5.3 % percent of the hospital heating required during winter and up to 12% of cooling demand during summer.

Technology	Energy generated (kWh)	Capacity (kW)	Carbon saving $kgCO_2/kWh$
Wind	59,824	34 (Two 17kW wind turbine)	15,554
Photovoltaic-PV	10,306	25 (72 units of 1770AH @240V Batteries)	41,028
Biomass	864,000	250 (388 tonnes of woodchips)	7,750
Ground source Heat Pump (GSHP)	74,816	85	39,690

Table 12: Result from Simulation II (Based on higher demand in energy consumption in the hospital)

5.8.1 Higher Demand Analysis

This Simulation was performed on the assumption that the hospital energy demand may increase, if there is an expansion in the size of the building, longer operational/ occupancy hour and increase in general services. The simulation result as shown in table 14 was based on 25 to 30 percent assumed increase from what is obtainable at present. This can be of use for the future energy use in the hospital. The result of this simulation shows that for higher energy demand, biomass can be used as an alternative energy supply for the building due its large capacity, sufficient energy generation and availability of the resources in Dumfries and Galloway. With the same biomass plant capacity used the simulation I, 250kW that generates up to 864,000 kWh .It still stands as a preferred option in the event of an increase in demand, even when other renewable energy options capacity were increase.

Biomass has short payback period because of the output .Although the system initial cost is always high and it also involves transportation and storage of resource materials. If biomass energy is to used as a fossil fuel substitute the energy provide should be greater than the fossil fuel energy needed to produce it. Determining the overall energy balance requires taking account both the energy required to produce the biomass and the energy required to convert the biomass feedstock into the energy carrier that will be use.

Technology	Energy generated (kWh)	Capacity (kW)	Carbon saving $kgCO_2/kWh$
Wind	29,912	17 wind turbine	7777
Photovoltaic-PV	5,153	15 (42 units of 1770AH @240V Batteries)	20,514
Total	35,065	32	27,560

Table 13: Simulation III (Based on lower or reduced demand in energy consumption in the hospital)

5.8.2 Lower Demand Analysis

The simulation was for a possible combination of wind turbine and solar PV systems in offsetting the remaining demand after demand reduction measures has been applied. The result shows that if combinations of 17kW wind turbine and 15kW of solar PV are installed in the hospital, a total of 35,065 kWh of energy will be generated with up to 27,560 kgCO2/kWh of carbon emission reduced from the building. The wind and PV capacity in this simulation is the same with simulation I only that simulation III does not consider biomass and ground source heat pump for a lower demand analysis. On the economic point the two system can use same equipment like battery storage there by reducing the initial /installation cost of the both system .The combination of both system can still suffer some financial set back as shown in table 15 due to high initial cost of solar PV system ,long payback period and negative NPV. This simulation result can only be applicable if the hospital implements the demand reduction measures as mentioned earlier in this chapter. By implementing these measures the hospital may get up 30-40% reduction on their current energy demand, thereby making it easy for low cost and low output renewable energy technologies to be preferred option for an alternative energy supply.

5.9 Financial Analysis

Energy is one of the largest controllable costs in most organizations, because there is usually considerable scope for reducing consumption in buildings. Economic analysis is a must for any renewable energy project, it highlights the cost requirement for that project in terms of investment and the intended profits or benefits estimated from it in order to justify it economically viable. The software used for this project also simulates estimated financial summary figures.

Financial Summary	Ground source heat pump	Biomass	Wind turbine	Photovoltaic PV
Cost (initial)	£63,006	£150,000	£58,500	£774,680
Simple Payback	12.4years	4years	7.2yrs	More than 25 years
Net present Value (NPV)	£7,560	£43,365	£21,528	£718,158
Project life	25 years	10years	25years	25years
Pre tax IRR and ROI	8.6%	74.3%	22%	Negative
After tax IRR and ROI	8.6%	74.3%	22%	Negative

Table 14: Financial summary of the RE technologies from Simulation 1

Economic analysis of the renewable energy that can be used in Annan hospital shows that an initial cost of £63,006 for 69kW installed capacity of Ground source heat pump with a pay back period of 12 years. GSHP has a positive Net Present Value even with major changes on the variables and a good internal rate of return. Biomass has a short term payback due to the capacity 250 kW used in this model. Although the initial cost can be high its output compensates for it. With an internal rate of return of 74.3% and a positive NPV, the technology looks economically feasible.

Using RETScreen to model Biomass gives it the flexibility to add Waste Heating Recovery system (WHR) though it was not added in this simulation. The difference in the initial cost when WHR is added is small but a WHR system reduces the amount of biomass fuel (tonnes of wood chip) needed.
Wind turbine has a positive economic status in the UK. The initial cost is £58,500 which is moderate for the output. Availability of wind resource and other installed component like large batteries capacity can reduce the payback period below 7.2yrs. The Net Present Value is positive. Solar PV is good option. High initial cost makes the payback period more than the project life which is 25 yrs. The Net Present Value, IRR and ROI are negative.

5.9.1 Limitation of RETScreen

- **Detailed variation of output**

RETScreen was used in this study due its ability to analyse a range of renewable energy technologies but it does not bring out or show the variation of the energy output at different seasons of the year especially winter and summer. For some renewable energy e.g. wind turbine and solar PV, their output can vary with the weather conditions where as RETScreen does not show the effect of this weather changes.

- **Cost**

Feasibility studies, installation and maintenance of RE system estimates made by RETScreen may not be applicable in the UK where the result of this study can be implemented. RETScreen financial analysis was based on Canadian dollars although it was converted to pounds, the cost of labour and project structure in the UK is differs, making it difficult to give a clear estimate on the actual cost of these renewable energy technologies.

5.10 Funding

Funding of renewable energy project encourages the development, improvement and usage of these technologies to reduce the dependence on conventional energy sources. Availability of funds for Government agencies or energy companies can help communities, Organisations, individual house owner to improve the insulation level, become more efficient and also help in carrying out a feasibility study on a suitable RE option to supplement for energy demand.

In the UK bodies that can provide funds are as follows;

- **Energy Savings Trust** -The Scottish Community and Householder Renewable Initiative is a Scottish Executive programme for small-scale renewable, delivered by the Energy Saving Trust and the Highlands and Islands Enterprise. It offers grants to community groups and households. Department for business enterprise and regulatory reform- also Low Carbon Buildings Programme provides grants towards renewable energy technologies.
  - **Carbon Trust** , Interest free loan for Renewable http://www.carbontrust.co.uk/energy/takingaction/loans.htm
  - **Shell springboard** http://www.shellspringboard.org/
  - **The Big Lottery Fund** - BECGS (Bio-Energy Capital Grants Scheme) promotes the early roll out of efficient heat and electricity generators fuelled by biomass – biological material like short rotation coppice or wood chips left over from forestry industries. BECS is joint initiative funded by the Department of Trade and Industry and NOF, with input from the Department of the Environment, Food and Rural Affairs.[23]

6 Environmental Concerns of Implementing Renewable Energy Technologies

Renewable energy technologies impact on the environment both positively and negatively. The impacts of renewable energy technologies include:

- **Reduction of Green house gases:** green house gases (GHGs) emitted by the use of fossil fuels are the main cause of climate change and global warming. The use of renewable energy technologies instead of fossil fuels will lead to reduction of GHG emissions and eventually reduce the impacts of global warming and climate change. (19)
- **Land Use/ Resource Depletion:** renewable energy technologies such as wind power and solar energy most often require the use of large mass of land, often resulting in clearing of forest reserves. Most geothermal power plants will require a large amount of water for cooling or other purposes. In places where water is in short supply, this need could raise conflicts with other users for water resources. Furthermore construction of a utility-scale solar power plants require large amount of land-approximately one square kilometre for every 20-60 megawatts (MW) generated- this poses an additional problem, especially where wildlife protection is a concern. (43)
- **Waste Generation:** installation and operation of almost all the renewable energy technologies results in solid waste generation. For instance construction of wind turbine results in variety of solid wastes such as metal scraps and aggregates. Also geothermal energy production can generate large amounts of solid wastes. (43)
- **Air and Water Pollution:** the construction of most renewable energy technology results in dust emissions and other sorts of air pollution. Geothermal energy often results in large volume of waste water; the disposal method is to inject the liquid wastes back into a porous stratum of a geothermal well, resulting in pollution of groundwater. Production of geothermal energy releases steam containing hydrogen sulphide (H_2S) as well as ammonia, methane, and carbon dioxide. Also the combustion of biomass produces air pollutants, including carbon monoxide, nitrogen oxides, and

particulates such as soot and ash. [43]

- **Impact on Wildlife:** apart from destruction of habitats, certain renewable energy technologies have been attributed to causes death of wild life. For instance wind turbines pose serious threats to birds. Also hydropower has been associated with causing death of salmons. [43]

6.1 Environmental Benefits

- Renewable technologies create jobs using local resources in a new, "green," high-tech industry with massive export potential. They also increase work indirectly in local support industries, like banks and construction firms.
- Some renewable technologies, like biomass, are relatively labour intensive, which is one of the reasons they are to some extent more expensive than their fossil fuel counterparts. For example, growing, harvesting, and transporting biomass fuels all involve labour, as does maintaining the equipment. This means that much of the revenue for installing, fuelling, and operating renewable power plants remains within the region where the power is used.
- Planning for and enabling greater use of renewable and low carbon sources of electricity can help us both meet emissions targets and provide energy security in a context of rising demand and increased dependence on energy imports [66]. In the scenarios with Solar PV, Wind turbine, Biomass and GSHP the CO_2 emissions were to be reduced by an average of 10% if any of the renewable technologies are installed
- Renewables offer benefits not only because they can reduce pollution, but because they add an economically established source of energy to the mix of UK generation technologies. Depending on only a few energy resources makes the country vulnerable to volatile prices and interruptions to the fuel supply [9]
- Increases the awareness on energy efficiency measures.

7 Conclusion and Recommendation

7.1 Conclusion

Hospitals are large consumers of electricity, heating and cooling energy. Since recent years the demand for cooling inpatient rooms has immensely increased due to the higher internal heat production of medical equipments, hot/long summer periods and higher comfort requirement of patient and staff.

This study shows that maximum demand reduction measures simply represent best practice and are therefore cheaper to implement than installing a large plant to meet the unnecessary energy use. Measures to reduce demand will encourage the use highly efficient appliances in the building and also make those (staff and patient) using the building to take more responsibility for their energy use and also act as a visual reminder of similar options which could be employed in the hospital. From the energy audit analysis, a rough demand reduction measures on the building energy use which include regular maintenance of the systems the building, will help identify waste which normally affects the thermal comfort and hot water system. It also helps in size calculation of the system for renewable energy offset.

Hospital buildings operate on a 24 hours basis unlike normally commercial building which makes their demand profile different. It is quite important that the hospital has a balanced energy management matrix in place because it will help them to actualize any laid down plan on either energy performance or energy supply of the building. The partial energy audit that was done in the hospital shows the type of hospital building as in building year, location and design.

The study also proposes age and occupancy level as essential parameters for the assessment of healthcare facilities needs, as an effective measure for long term facility maintenance planning, and for measuring effectiveness. For a typical hospital building, an energy audit ascertains the level and state of insulation in place, different types of energy systems being used to run the hospital and how efficient they are really matters. It is also gives figures of the energy bills for heating and electricity occupancy level, types of appliances that the hospital uses. Technically, all these measure and other in practice reduces the energy demand up to 50% and makes it easy for any hospital management to advance to green offset of their demand.

Currently, the NHS Dumfries and Galloway want to reduce their energy demand by 2% without targets on carbon emission reduction. These renewable energy technologies modelled in by using RETScreen show an output more than 2% of Annan hospital heating and electricity demand. Wind and solar PV were modelled to offset the electricity demand while biomass and ground source heat pump were for heating demand.

Wind turbine technologies as an option is well established in the UK. And due to its flexibility and abundance wind resources it can be used in variety of locations because the output is determined by the wind speed in that area. For a good wind turbine operation an average of 5m/s should be available. From the economic point of view, small wind turbine has a short payback period and low initial cost (micro wind turbine) when compared with solar PV.A wind turbine/Solar PV system can maintain a constant supply, since Solar PV works at maximum efficiency when there is sunlight and less wind .On the other hand, wind turbine provides energy at maximum when there is more wind and less sun. Both RE installed in the building can supplement for each other. The biomass option has a good energy output. The operation will have some noises impact on the hospital environment and requires a lot of transportation (fuel-wood chip). For Dumfries and Galloway, biomass has a lot of potential, although this has not been developed.

For this study, implementing demand reduction measures should be the hospital best option if they only want their demand to be reduced by less than 10%. Ground source heat pump technology is the preferred option for heat generation and also for reducing the energy demand in the hospital if more than 10-30% reduction of their annual energy consumption is required. A large capacity GSHP can provide all the heating energy required in the building. With minimal land use and also has a good and environmental friendly operation. The initial cost is not high though it varies with the installed capacity that will be implemented. The Net present value for the GSHP is positive.

The methodology used in this project will help any hospital in saving energy (reduced demand), improving building performance and enhancing quality of life (reduced air pollution) by applying energy efficiency measures before installing renewable energy technologies.

7.2 Recommendation

All energy development and production impacts the environment to some degree. But the use of geothermal energy can greatly minimize these impacts, resulting in environmental benefits for the hospital with growing energy needs.

This study recommend the use of ground source heat pump as alternative heating energy supply for the hospital if more than 30% reduction on energy consumption is required, knowing that it has great carbon emission saving capability. Its use has a positive net present value, short payback period and also greatly minimises the amount of resulting solid waste and land required for energy production.

In applying for funds, this study can be of great help, since funding sources like the low carbon buildings programme (LCBP) accesses eligibility by the number of energy efficiency measures the organisation or community have undertaken before going for a renewable energy source.

7.3 Further Work

Due to time constraints and detailed information on the hospital, this study outcome did not get a practical conclusion on the case study but a path way has been defined. Further work can be carried out on the case study by an energy consultant or a funded research student with the following in consideration.

- Analyse the building structure to determine were additional refurbishment or increased insulation is required in the building. Identify why there is an increase in the energy consumption (usage or occupancy and expansion).
- Re- evaluate the HVAC, hot water and all appliances in the building
- Apply steps to reduce the increasing energy demand
- Specify the renewable energy, the required performance and a more detailed feasibility study on the proposed renewable energy supply for the case study.

References

1. Amini, M. (2004) Renewable Energy systems for Rural Health clinics in Algeria: Homer Application in World Renewable Energy Congress VIII and Expo.
   (WREC VIII). Available Online:
   http://www.nrel.gov/docs/gen/fy04/36703.pdf

2. BC Hydro (2007). Managing Energy Cost in Hospitals, Available online : http://bchydro.com/business/investigate/investigate5988.html

3. BRECSU (1998), The Government's Standard Assessment Procedure for Energy rating of Dwellings, Department of the Environment Transport and the Regions, London

4. BritishWind Energy Association (BWEA). Available on : www.bwea.com

5. The Building Regulations 2000, Conservation of fuel and power, Approved Document L1B
   – Work in existing dwellings (2006 Edition)

6. CADDET (2005). Saving energy with Energy Efficiency in Hospitals. Available online at:
   http://www.fireitalia.it/eell/ospedali/energy_efficiency_in_hospitals_maxi_brochure_5_CADDET.pdf

7. CIBSE (2004).Briefing The Energy Performance Buildings Directive. Available online: http://www.diag.org.uk/pdf/CIBSE_Briefing.pdf

8. Clean Energy (1999). Public Benefits of Renewable Energy Use, Available Online: http://www.ucsusa.org/clean_energy/renewable_energy_basics/public-benefits-of-renewable-energy-use.html

9. CleanMed Europe (2006). The International Healthcare Congress on Sustainable Practises and Products. Available online: http://www.cleanmed.org/europe/2006/docs/abstract_book.pdf

10. Cooke, .R, Cripps, A., Irwin, A. and Kolokotroni, .M. (2007). "Alternative

energy technologies in buildings: Stakeholder perceptions", Renewable Energy 32: 14

11. Consortium of Energy Efficiency (2007). Available Online: http://www.cee1.org/

12. Degree Days Direct. Available online: http://www.vesma.com/ddd/

13. Department of Environment (1994). Introduction to Energy Efficiency in Hospitals.

14. DEFRA (2007). Guidelines to Defra's GHG conversion factors for company reporting. Available Online: http://www.defra.gov.uk/environment/business/envrp/pdf/conversion factors.pdf

15. Department of health, NHS Estates (Health building Note 18) HMSO 1991

16. Department of Business Enterprise and Regulatory Reform (2007).Energy and Environmental Issues: Smart Metering. Available online: http://www.dti.gov.uk/energy/environment/smart-metering/index.html

17. Department of Business Enterprise and Regulatory Reform (DBERR, 2007). UK Energy in Brief. Available online: http://www.berr.gov.uk/files/file39881.pdf

18. Department for Communities and Local Government (DCLG, 2007). The Future of Building Control. Available online: http://www.communities.gov.uk/documents/planningandbuilding/doc/324876.doc

19. Department for Communities and Local Government (2007). Planning for a

Sustainable Future: White Paper. Available Online:
http://www.communities.gov.uk/publications/planningandbuilding/planningsustainablefuture

20. Detlef Westphalen and Scott Koszalinski (2001). Energy Consumption Characteristics of Commercial Building HVAC Systems

21. D&G Online (2005). Map of Dumfriesshire, Available Online: http://www.dumfries-and-galloway.co.uk/maps/dumfriesshire.htm

22. Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings

23. Dti (2002). Energy Consumption in the UK. 2002. Available online: http://www.berr.gov.uk/files/file32005.pdf

24. Dti (2003). Energy white paper: Our Energy Future- Creating a Low Carbon Economy, Available Online: http://www.berr.gov.uk/files/file10719.pdf

25. Eaton, L. (2006). Green buildings. Available Online: http://www.bmj.com/cgi/content/full/332/7554/1389?ehom&ck=nck

26. Edwin Hon Wan Chan (2000). Building Hong Kong: Environmental Considerations pp145, Hong Kong University Press ISBN-10: 962209502X

27. EEA (2005). Environmental management at the EEA. Available online: http://www.eea.europa.eu/documents/emas/

28. E.on (2007). Loft Insulation. Available Online: http://www.eonenergy.com/At-Home/Going-Green/Energy-Efficiency-Products/Loft-And-Cavity-Wall-Insulation/loft-insulation.htm

29. Energy Design Resources (2004). Daylight in building design. Available

Online: http://www.energydesignresources.com/docs/dl-02.pdf

30. ETSU (1994). An Assessment of Renewable Energy for the UK.

31. EuroACE (2007). High Rise Buildings: Refurbishment Measures. Available Online: http://www.euroace.org/highrise/potential.htm

32. European Commission (EC, 1997). Energy for the Future: Renewable Sources of Energy –White Paper for a Community Strategy and Action Plan COM (97) 599 Final. Available Online: http://ec.europa.eu/energy/library/599fi_en.pdf

33. Foxon, T. J., Gross, A., Chase, R., Howes, J., Arnall, A. and D. Anderson (2005). UK Innovation Systems for New and Renewable Energy Technologies: Drivers, Barriers and Systems Failures. Energy Policy 33:16

34. Friends of the Earth (2007) League Table of UK Green Electricity Tariffs, Available online: http://www.foe.co.uk/pubsinfo/briefings/html/20020510181725.html

35. Green Consumer Guide (2007). Loft Insulation. Available Online: http://www.greenconsumerguide.com/domesticll.php?CLASSIFICATION=60&PARENT=54

36. Hanreich, G. (2002). Renewable Energy in European Union Policies. Available Online: http://ec.europa.eu/energy/res/sectors/doc/photovoltaic/hanreich_paper_for_munich1_amended_version.pdf

37. Heerwagen, D. (2003). Passive and Active Environmental Controls: Informing the Schematic Designing, McGraw-Hill Professional

38. Igal M. Shohet (2006). Key Performance Indicators for Strategic Healthcare Facilities Maintenance Journal of Construction Engineering and Management

39. International Energy Agency (1989). A guide for Energy Management in Hospitals

40. Jorge R., Martin R., Athena S., (2006), How to Conduct an Energy Audit: A Short Guide for Local Governments and Communities, Available Online:

www.state.nj.us/dep/dsr/bscit/SustCommunities.htm

41. Katsanis, J.S, Halaris, P.G., Malahias, G.N. and Bourkas, P.D (2005). Estimation of Energy Consumption in Hospitals. European Power and Energy Systems: 468

42. Levermore, G.J (1992). Building Energy Management Systems: An application to heating and control, E& FN Spoon 45

43. Lynas, M. (2007). It's Carbon Judgement Day. Available Online: http://environment.guardian.co.uk/ethicalliving/story/0,,1997277,00.html

44. M. Krarti. 2000. Energy Audit of Building Systems: An Engineering Approach. CRC Press, Bota Raton, FL.

45. Mcloughlin, N (2006). Geothermal Heat in Scotland, SPICe briefing

46. McMullan, R.(2007). Environmental Science in Building 6th edition, Palgrave Macmillan

47. Michael Brower, (1992). Cool Energy: Renewable Solutions to Environmental Problems, UCS.

48. Ministry of Health, UK, Noise control (Hospital Design Note 4).HMSO,1966

49. NBS (2006). 'The Non-Domestic Heating, Cooling and Ventilation Compliance Guide'. Available Online: http://www.thenbs.com/BuildingRegs/associatedDocuments/ShowContents.asp?section=NONDOMESTIC&topic=b_0601_ASSDOC_NONDOMESTIC

50. The National Energy Foundation (2007). Simple Carbon Calculator, Available Online: http://www.nef.org.uk/energyadvice/co2calculator.htm

51. Natural Resources Canada (2003). Benchmarks and Best Practices for Acute and Extended Health Care Facilities. Available online: http://www.oee.nrcan.gc.ca/publications/infosource/pub/ici/eii/pdf/m144-7-2003E.pdf

52. National Institute of Standards and Technology Handbook 135 (NIST, 1995), Life-Cycle Costing Manual for the Federal Energy Management Program.

53. NHS Foundation Trust (2007). Guy's and St Thomas' launches campaign to save energy - and the environment. Available online: http://www.guysandstthomas.nhs.uk/news/newsarchive/newsarticles/energycampaign.aspx

54. NHS Supply and Purchasing Agency (2007). Sustainable development action plan, Available Online: www.pasa.nhs.uk/pasa/Doc.aspx?Path=%5BMN%5D%5BSP%5D/NHSprocurement/Sustainable%20procurement/SDactionplan.pdf

55. NHS Trust (2005). The Gateway Surgical Centre. Available online: http://www.nhs-procure21.gov.uk/content/home/documents/GatewaySurgicalCentreNewhamCaseStudy_000.pdf

56. NHS Trust (2007). The Riverside: Lewishan Hospital. Available online: http://www.lewisham.nhs.uk/phase3.php

57. NJBPU (2003). New Jersey Clean Energy Annual Report 2002. Available Online: www.njcleanenergy.com/media/NJCEP-AnnReport2002-9-22.pdf

58. Oppenheim, D. 2000. "A Participatory Approach to Energy Efficient Design" in Environment Design Guide August 2000. Royal Australian Institute of Architects,

Sydney, Australia

59. Performance Regulations: Hospitals http://fermacellmarketing.co.uk/acousticregs/html/hospital/hospitals_01.html

60. A. PFE (1989). A guide for energy management in hospitals December 1989 (International energy Agency). Available online: http://www.ecbcs.org/docs/annex_13_5_services.pdf

61. Reed, C (2005). Saving Water Counts in Energy Efficiency. Available online: http://www.energystar.gov/index.cfm?c=healthcare.ashe_sept_oct_2005

62. RETScreen website http://www.retscreen.net/ang/impact.php

63. Renewable Heat Pumps in the Healthcare Institutions, SUSTAINABLE ENERGY IRELAND. Available online: http://www.sei.ie/uploadedfiles/RenewableEnergy/HospitalsFactsheetforWeb.pdf

64. Rey F.J., Velasco, E. and Varela, F. (2006). A paper on Building Energy Analysis (BEA): A methodology to assess building energy labelling Thermal Engineering Group, School of Industrial Engineering, University of Valladolid, Paseo del Cauce:Valladolid, Spain

65. Roaf, S. and Hancock, M.(1992), Energy efficient Building: A Design guide. Blackwell Scientific Publications, Oxford: : England

66. Scottish Executive (2003). UK Energy Review, Available Online: http://www.cabinetoffice.gov.uk/upload/assets/www.cabinetoffice.gov.uk/strategy/scottishexecutivesub.pdf

67. The Scottish Executive (2005/06). Review of the Renewables Obligation

(Scotland) Order (Preliminary Consultation), Available Online: http://www.eon-uk.com/downloads/Response_to_2005-6_Review_of_the_RO_Scotland.pdf

68. Scottish Power (2007). Scottish Power Fuel Mix Breakdown: April 2005 - March 2006, Available Online: http://www.scottishpower.co.uk/Small_Business/Customer_Services/Where_we_get_our_energy/

69. Simpson, V. (2007). Sustainability: The Green Trial. Available on: http://www.hdmagazine.co.uk/story.asp?sectionCode=20&storyCode=2043322

70. Studebaker, J.M. (2000). "Electricity Cost Control through Bill Auditing Procedures" in Energy User News December 2000. (Fundamental Series).

71. Sustainable commission (2005). Progress in Practise. Available online at http://www.sd-commission.org.uk/publications/downloads/Antrim_Area_Hospital_Wind_Turbine_PiP.pdf

72. Sustainable Energy Ireland (SEI, 2007). Performance Indicators for Public Sector Buildings. Available Online: http://www.sei.ie/index.asp?locID=360&docID=-1

73. Sustainability Victoria (2004). Calculating Energy Use and Greenhouse Emissions, Available Online: http://www.sv.sustainability.vic.gov.au/advice/business/calculating/index.asp

74. The MertonRule.org (2007). Greens in Call for Renewable Energy. Available online: http://www.themertonrule.org/articles/news?from=87

75. Thuman, A. 1998. Handbook of Energy Auditing. Fairmont Press, Lilburn, GA.

76. Thuman, A. and Hoside, R. 1994. Energy Management Guide for Government Buildings. Fairmont Press, Lilburn, GA.

77. University of Strathclyde (2006). Demand Side Management:" Towards a Carbon Neutral Community", Available Online: http://www.esru.strath.ac.uk/EandE/Web_sites/06-07/Carbon_neutral/START%20PAGE.htm

78. US Department of Energy (1998). Energy Information Administration, the Commercial Buildings Energy Consumption Survey in the U.S. Available online: ftp://ftp.eia.doe.gov/pub/consumption/commercial/fueloil.pdf

79. US Department of Energy (2007). Energy Efficiency and Renewable Energy, Available Online: www.eere.energy.gov/EE/buildings_energy_audits.html

80. US Department of Energy (2007). Energy Star, Available Online: http://www.energy.gov/energyefficiency/energystar.htm

81. Williams J.M. (1995). Energy consumption in large acute hospitals, Fuel and Energy Abstracts, 36(6):473-473(1)

82. William J. M, Stein, B. and Reynolds, J.S (1980). Mechanical and electrical equipment for buildings, Sixth edition

83. WWF (2007). Your chance to help combat climate change! Available online at http://wwf.org.uk/core/about

84. Zobler, N. and Hatcher, K. (2003). Financing Energy Efficiency Projects, Government Finance Review. Available Onlinewww.energystar.gov/ia/business/government/Financial_Energy_Efficie

ncy_Projects.pdf

Appendix 1

Appendix 1

Gas and Electricity Consumption for 2005/2006

Months 2005/06	Gas GJ	kWh	Electricity GJ	kWh
April	325.7	90,479.50	56.4	15,667.90
May	276.8	76,895.00	56.6	15,723.40
June	253.6	70,450.00	70.1	19,473.70
July	160.9	44,698.00	48.3	13,417.70
August	259.4	72,061.30	63.3	17,584.70
Sept	213.6	59,338.00	74	20,557.20
Oct	265.2	73,672.50	60.5	16,806.90
Nov	295.7	82,145.40	54.1	15,028.98
Dec	303.5	84,312.30	59.5	16,529.10
Jan	475.8	132,177.20	91	25,279.80
Feb	318.2	88,395.90	64	17,779.20
March	394.3	109,536.50	79.5	22,085.10
Total	**3542.8**	**984,189.80**	**777.3**	**215,933.68**

Gas and Electricity Consumption for 2006/2007

Months 2006/2007	Gas GJ	kWh	Electricity GJ	kWh
April	334.6	92,951.80	62	17,223.60
May	303.7	84,367.86	57.7	16,029.00
June	226.1	62,810.50	71.6	19,890.40
July	196.6	54,615.40	56.7	15,751.20
August	196.8	54,671.00	56.4	15,667.90
Sept	277.4	77,061.70	70.5	19,584.90
Oct	267.4	74,283.70	62.1	17,251.30
Nov	350.3	97,313	64.3	17,862.50
Dec	369.9	102,758.20	66	18,334.80
Jan	388.8	108,008.60	79.3	22,029.50
Feb	349.7	97,146.60	62.6	17,390.20
March	381.3	105,925.10	75.8	21,057.20
Total	3642.6	1,011,914.20	785	218,073.00
Using 1GJ=277.8kWh				

Appendix 2

Effects of Improved Insulation on Gas Consumption

2006/2007	Gas Consumption Before Improved Insulation (kWh)	Gas Consumption after Improved Insulation kWh
April	92,951.80	77,614
May	84,367.86	67,915
June	62,810.50	52,446
July	54,615.40	45,603
August	54,671.00	45,630
Sept	77,061.70	64,346
Oct	74,283.70	62,027
Nov	97,313	81,257
Dec	102,758.20	86,702
Jan	108,008.60	90,187
Feb	97,146.60	81,117
March	105,925.10	88,448
Total	1,011,914.20	844,949

Using 1GJ=277.8kWh

Reduced gas consumption

Since space heating is assumed to be 75% (based on BRECSU figures[3]) of the total gas consumption and a 22% reduction is realised by improving the building insulation. This simple calculation was done to get the actual reduced monthly gas consumptions; the example below is based on the April bill for 2006/2007.

Space heating energy consumption

= 75% of 92,951 (A) = 69,713 kWh

Energy Saving after improved Insulation

= 22% of 69,713 (B) = 15,337kWh

Actual reduced monthly gas consumption (for April)

= 92,951- 15,337 (A- D) = 77,614 kWh.

The same step was followed to obtain the reduced gas consumption for all the months of 2006/2007

Appendix 3

Degree-day data for region 13EEO: W Scotland

2006/2007	Actual Degree days	20-year Average
April	244	227
May	165	154
June	71	85
July	30	51
August	53	54
Sept	48	96
Oct	129	181
Nov	242	267
Dec	294	347
Jan	288	338
Feb	272	302
March	272	291
Total	2108	2393