MSC DISSERTATION
De Montfort University, Leicester
Institute of Energy and Sustainable Development

WORD COUNT 17900 (EXC APPENDICES)

REDUCING CARBON EMISSIONS IN AN OUTDOOR EDUCATION CENTRE

Submitted in partial fulfilment of the requirements of Master of Science in Climate Change and Sustainable Development

by

AUDREY TULLY
P08179101

Dissertation supervisor: Professor Li Shao

September 2011

Declaration

I …………………………………….., confirm that this work submitted for assessment is my own and is expressed in my own words. Any uses made within it of the works of other authors in any form (eg ideas, equations, figures, text, tables, programmes) are properly acknowledged at the point of their use. A full list of the references employed has been included.

Signed: ………………………………….

Date: …………………………………….

CONTENTS

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank everyone who has contributed in any way to the completion of this dissertation. These include:-

Professor Li Shao	-Dissertation Supervisor for guidance throughout this process.
Mr Mike McKeown	-Mechanical Design Engineer, City of Edinburgh Council for his contribution to the fuel and feasibility study for Benmore Outdoor Education Centre as part of my work related project on behalf of the Council.
Ms Jayne Haddon	-Bursar, Benmore Outdoor Education Centre, for her site knowledge of Benmore and taking time to respond to my written questionnaire and also during my site visit with Mr McKeown.
Mr Angus Macleod (MBE)	-Head of Construction and Forestry, Inverness College for his time help in understanding the renewable technology industry is ensuring quality standards by training Contractors regarding installing and maintenance of renewable technologies.
Mr Bill Henderson	-Energy and Water Manager, City of Edinburgh Council for his invaluable support and encouragement to lead on Benmore Outdoor Education Centre, biomass project as part of my dissertation.
Mr Paul Jones	-Energy and Water Officer, City of Edinburgh Council for his invaluable support, encouragement and utility information during my various stages of research.
Mr Alex Elliott	-Facilities Manager, Culloden Visitor Centre for his time and provision of information on the biomass installation during my site visit.

ABSTRACT

This study looks at ways in which carbon emissions can be reduced in outdoor education centres which are rural by nature of the functionality and services they provide i.e. outdoor pursuits, rock climbing, caving and so on. By location, they may be unable to connect to the gas and electricity networks and must rely on generating electricity themselves using diesel generators. They may be connected to the electricity network but are using liquid petroleum gas (LPG) for catering needs. All electric sites are high emitters of carbon and it is important to look at ways in which they can reduce carbon emissions by means of converting plant and other energy saving measures and technologies and including renewables by looking at case studies as well as using my own knowledge as an Energy & Water Officer.

Political drivers and carbon reduction legislation are relevant to businesses and Local Authorities and this study explains why there is the need to address them along with the penalties if they are ignored.

Wood fuel is explained in depth, that is, how it is grown and resourced, looking at energy crops and waste wood. Burning efficiencies of wood are compared to fossil fuels along with CO2 emissions for fuels.

In the case of Benmore Outdoor Education Centre this is part of a work related project. The centre is situated in Argyll, Dunoon and as the Centre is located out with Edinburgh it does not come under Edinburgh Council's Clean Air Act 1993. Instead it comes under Argyll and Bute Council's legislation due to its location on the West coast of Scotland.

Benmore OEC consumption figures are provided as a comparison report for 2 years ending February 2011 along with analysis of electricity half hourly data to give the reader an understanding of the consumption pattern and heating demand over a typical year and to identify increases/decreases in usage.

The study looks at whether a biomass heating system is more expensive to traditional fossil fuel plant and why the sizing of biomass plant is important and this is true for other similar type buildings is investigated and technical calculations forms part of the study under the "Alternative Fuel Study" section. Included in this section is the cost and environmental savings.

The spatial, storage and fuel delivery system requirements are investigated along with different boiler types.

The need for Contractors/installers of renewable technologies is important to the quality assurance and reliable workings of the technology in question. Investigations were carried out regarding this.

Monitoring and targeting systems is an important tool for identifying energy wastage and helping drive down carbon emissions. Methods are discussed including the importance of degree day analysis and an example of a year on year comparison report for Benmore OEC.

1.0 INTRODUCTION

1.1 Overview

Legislation is driving down carbon emissions and the onus is on building owners to take responsibility or else pay the price for emitting carbon. This study has investigated the various legislation and political drivers for reducing energy and carbon.

These drivers led to me leading on a work related project at Benmore OEC in my role as Energy Officer at City of Edinburgh Council. This meant investigating converting the centre from electric heating to heating supplied by a biomass boiler with a comparison to an LPG boiler. The justification for this comparison to LPG was because there is an existing LPG storage tank in operation situated in front of the building, serving the catering facilities in the kitchen. The study looks at available options, advice on plant space requirements and identifies any additional carbon reduction measures. This study also states the capital costs associated with installing either plant option including a wet heating system with zoning controlled by a Building Management System (BMS).

It is fairly typical of an outdoor education centre to be all electric or electric/LPG due to its location and remoteness away from mains gas and sometimes mains electricity as one of the case studies show. This study has investigated how carbon emissions can be reduced in other outdoor education centres, in similar circumstances and rural location.

The study also identifies ways to reduce CO2 emissions and to improve thermal comfort for service users and staff, along with the complexities of using biomass boilers, wood fuel supply and the burning efficiencies of wood fuel compared to fossil fuels.

1.1.1. Existing Situation

Benmore OEC is situated in a rural location in Dunoon, Argyll, Scotland within the grounds of the Royal Botanical Gardens. Typically, outdoor education centres are located in rural areas so they can provide outdoor pursuits, for example, rock climbing, rafting, caving and so on. The building has been “B” listed since 28th August 1980 according to the British Listed Buildings website. Benmore OEC has no mains gas due to location. The centre has electric storage heaters throughout the building which are uncontrollable. The electricity also serves lighting and general power and is billed on a monthly maximum demand tariff as it is >100 kW (explained in later in this study).

The building is in need of a heating upgrade as the electric storage heaters are not flexible enough to control by building users and complaints were being received from service users about thermal comfort levels being inadequate. The project would encompass fuel conversion and also a heating upgrade to a wet heating system with thermostatic control valves controlled by a building management system (BMS) to combat the complaints.

At the time of writing (Sept 2011) Benmore OEC has not had any further progress regarding the installation of a biomass boiler or other type of heating. The alternative fuel study included in this study is the latest action to be carried out.

1.2 Research Aim

The aims of this study are to identify ways in which owners of outdoor education centres, for example Local Authorities, can reduce carbon emissions in order to comply with Government targets and legislation.

The study shall demonstrate how biomass boiler installations and other renewable technologies have worked in other outdoor education centres and other centres in rural areas with similar circumstances to Benmore OEC and the impact on environmental and cost savings. The alternative fuel study analyses the benefits of converting Benmore OEC from electric storage heating to a biomass boiler compared to an LPG boiler system. The study demonstrates how carrying out such a measure can reduce carbon emissions and value for money in terms of investment pay back. The Council has considered using LPG in the past in place of biomass and the research identifies the benefits/problems associated with using LPG or biomass.

This study shall identify current consumption levels including emissions from all fuel used at Benmore OEC including LPG.

This study shall demonstrate the impact of reducing the electricity consumption not just on carbon dioxide emissions but also on reduced electrical load and the impact on the supply profile or MPAN (meter point administration number) as it is known in the electricity industry. The building is classed as a half hourly site or 00 supply profile at present and this will probably change due to electrical load reduction when the heating is converted to either fuel. Depending on the new predicted annual consumption, impact on billing and cost shall be explained.

This study also considers the following items under the alternative fuel study:-

Fuel types
Fuel storage and spatial requirements and fuel delivery systems
Fuel handling systems
Boiler plant types
Procurement mechanisms
Ash removal

2.0 LITERATURE REVIEW

2.1 Carbon Trust – Biomass Heating

What is biomass heating? It is important before progressing further to understand the technology and how it operates. Also what types of biomass, wood fuel, can be used in the operation of plant.

It is used as a carbon reduction technology because the carbon captured within the wood whilst growing is then released in the combustion process. This is why it is deemed "carbon neutral". This is also explained by the Carbon Trust's online help page "Biomass Technology Advice".

The Energy Savings Trust (information available on website) also states:-

"A low carbon option: the carbon dioxide emitted when wood fuel is burned is the same amount that was absorbed over the previous months and years as the plant was growing. As long as new plants continue to grow in place of those used for fuel, the process is sustainable. There are some carbon emissions caused by cultivation, manufacture and transportation of the fuel, but as long as the fuel is sourced locally, these are much lower than the emissions from fossil fuels".

The Carbon Trust's help page goes onto state the following:-

"Biomass heating refers to the production of heat for space or process heating through the use of organic materials including: virgin wood (i.e. wood which is untreated and free of chemical or finishes), certain energy crops, clean industrial residues and certain agricultural residues. Heat is produced by a combustion process to heat water or air; the heating system

itself consists of the biomass boiler plant, ancillary equipment, and infrastructure to receive and store fuel and transfer it to the main boiler.
Rated thermal capacities of biomass systems can range from as little as a few kW to greater than 5 MW and vary from small manually fed systems with basic controls, to fully automated systems with advanced controls.

It is important therefore that wood fuel is from a sustainable source so as it is truly carbon neutral, the carbon is captured and released in the wood fuel cycle, and to sustain supply for future generations.

Considerations

A biomass heating system is more expensive than an equivalent capacity fossil fuel fired system; thus determining the optimum sized boiler to match a site's requirements is of great importance.

Due to the physical properties of the fuel, the system footprint is also larger for biomass plant than an equivalent capacity fossil fuel fired system; space is also required for fuel delivery, storage and transfer. A well designed and implemented solution for the delivery, storing and handling of the fuel is important, and will help to save money over the boiler's lifetime.

It is important to use a fuel which is available, reliable, accessible and appropriate for the job. The key characteristics of a biomass fuel include its moisture content (which affects its calorific value) and particle size or grade. Costs vary dependent on market availability, quality, form and proximity of fuel source to point of use. For businesses that don't produce such fuels as by-products, there is a wide range of fuel suppliers in the UK".

It is necessary to explain the reasons for changing to low carbon alternatives. This section identifies the various political drivers for change. Scottish Government literature was reviewed along with the City of Edinburgh Council's Climate Change Framework in order to identify the political and environmental drivers behind the need to carry out carbon reduction measures in buildings which would include outdoor education centres like Benmore.

It is now mandatory to reduce carbon emissions with the Carbon Reduction Commitment (CRC) Energy Efficiency scheme now in place and the onus is on organisations to reduce carbon by implementing energy saving projects/schemes. If they don't they will have to pay a price for carbon emissions. This is now explained in the following literature.

2.2 Climate Change Act (Scotland) 2009

The Scottish Government's Climate Change Act was given royal assent on 4th August 2009 committing the Scottish Government to reducing greenhouse gas emissions and moving towards a low carbon economy.

The Act provides the statutory framework for reductions greenhouse gas emissions in Scotland. Part 1 of the Act states an interim 42 per cent reduction by 2020 and an 80 per cent reduction by 2050 based on 1990 emissions. There are six greenhouse gases included in the Act, carbon dioxide; methane; nitrous oxide; hydrofluorocarbons; perfluorocarbons; sulphur hexafluoride. Part 1 of the Act requires Scottish Ministers to set annual targets for Scottish emissions between 2010 and 2050.

2.3 The Carbon Reduction Commitment (CRC) Energy Efficiency Scheme

The Department of Energy and Climate Change (DECC) website was accessed for information on the scheme. The CRC Energy Efficiency Scheme is a UK wide mandatory scheme incorporating public and private sector organisations whose total electricity consumption for year 2008 was greater than 6,000 MWh.

The scheme requires organisations to monitor their consumption and purchase allowances in June 2012 for retrospective emissions in financial year 2011/12.

The scheme originally required that an organisation would monitor consumption and purchase allowances in a carbon trading scheme from 2011. However, following the UK government's spending review in the Autumn of 2010 the trading scheme has changed and will operate like a carbon tax commencing 2012.

The City of Edinburgh Council will not only be required to purchase their energy but also be liable to pay additional money for emissions under this scheme.

The City of Edinburgh Council confirmed their energy spend and CO2 emissions for operational buildings for 12 months ending March 2011. Paul Jones, Energy and Water Officer confirmed by email that electricity and gas spend for the Council is around £9 million, electricity was £5,531,000 and Gas was £3,515,000. It was also confirmed that this equated to emissions of 25,700 and 26,663 tonnes of CO_2 for electricity and gas respectively. The Council confirmed that they had estimated that this would mean an additional cost of £12/tonne of CO_2 equating to £628,356 in additional cost to the Council.

In Scotland, SEPA (Scottish Environmental Protection Agency) have the duty of auditing all organisations' submissions under the CRC scheme. Any false information given by organisations will be subject to fines.

The CRC scheme is to encourage organisations to reduce carbon emissions to help the UK Government meet Climate Change targets.

Monitoring and targeting of energy consumption by organisations under the CRC scheme has begun from financial year 2010/11.

2.4 The Public Bodies Climate Change Duties

The Public Bodies Climate Change Duties came into effect on 1st January 2011. The Sustainable Scotland website states "The Act requires that a Public body must, in exercising its functions, act:

- In the way best calculated to contribute to delivery of the Act's emissions reduction targets.
- In the way best calculated to deliver any statutory adaptation programme, and
- In a way that it considers most sustainable.
- The purpose of the guidance is to assist public bodies in exercising their climate change duties, and public bodies must, under the terms of the Climate Change Act, have regard to the guidance.
- It is an advisory document only and not definitive statement of law.
- Responsibility for compliance with the climate change duties rests with public bodies themselves. It is therefore up to each public body to seek its own legal advice where appropriate on interpreting what the duties will require, and to satisfy itself that it is compliant.
- The guidance will not tell public bodies what they need to do in order to be compliant with the climate change duties.

2.5 The Energy Efficiency Action Plan

The Scottish Government published The Energy Efficiency Action Plan in October 2010. The action plan is to help achieve targets set out in the Climate Change (Scotland) Act 2009 and as a framework so as to address micro-generation and energy efficiency.

The Scottish Government's website summarises the lists of actions as follows:-

1 Encouraging Behaviour Change

"We will focus attention on understanding and shifting behaviour through our co-ordinated approach to Climate Change research, sustainability in education, and influencing practical behaviour through social marketing, information and advice".

2 Domestic Energy Efficiency

"Improving the energy efficiency of the domestic sector is vital, as around 29% of all energy consumed in Scotland is used in our homes for space and water heating, cooking, lighting, and running electric appliances".

3 Energy Efficiency for Business

"We will support businesses to maximise competitiveness through the improved energy efficiency of non-domestic buildings and business processes and by taking advantage of the opportunities that energy efficiency will offer in the transition to a low carbon economy".

4 Energy Efficiency across the Public Sector

"We will provide clear energy efficiency guidance and leadership to the public sector to enable the delivery of energy saving improvements and exemplary behaviour".

5 Achieving Energy Efficiency Through Building Standards

“We will drive improvements to the energy efficiency of Scottish building stock through building standards”.

6 Infrastructure for the Built Environment

“We will proactively support developments across the built environment which strengthen the impact of energy efficiency”.

7 Changing how we use our Transport Systems

“We will create an energy and fuel efficient transport system as part of our drive towards a low carbon future for Scotland”.

8 Developing the Skills for Energy Efficiency

“In making the most of the new opportunities presented by energy efficiency, we will ensure that our training and education systems are ready and capable to develop the required skills and knowledge so that as many people as possible take up the openings in employment”.

9 Financing Energy Efficiency

“We will pursue our work on financing energy efficiency on three fronts:

i. making the case for spending on energy efficiency in future budgeting decisions as part of the broader climate change and economic agendas;

ii. seeking to maximise the contribution that other public funding can make to energy efficiency, e.g. from Europe; and

iii. exploring new finance mechanisms”.

10 Taking Energy Efficiency Forward

“We will seek to drive forward energy efficiency through our partnerships within Scotland and our national and international engagement, using these to promote and learn from best practice”.

2.6 City of Edinburgh Council – Climate Change Framework

The City of Edinburgh Council published a Climate Change Framework (2007) and have their own targets. They aim to reduce all Council greenhouse gases inparticular carbon dioxide emissions by 20% by 2015 and 30% by 2025 and to have the Edinburgh economy carbon free by 2050.

The framework tackles mitigation and adaptation. Mitigation being ways of tackling carbon emissions and adaptation, being ways in which the Council can adapt to cope with the predicted impact of climate change.

Through converting Benmore OEC from electricity to biomass it is hoped that this will provide evidence that the Council is taking steps in both mitigation and adaptation.

2.7 Renewable Heat Incentive

It is worthwhile point out at this stage that the RHI is not applicable in the case of the Energy Services Contractor owning the plant.

The Department of Energy and Climate Change (DECC) website provides information on the the Renewable Heat Incentive (RHI). The scheme was introduced by the UK Government in March 2011 and has been created to help the UK achieve renewable energy targets and a low carbon economy. In doing so, RHI should help meet carbon emission targets and combat issues relating to security of supply. The scheme shall incentivise renewable heating technology projects.

The UK government is phasing in RHI, the first phase is aimed at the non-domestic sector or the large emitters of carbon with long term tariff support. This will include community heating, small businesses and large scale industrial heating projects. It is thought that during this phase, the large proportion of renewable heat taken up will meet government targets.

The government has also introduced Renewable Heat Premium Payments on 1st August 2011 for the domestic sector as part of this first phase, with funding of around £15 million covering around 25,000 installations. Premiums will be paid to households who install renewable heating to help subsidise costs of technologies which qualify. Participants of the scheme will be asked to provide information on the technologies installed and suppliers will have to carry out a follow up service in response to any issues raised. As part of this exercise, the information gathered will help educate the government, manufacturers, suppliers and installers understand the technology better and make improvements to ensure optimum performance. The scheme will be UK wide for households using gas and off grid customers using fossil fuels such as oil which has a higher carbon content and higher cost. The government may wish this part of the scheme to concentrate funding on the off grid customers to fund heat pumps and biomass boilers.

During the second phase of the RHI scheme, the government shall be reviewing other technologies for possible inclusion which were not considered initially.

Page 7, paragraph 2 of the RHI document available on DECC's website which I used for research states "Given the current economic climate it is more important than ever that the RHI delivers value for money and ensures there is a fair spread of technologies across a range of property types. The Renewable Heat Premium Payments will help ensure that, before we commit to long term payments in a sector where it is difficult to predict levels of take-up and levels of performance of the different heat technologies, we manage their roll-out and learn more about them, as well as controlling budgets and ensuring the money goes where it is intended to."

The document immediately goes on to state the key aspects of the RHI tariffs for the non-domestic sectors as follows:-

Support for a range of technologies and fuel uses including solid and gaseous biomass, solar thermal, ground and water source heat-pumps, on-site biogas, deep geothermal, energy from waste and injection of biomethane into the grid;

Support for all non-domestic sectors including: industrial and the commercial sector; the public sector; not-for-profit organisations and communities in England, Scotland and Wales;

RHI payments to be claimed by, and paid to, the owner of the heat installation or the producer of biomethane;

Payments will be made quarterly over a 20 year period;

For small and medium sized plants (up to and including 45 kWhth), both installers and equipment to be certified under the Microgeneration Certification Scheme (MCS) or equivalent standard, helping to ensure quality assurance and consumer protection;

Tariff levels have been calculated to bridge the financial gap between the cost of conventional and renewable heat systems, with additional compensation for certain technologies for an element of the non-financial cost;

Heat output to be metered and the support calculated from the amount of eligible heat, multiplied by the tariff level;

Biomass installations of 1 MWth capacity and above will be required to report quarterly on the sustainability of their biomass feedstock for combustion and where they are used to produce biogas;

Eligible non-domestic installations completed on or after 15th July 2009, but before the start of the RHI, will be eligible for support as if they had been installed on the date of its introduction;

The Gas and Electricity Market Authority (Ofgem) will administer the RHI including: dealing with applications; accrediting installations; making incentive payments to recipients; and monitoring compliance with the rules and conditions of the scheme; and

The RHI will be funded from general Government spending, not through the previously proposed RHI levy.

The RHI scheme is included in this study for Benmore OEC particularly for financial appraisal purposes.

2.8 Energy Security

Energy security includes the stability of prices and continuity of supply. DECC's work includes ensuring energy supplies are secure, are of quality, reliable and able to supply for future generations.

In November 2010 DECC and Ofgem produced the “Statutory Security of Supply Report” of which the Executive Summary on page 3 sets out security of supply outlooks up to 2025 for electricity, gas and oil from analysis carried out by Government, National Grid, Ofgem and others. This is summarised in the following sections.

2.8.1 Electricity

According to the above report, National Grid predict that electricity demand will remain stable at around 60 GW but this is depends on fuel conservation, power generation and output, energy prices, number of households, CHP and embedded generation and reports.

The UK generation capacity is currently 85.3 GW, however electricity markets are set to change with the closure of generating plant such as oil and coal which are considered too polluting along with nuclear plants coming to the end of their useful life expected to close by 2020.

9GW of new plant which will be joined to the national grid is being built which will have an additional 10.8 GW connected in future years currently has planning permission of which 6.7 GW is gas fired plant.

August 2010 statistics show that 4.6 GW of renewable projects being constructed within the UK. This includes connecting capacity to the National Grid and local networks. 6.7 GW of further generation projects have planning permission awaiting construction with additional 14.2 GW awaiting planning permission. The Government hopes that this new generating capacity will make up for the plant capacity due to close securing supplies and reducing greenhouse gas emissions.

2.8.2 Gas

The report states that UK gas demand is set for a downwards trend according to DECC and the National Grid. Peak demand is projected at current levels at around 500 million cubic metres per day (mcm/d) or down to around 450 mcm/d 2010 to 2025.

The UK Continental Shelf (UKCS) is reportedly in decline and the UK can utilise the increasing amounts of diverse ranges of import sources.

Should new import and storage capacity be identified, the UK would continue to be resourced. However, practically, it is known that projects may fail or fall behind and therefore not all of the capacity may be available.

2.8.3 Oil

It is stated in the report that oil is consumed in 33% of primary energy relying on it for the majority of the UK's motor transport requirements. In 2009, transport accounted for around 85% of energy consumption of oil products totalling 49.6 million tonnes of oil.

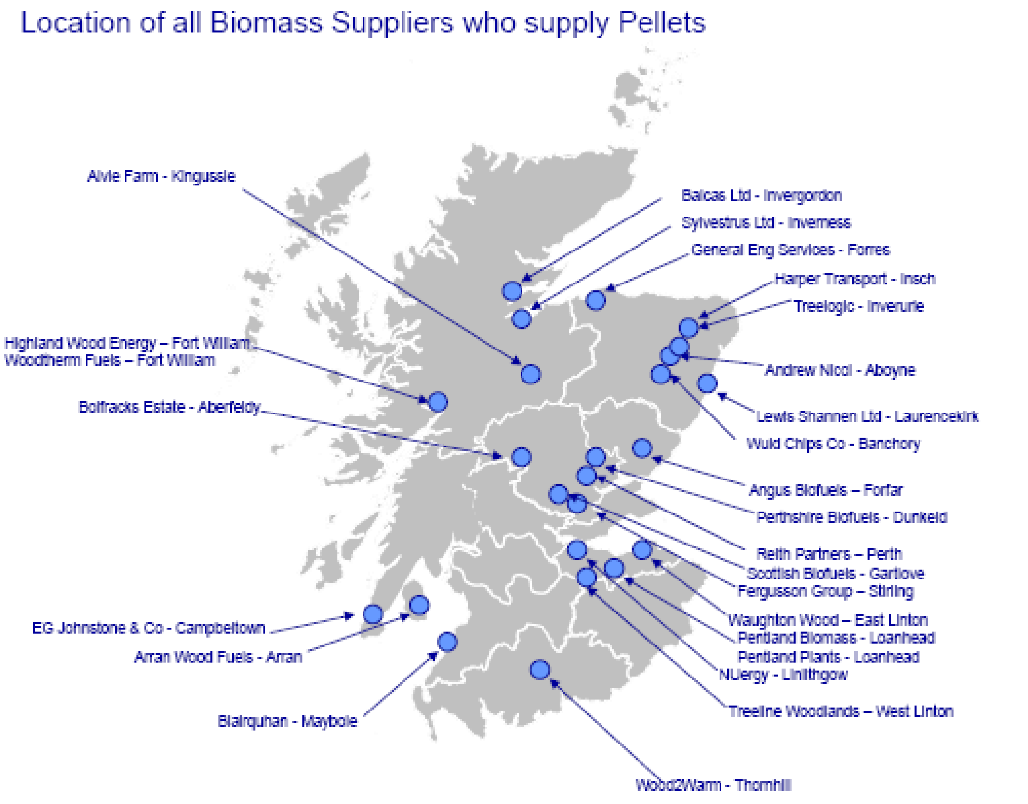
It is stated that the demand will likely reduce as technology changes, more heat from renewables, more electric vehicles and more use of public transport through the impact of Government's policies on energy efficiency. However, these reductions are not likely to be realised over the next 10-15 years.

Oil imports are predicted to increase through to 2025 with UK production having peaked in 1999 now in decline. DECC aims to improve the effectiveness of oil markets through working with international partners to encourage both "increasing oil supplies and reducing oil demand".

3.0 WOOD FUEL, SOURCES, FUTURE DEMAND, BURNING EFFICIENCY AND COST

Where does the wood fuel come from? How will it meet future demand? What is the burning efficiency of wood fuel compared to mains gas and oil?

The Forestry Commission's website has been useful in providing information on wood fuel. Their document "Wood fuel Meets The Challenge" (2006) was particularly useful in investigating and answering some of the above questions. Below is a map displaying biomass suppliers of wood chips in Scotland which is relevant in the case of Benmore OEC.



3.1 Forests and Woodlands

The above mentioned document states that wood fuel can be produced from forests and forest residues. Round wood from thinnings and branch wood from mature broadleaves are used as fuel sources.

3.2 Wood Fuel from Energy Crops

Wood fuel can also be grown as energy crops under short rotation coppice (SRC) or short rotation forestry (SRF) systems. Fast growing systems such as willow and poplar are used for SRC systems and eucalyptus species for SRF systems.

3.2.1 Harvesting Systems

There are 2 main systems for harvesting SRC. The first, cutting and chipping in one operation and the second, cutting the crop with the stems left intact to air-dry. Chipping is then carried out as a separate operation later on. SRF harvesting includes the use of similar systems to that of conventional forest harvesting.

3.3 Wood fuel from Co-Products

The large quantities of co-products produced by sawmills can be processed into wood fuel. Co-products such as slabwood, offcuts and sawdust are examples.

3.4 Wood Fuel from Arboricultural Arisings

Arisings are produced by the arboricultural sector and local authorities from looking after street and amenities trees. This “waste” material can be used as a fuel source instead of it being sent to landfill or chipped and left to erode. This would be a saving also in landfill costs.

3.5 Wood Fuel from Waste Wood

Wood which is known as “clean” can be used as wood fuel. This is wood which has been untreated and not painted or contaminated with any other materials. This can be any reclaimed timber, wood used in packaging, unpainted scrap pallets or loose wood.

3.6 Burning Efficiency

The various burning efficiencies are important in determining which fuel source to procure especially in terms of driving down carbon emissions. This is based on emissions, kg CO_2/kWh, as listed below with a comparison to fossil fuels, mains gas, coal and oil.

Table 1 Burning Efficiency and Typical Emissions by Fuel Type

Fuel Type	Percentage Efficiency	Emissions kg CO_2 per kWh
Wood Logs	70% in simple free-standing stoves 85% + in modern boiler systems	0.025
Wood Chips	85%+	0.025
Wood Pellets	90% + achievable with a range of units	0.025
Coal	35% in fire places 60% in central heating boilers	0.291
Mains Gas	65% in central heating boilers 90% in modern condensing boilers	0.194
Oil	65% in central heating boilers 90% + in condensing boilers	0.265

Source: Forestry Commission, “Wood Fuel Meets The Challenge” (2006)

In conclusion, wood logs, wood chips and wood pellets have around 85-90% burning efficiency in modern boiler systems, similar to gas and oil boilers but have lower carbon emissions.

3.7 Cost

It is relevant to this study to compare the prices of wood fuel to fossil fuel as part of the consideration of a biomass boiler installation.

The table which follows indicates the comparison of prices, based on the delivered price of wood fuel and assumed standard tipped deliveries of 25-30 cubic metres of wood chip.

Table 2 Price £ per kWh for Each Fuel Type

Fuel Type	Price £ per kWh
Woodchip	0.03
Pellets (loose)	0.047
Pellets (bagged)	0.055
Heating Oil (domestic)	0.056
LPG (domestic)	0.086
LPG (commercial)	0.035
Electricty (domestic)	0.13
Mains Gas (domestic)	0.041
Hardwood Firewood	0.035

Source: Forest Fuels (July 2011)

3.8 <u>Inverness College's Experience of Biomass</u>

I met with Angus MacLeod (MBE) who is Head of Construction and Forestry at Inverness College to learn from his experiences using and teaching on renewable technologies. The College runs courses on installing renewable technologies such as biomass boilers, photovoltaics, solar thermal, ground and air source heat pumps so that the Contractors doing the installation work are then certified. However, there is no register of certified Contractors at the moment.

There are essentially three types of wood biomass fuel, logs, woodchips and pellets.

Woodchips can be produced from a number of wood sources and are normally produced by industrial chippers that reduce the larger wood stems to, typically, 15-30 mm diameter and 5-10 mm long. The final chip will have the same density as the original wood stems and will require drying. All of the above processes would be carried out by the supplier but has the potential to lead to varying moisture content and hence varying calorific value. The density of woodchips is much lower than pellets (300-550 kg/m3) with higher transport costs and/or more frequent deliveries increasing the carbon footprint. The energy content of woodchips is very variable according to moisture content but, for example, at 30% moisture content, the energy content is around 3500 kWh/tonne. Woodchip quality can be problematic when used in automatic boiler plant and can cause blockages to feed systems.

Wood pellets are compressed wood generally made from sawdust and wood shavings and are typically 6-12 mm diameter and 6-20 mm long. Pellets are dry and consistent in shape and composition which allows them to be easily handled with free flow through hoppers and fuel fed systems which is suited to automatic boiler plant and fuel handling systems. Pellets have a high density (600 – 700 kg/m3) which reduces transport costs and/or frequency of deliveries. Pellets are also more expensive than woodchips. The energy content of pellets is significantly higher than chips (4800 kWh/tonne) and is generally more consistent.

Image 1 - Picture taken at Inverness College displaying bags of wood pellets dropped off by a supplier.

Mismatches between fuel requirement and fuel supplies can occur because of the following:-

a) The system installer not ensuring a suitable local fuel supply
b) The user not understanding the importance of correct fuel specifications
c) The fuel supplier not understanding the importance of correct fuel specifications or delivering fuel of an inferior specification.

This is all relevant in the feasibility of a biomass installation and highlights the importance of selecting a suitable qualified contractor to carry out the design and/or installation works.

4.0 MONITORING AND TARGETING

Monitoring and targeting (M & T) is an important part of energy management and it helps in the reduction in carbon emissions. Why?, this because knowledge of how much a building is consuming in energy is required initially to help identify energy waste. It can then be used to compare annual consumption figures against national benchmarks for similar types of building for example kWh/m2. It is also necessary so that savings from energy efficiency measures/projects can be calculated in terms of both environmental and financial savings and give an indication of the length of payback i.e. months/years and can help in the judgement of whether a measure/project has been as effective as first thought and help in decision making in the future.

Centralised utility information, including water can be stored in an M&T system and is particularly useful for large organisations such as Local Authorities, National Health, Leisure Trusts etc. It enables them to report on energy performance per site quickly and easily and can also produce league tables of the best and worst performers. This helps to identify buildings which require priority attention compared to national benchmarks and other sites in their portfolio.

An example of an M&T report can be seen in the sections which follow relating to Benmore OEC.

4.1 Electricity Consumption & Cost Comparison Year on Year

The City of Edinburgh Council's Bill Henderson, Energy Manager was contacted in order to request latest year consumption and cost data for all fuels including tariff information to understand patterns of use and confirm CO_2 emissions.

Table 1 confirms that in the 12 months ending February 2011, Benmore OEC consumed 434,169 kWh at a cost of £49,971. This equated to an average cost rate of 11.51 pence/kWh.

A year on year comparison report is useful to identify any unusual patterns or exceptions in consumption. This report has been included for Benmore OEC for illustration purposes.

BENMORE OUTDOOR EDUCATION CENTRE

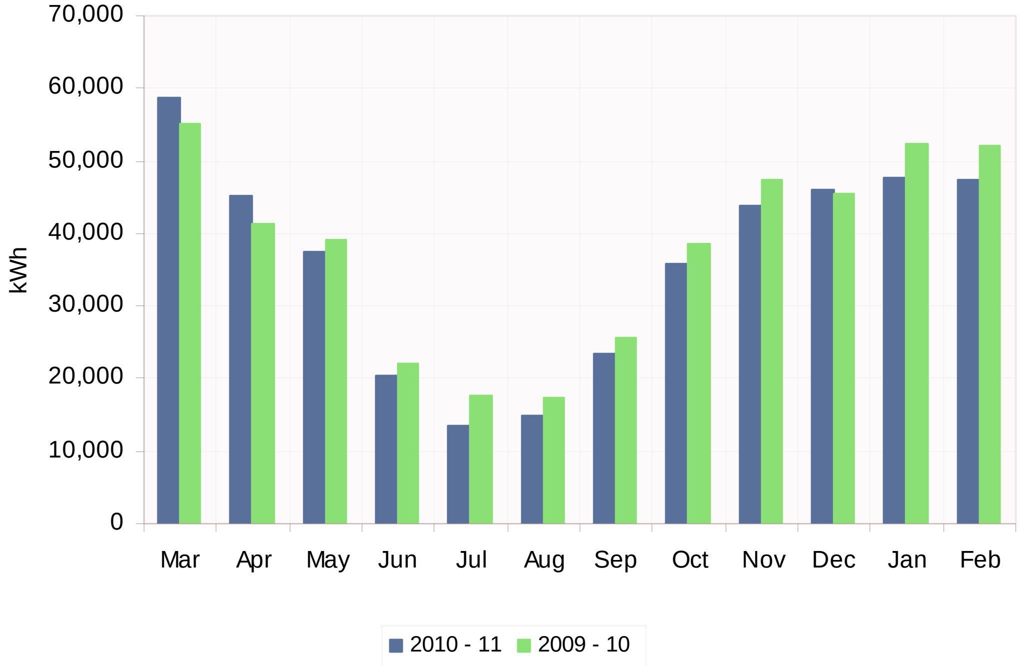
Table 3 Electricity Consumption & Cost Comparison Year 09/10 vs Year 10/11

Month	2010 - 11 kWh	2009 - 10 kWh	Variation kWh	Variation %	2010 - 11 Cost (£)	2009 - 10 Cost (£)	Variation Cost (£)	Variation %
Mar	58,602	55,165	3,437	6.23	7808	7393	415	5.61
Apr	45,130	41,413	3,717	8.98	6182	5733	449	7.83
May	37,482	39,123	-1,641	-4.19	5259	5457	-198	-3.63
Jun	20,272	22,172	-1,900	-8.57	3181	3410	-229	-6.73
Jul	13,434	17,540	-4,106	-23.41	2356	2851	-496	-17.38
Aug	14,858	17,280	-2,422	-14.02	1688	2820	-1131	-40.12
Sep	23,375	25,722	-2,347	-9.12	2382	3839	-1457	-37.95
Oct	35,941	38,541	-2,600	-6.75	3419	5386	-1968	-36.53
Nov	43,880	47,459	-3,579	-7.54	4179	6463	-2284	-35.34
Dec	46,095	45,384	711	1.57	4477	6212	-1735	-27.93
Jan	47,728	52,244	-4,516	-8.64	4562	7040	-2478	-35.20
Feb	47,372	52,044	-4,672	-8.98	4479	7016	-2537	-36.16
Total	434,169	454,087	-19,918	-4.39	49971	63621	-13650	-21.46

Average Cost Rate	11.51	14.01

Figure 1 below illustrates the gradual decrease in electricity consumption each year, from March to August increasing again from September to February.

Graph 1 Electricity Consumption Comparison Year 09/10 vs 10/11



Source: City of Edinburgh Council, Energy & Water Management

4.2 Maximum Demand and Power Factor

Mr Paul Jones, Energy and Water Officer, City of Edinburgh Council, was contacted to request half hourly electricity data identify peak loads and consumption patterns. Maximum demand (MD) and power factor (PF) information was also requested to report on the impact on reduced MD from conversion from electric storage heaters on future contract prices due to the likelihood that the Meter Point Administration Number (MPAN) would change. Any change in MPAN has to be requested by the Customer, City of Edinburgh Council to the supplier, who in this case is Scottish and Southern Electric Plc via Procurement Scotland contracts using their customised templates so tender lists can be kept up to date.

KVa is the highest reactive load recorded on the electricity metering for the relative billing period. The KVa is then divided by the average recorded power factor for the month to produce the maximum demand figure in kW which electricity suppliers use to bill. It is therefore important to reduce the kVa or load on the system to lower monthly maximum demand charges, but also, to ensure that the power factor is as close to unity as possible. Why? The lower the power factor, the higher the MD will be. Electricity companies have the right to penalise customers if they have lagging average power factor of less than 0.95

CIBSE Guide K “Electricity in Buildings”, section 3.2.6 describes power factor, “power factor is defined as the ratio of the apparent power in a circuit (V.A) to the useful power (W) if the voltage and current are sinusoidal; i.e. power factor = kW/kVA”.

Lagging power factor can be rectified by using power factor correction equipment. This includes the installation of a capacitor which levels reactive power or the power factor towards unity.

If the conversion to biomass or LPG goes ahead then there will be a reduction in electricity consumption and demand. This will mean that maximum demand charges will not apply as based on experience, a building of this type will move to a general standard tariff under profile class 03 which will have a saving on the unit cost and therefore on the annual electricity costs.

Table 4 Maximum Demand and Power Factor March 2010 to February 2011

Month	Maximum Demand	Power Factor
March	274	1.00
April	267	1.00
May	216	0.99
June	131	0.98
July	104	0.98
August	158	0.99
September	184	0.99
October	197	1.00
November	255	1.00
December	251	1.00
January	291	1.00
February	287	1.00

Source: City of Edinburgh Council, Energy & Water Management

The data above displays how the maximum demand increases in the winter period and lowers in the summer period in reaction to seasonal heating demand due to the use of electric storage heaters.

4.3 Liquid Propane Gas (LPG)

LPG delivery information was difficult to get hold of and as a consequence, is difficult to keep the Energy & Water Unit's database up to date. Therefore, I contacted Ms Haddon, Benmore OEC Bursar, who confirmed that at present LPG supplies the cookers in the kitchen only and serves the catering needs of the service users throughout the year and that 2261 litres is consumed per annum (confirmed in questionnaire further on in this report).

Data provision may also be a problem in terms of LPG for other sites i.e. information not forthcoming from finance divisions or as a summary statement from fuel suppliers.

4.4 Degree Days

Use of degree days is a regression technique looking at historical data. It is mainly graphical by plotting energy consumed against degree days for each month. The result should be a line of best fit showing how much energy is used per degree day or related to the outside weather temperature.

This is relevant to monitoring and targeting as the graphed points should be close to the line of best fit as possible, if they are not, then it is an indication that there is energy wastage. In oil fired or gas heated outdoor education centres where the large proportion of heating is served by either fuel, it is easy to analyse by degree days. However, since Benmore is all electric and only its catering is served by LPG it is more difficult to analyse how much of the electricity is used for heating and which is used for general lighting and power (non weather dependent consumption or base load). However, from either 1 or 2 years of electricity consumption figures provided, an estimation of the amount of the electricity serving the storage heating can be calculated. By looking at one of the summer months consumption which has the lowest amount of kWh due to no heating demand and likely only to serve general lighting and power anyway, subtracting this figure from each month's consumption will provide an estimation of the heating consumption attributable to electricity.

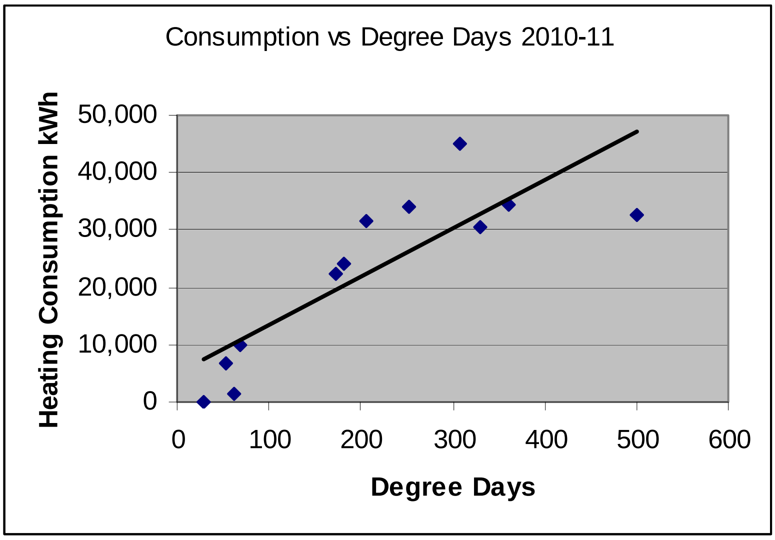
This is backed up by Energy Lens, their website explains how degree days work and also advising on analysing electrically heated buildings.

In the case of Benmore, I have taken the July 2010 consumption figure of 13,434 kWh and have subtracted it from the monthly figures then used excel to analyse consumption vs degree days with a line of best fit as seen below:-

Table 5 Total Electricity, Heating Proportion and Degree Days

Month	**2010-11 Total Electricity Consumption kWh**	**Heating kWh**	**Degree Days 2010-11**
Mar	58,602	45,168	308
Apr	45,130	31,696	205
May	37,482	24,048	181
Jun	20,272	6,838	54
Jul	13,434	0	29
Aug	14,858	1,424	62
Sep	23,375	9,941	69
Oct	35,941	22,507	172
Nov	43,880	30,446	329
Dec	46,095	32,661	500
Jan	47,728	34,294	360
Feb	47,372	33,938	253
Totals	434,169	272.961	2522

Graph 2



Analysis by degree days can thus help reduce carbon emissions in outdoor education centres. You can see in the case of Benmore, there are only 6 points close to the line of best fit with the rest of the points displayed on the graph representing energy wastage probably down to the lack of control with the form of electric storage heating as suspected.

Vilnus Vesma's website explains the theory behind degree days which helps explain the theory to the reader. The value of 15.5ºC is commonly used in the UK as a base temperature, or in other words, when the outside air is above this temperature, buildings do not require to be heated. Conversely, if the outside air is below the base temperature then the building requires heat but only proportional to the temperature difference between actual and the base temperature. The cumulative differences or degree days are then calculated for any given month. The colder it is, the higher the degree day, the warmer it is, the lower the degree day.

Vesma's website also provides free degree day data for each region of the UK. The West of Scotland Degree Day data was best suited to Benmore OEC's location and sourced for the same period as energy data reports. Vesma's report also includes 20 year average figures, as displayed in table 6 below.

Table 6 Degree Day Data - West of Scotland

Month	Actual Degree Days	Previous Year Actual Degree Days	20 Year Average
Mar 2010	308	283	293
Apr 2010	205	197	217
May 2010	181	178	155
Jun 2010	54	75	83
July 2010	29	38	50
Aug 2010	62	40	52
Sep 2010	69	76	91
Oct 2010	172	128	182
Nov 2010	329	236	263
Dec 2010	500	414	360
Jan 2011	360	438	346
Feb 2011	253	358	300
Totals	**2522**	**2461**	**2392**

Source: Vilnus Vesma

It is obvious immediately that the year ending February 2011 was colder at 2522 degree days than the 20 year average figure of 2392.

The reason for this can be identified in the Winter months, November to December 2010 and January 2011 where it has clearly been a lot colder than the 20 year average. The relationship between actual electricity usage and weather can be seen in the two year comparison report above. Apart from December 2010 where the consumption levels appear to be about the same as the last year due to the degree day being lower/weather milder, you can see the impact on consumption of colder Winter weather during period January and February 2011.

5.0 CASE STUDIES

5.1 High Ashurst Outdoor Learning Centre

This outdoor education centre is located near Dorking, Surrey. The heating system was served by an oil fired boiler and is now served by two wood pellet boilers rated at 140 kW. The wood pellets are sourced from Surrey Hills Wood Fuel (SHWF) and stored in purpose built sized silos adequate for deliveries during the year. The deliveries vary, in summer deliveries are every 3 months and every 2 months in winter.

The heat distribution pipework which run underground are insulated to prevent heat loss which in turn helps the system to maintain a lower flow/return temperature differential leading to higher efficiency.

The biomass heating system is saving the Centre 50 tonnes of CO_2 per year compared to oil. The Centre used the RHI (Renewable Heat Incentive) to purchase the biomass boilers and payback is under 9 years, after 15 years of operation the biomass system will have cost 30% less than compared to operation under oil fired plant. If oil prices were the same or lower than wood fuel though, the financial savings may not be realised and awareness of costs per kWh for various fuels is advised as per price comparison table included in this study.

SHWF as mentioned above are a non profit organisation who promote and produce wood fuel. The Surrey Hills is an AONB (area of outstanding natural beauty) and has around 40% woodland cover.

5.2 Pinkery Outdoor Education Centre – Exmoor National Park

What are the options for outdoor education centres which are completely off grid, i.e. not attached to the electricity network or mains gas and have to generate electricity for the whole site using generators?

Pinkery outdoor education centre operated in this fashion and has been chosen as part of this study to demonstrate how it and other centres like it can reduce carbon emissions. The case study (page 1) states "Since 2001, electricity for the site has been provided by the combination of a diesel generator, (the centre is considering experimenting with bio diesel), a 6kW wind turbine and a solar photovoltaic (PV) array. The wind turbine and solar PV array charge a set of batteries enabling energy to be stored for use when it is needed. When there is insufficient charge in the battery bank then the diesel generator 'kicks in' to provide power. Any excess charge from the wind turbine is 'dumped' into the central heating system to offset heating fuel demand. Since the renewable electricity generating equipment was installed the diesel generator has been in frequent use as the electricity usage at the Centre regularly outstrips the amount of renewable electricity generated. In order to reduce this reliance on diesel, Exmoor National Park Authority applied to Carbon Neutral Exmoor, which had obtained funding through the Low Carbon Community Challenge, for funding to install a larger wind turbine”.

Image 2 Picture of a solar PV array at Inverness College

5.2.1 <u>Costs and Savings</u>

It is stated that “The total installed cost of the system including the extra batteries and painting the tower of the turbine green to reduce its visual impact was £70,554.04 including VAT.

The benefits of the system are:

It is likely to reduce the carbon emissions of the Centre by approximately 14,000 kg of CO2 per annum.
Based on the turbine’s predicted electrical output a Feed in Tariff revenue of approximately £10,000 per annum will be generated and paid into a fund to be reinvested in community low carbon projects”.

5.2.2 <u>Wider Benefits</u>

The report states “The turbine will (alongside other renewable energy technology installed at the Centre) help to raise awareness of climate change and the technologies that can help us to make the transition to low carbon living”.

5.3 Culloden Visitor Centre

Culloden Visitor Centre forms part of this study. The visitor centre is located near Inverness, Scotland and was built in 2004. It's rural location is similar to that of an outdoor education centre and so it was relevant to my study into reducing carbon emissions. The visitor centre has no access to gas mains the same as Benmore Outdoor Education Centre.

The site Facilities Manager, Mr Alex Elliott confirmed that the Company, Highland Wood Energy (HW Energy) installed the biomass boiler. The visitor centre has an energy services contract in place with HW Energy on a supply of heat basis. This includes supply and installation of the biomass boiler and supply of woodchip as well as maintenance and call outs for any service issues.

The usable floor area of the visitor centre is 2224 m2. Heating and domestic hot water is fed off the biomass boiler. The boiler is rated at 220 kW and has standby plant using liquid petroleum gas (LPG).

Image 3 Picture taken during a site visit, underground storage of wood chips.

6.0 BIOMASS STANDARDS

An investigation on biomass standards was carried out. These standards are to ensure quality and used to describe both combustion equipment and wood fuels. There are minimum standards for moisture, ash content and calorific value so that wood fuel users can purchase and have confidence to ensure trouble free operation of plant, minimising failure and ensuring continuity of service applicable to outdoor education centres.

The Biomass Energy Centre website states “CEN/TC 335 is the technical committee developing the draft standard to describe all forms of solid biofuels within Europe, including wood chips, wood pellets and briquettes, logs, sawdust and straw bales”. CEN/TC 335 “allows all relevant properties of the fuel to be described, and includes both normative information that must be provided about the fuel, and informative information that can be included but is not required. As well as the physical and chemical characteristics of the fuel as it is, CEN/TC 335 also provides information on the source of the material”. UK wood fuel suppliers have to abide by the quality rating CEN/TS 14961:2005. “This is the fuel specifications and classes for all solid biofuels”. It “defines certain parameters and property classes”.

6.1 Normative Specifications for Woodchips

- Origin
- Particle size (P16/P31.5/P45/P63/P100)
- Moisture content (M20/M25/M30/M40/M55/M65)
- Ash content (A0.7/A1.5/A3.0/A6.0/A10.0)

6.2 Normative Specifications for Chemically Handled Wood or Used Wood

- Nitrogen (N0.5/N1.0/N3.0/N3.0+)

6.3 Informative Specifications for Wood Chips

include:-

- Net energy content (lower heating value (LHV) as MJ/kg or kWh/m3 loose

- Bulk density in kg/m3 loose
- Chlorine content (Cl0.03/Cl0.07/Cl0.10/Cl0.10+)
- Nitrogen (N0.5/N1.0/N3.0/N3.0+)

Many other properties may also be specified, including concentrations of many other elements and volatile matter and ash melting behaviour. Different specifications are required for different fuels, and for pellets and briquettes these include mechanical durability and particle density.

6.4 Technical Standards

For specified parameters to be relevant it is important that there is a standard way of measuring them to ensure that measurements are reproducible and unambiguous.

There are therefore a list of technical standards that define terminology, measurement methods and sampling methods.

Table 6 Published Technical Standards

Standard Reference	Title
BS EN 14774-1:2009	Solid biofuels – Determination of moisture content – Oven dry method. Total moisture: Reference method
BS EN 14774-2:2009	Solid biofuels – Determination of moisture content – Oven dry method. Total moisture: Simplified method
BS EN 14774-3:2009	Solid biofuels – Determination of moisture content – Oven dry method. Moisture in general analysis sample
BS EN 14775:2009	Solid biofuels – Determination of ash content
BS EN 14918:2009	Solid biofuels – Determination of calorific value
BS EN 14961-1:2010	Solid biofuels – Fuel specifications and classes - Part 1: General requirements
BS EN 15103:2009	Solid biofuels – Determination of bulk density
BS EN 15148:2009	Solid biofuels – Determination of the content of volatile matter

BS EN 15210-1:2009	Solid biofuels – Determination of mechanical durability of pellets and briquettes
CEN/TS 14588:2004	Solid biofuels – Terminology, definitions and descriptions
CEN/TS 14778-1:2005	Solid biofuels – Sampling – Part 1: Methods for sampling
CEN/TS 14778-2:2005	Solid biofuels – Sampling – Part 2: Methods for sampling particulate material transported in lorries
CEN/TS 14779:2005	Solid biofuels – Sampling – Methods for preparing sampling plans and sampling certificates
CEN/TS 14780:2005	Solid biofuels – Methods for sample preparation
CEN/TS 15104:2005	Solid biofuels – Determination of total content of carbon, hydrogen and nitrogen – Instrumental methods
CEN/TS 15105:2005	Solid biofuels – Methods for determination of the water soluble content of chloride, sodium and potassium
CEN/TS 15149-1:2006	Solid biofuels – Methods for the determination of particle size distribution – Part 1: Oscillating screen method using sieve apertures of 3.15 mm and above
CEN/TS 15149-2:2006	Solid biofuels – Methods for the determination of particle size distribution – Part 2: Vibrating screen method using sieve apertures of 3.15 mm and above
CEN/TS 15149-3:2006	Solid biofuels – Methods for the determination of particle size distribution – Part 3: Rotary screen method
CEN/TS 15150:2005	Solid biofuels – Methods for the determination of particle density
CEN/TS 15210-2:2005	Solid biofuels – Determination of mechanical durability of pellets and briquettes. Part 2: Briquettes
CEN/TS 15234:2006	Solid biofuels – Fuel quality assurance
CEN/TS 15289:2009	Solid biofuels – Determination of total content of sulphur and chlorine

CEN/TS 15290:2006	Solid biofuels – Determination of major elements
CEN/TS 15296:2006	Solid biofuels – Calculation of analyses to different bases
CEN/TS 15297:2006	Solid biofuels – Determination of minor elements
CEN/TS 15370-1:2006	Solid biofuels – Method for the determination of ash melting behaviour – Part 1: Characteristic temperatures method

Below is a picture taken at my visit to Inverness College to meet with Mr Angus MacLeod which displays the one of the biomass boilers and what is displayed on them used for training courses.

Image 4 Biomass Boiler Display of Technical Information

7.0 <u>QUESTIONNAIRE</u>

A written questionnaire was emailed to the Benmore OEC's Bursar, Ms Haddon shortly after my site visit in March 2011. It was important to this study to find out perceived problems with the heating levels at present. The future mechanical design and installation project if the feasibility study gets approval to progress to works, required some information on this and also, staff numbers and guest numbers to factor into loading of boiler(s).

It was important for the study to obtain contact details for the Royal Botanical Gardens in terms of ash removal and any courtesy information to be provided to them regarding the project proposal which would be taken up by the Client Project Officer, Dawn Jeffs at a later date.

Table 7 Questions and answers.

Question	**Answer**
1 When did the Council take ownership of Benmore OEC from the Younger Family?	Building was in the hands of the Forestry commission until 1965, when the building was given over to Benmore Outdoor Centre. The Forestry Commission was given property in 1925 by Younger Family
2 Are there any arrangements with the Botanical Gardens including contact names/nos there?	The contact there is Ian Lawrie who is the Line Manager of Peter Baxter, I think his office is in the Edinburgh Botanic Gardens. Peter Baxter Curator of the gardens can be contacted on 01369 706261
3 How many children/schools stay per year, off peak/peak times of year etc.	Please refer to Appendix 1 excel spreadsheet from Jayne Haddon for information – see tab “Visitor Numbers and Days”
4 How many staff work at Benmore, out of which do any reside within Benmore?	7 catering staff (Kitchen and Domestic) 1 Handyman/Driver 1 Admin Officer 6 permanent Instructors 1 Principal Teacher 5 teachers Approx. 10 freelancer instructors registered with us, work ad hoc 4 trainees that work mainly on a yearly basis.
5 LPG deliveries - what are the delivered loads, costs and dates of delivery?	Approximately 2261 litres propane gas per year. The last delivery was on 5.5.2011
6 Is LPG used for kitchen only?	Yes
7 What size of storage tank do you have for LPG (underground tank)	We have a 4,000 litre tank
8 What is your perception of heating levels within the building, too hot, cold, draughty? General comments about thermal comfort welcomed.	Heating levels are always too cold in the winter and too hot in the summer, simply because we cannot regulate the temperature, the storage heaters require about 36 hours to get up to temperature. The Castle part of the

	building is draughty in all areas. Ideally, we would like an ambient all round temperature, one that we can regulate by a control
9 What is the name of the access road that the lorries take to deliver fuel at the moment, would also be proposed if Biomass is best option? Would you be able to highlight this road on a map for me please?	If the Lorries are to come over the "Rest" and by "Thankful Way" the road required is the A815 to the bottom of Loch Eck. If they were to come over the ferry from Gourock to Hunters Quay the road number is A885. Map attached
10 Do you know when the heating plant was converted from coal to electric heating?	Not sure if done by one step, storage heaters were put in mid 70's
11 What hours are the drying areas heated and to what temperature?	Hours of heating between 8 am – 6 pm (10 hours) per day. This is a combination of heating and using the dehumidifier to dry clothes. The dehumidifier is a commercial size, heat gets to about 30 degree's before the thermostat cut in/out

8.0 ARGYLL AND BUTE COUNCIL

Argyll & Bute Council were contacted to identify any restriction on the installation and operation of biomass (woodchip/pellets) boilers in Argyll and Bute.

They were asked if there was any legislation which a Biomass boiler installation would have to comply with.

They were also asked to confirm if they monitor emissions at present as part of environmental management.

9.0 ALTERNATIVE FUEL STUDY – BENMORE OEC

My study, in connection with Benmore OEC meant working alongside City of Edinburgh Council's mechanical design engineer, Mr McKeown, to identify and confirm biomass boiler loads and to obtain information on a comparison to LPG.

The alternative fuel study has provided some design engineering figures used in this section.

During a site survey, I met with the Bursar of Benmore OEC, Jayne Haddon to carry out an initial survey of the building. Some information was immediate such as Ms Haddon confirmed that the centre can accommodate up to 120 people at any one time from various schools or private group bookings. It is therefore important that boiler plant is designed to cope with peak heating and hot water demand loads.

It was noted during the site survey that the electric heating was uncontrollable and not adequate to heating the bedrooms or communal and office areas. Rooms in the South elevation suffered from solar gain which meant service users experiencing discomfort leading to staff opening windows to cool down the room whilst the heaters were emitting heat. This is unacceptable as it is not helping to reduce carbon emissions or costs for the Centre.

Some of the windows were in bad repair and gaps were visible. The windows would benefit from replacement/repair and/or secondary glazing to combat heat loss. These issues are hard to fix due to Council budget restraints. This may be the case for other centres in the UK which are owned by the Local Authority.

From discussions with Mr McKeown it was evident from his experience that the following information should be adhered to:-

1 It is extremely important not to oversize biomass boilers as continuous operation, a “fast burn” and high combustion temperature are crucial to a problem free and clean operation.

2 An accumulator vessel <u>must</u> be employed.

3 Drying rooms can be used as a “heat sink” to provide demand to the boiler(s).

4 For summer use, consider an LPG boiler for domestic hot water only (estimated 180 kW).

9.1 Proposed Fuel Types

9.1.1 Liquified Petroleum Gas (LPG)

LPG is a consistent high grade fuel with a high energy content (5.8 kWh/litre) suitable for automatic boiler plants with minimum attendance requirements.

There are a number of suppliers in the area who can also provide regular inspection and maintenance.

LPG is more expensive than biomass fuel though attendance and maintenance costs are lower.

9.2 Fuel Storage and Spatial Requirements Fuel Delivery Systems

It is important to consider fuels, fuel storage and spatial requirements for fuel delivery systems as part of any proposal of biomass boilers. The relevance of this is explained in the following sections with reference to Benmore OEC.

9.2.1 Liquified Petroleum Gas (LPG)

There are no particular technical issues in relation to the storage of LPG which has been common for many years and is well understood.

Storage tanks can be located externally, internally or buried below ground, which is the case for the catering gas storage at Benmore OEC.

9.2.2 Biomass Fuel

Whether woodchips or pellets are used, the issues surrounding the storage of biomass fuel are more complex.

Generally, there are three options for the design of biomass storage:-

1 Fully Underground
2 Partially underground
3 Surface, either in a custom built building or containerised

The design of the storage system and the delivery method are extremely important and must be considered at the earliest stages of design. The simplest method of delivery is tipping which would require that the silo be wholly or partially below ground or that ramp access is provided to an above ground silo. The difficulties associated with wholly or partially buried storage is that the provision of drainage and ventilation, which are extremely important, become very difficult to provide. Drainage is required to combat inadvertent ingress of water and for cleaning out the silo in the event of blockage or contamination. Ventilation is required to prevent the build up of condensation, allow additional drying and to prevent the formation of moulds, the spores of which, if inhaled, can present a serious health hazard. Generally the above problems are less likely, but still possible, with pelleted fuel. There are various specialist vehicles which can deliver pellets by pneumatic feed but these are not widely available at present and availability requires further research.

In all cases the silo design should allow the free flow of fuel to the take off point, usually at the bottom of the silo and should provide protection from the ingress of water, both in storage, during fuel deliveries and from ground water.

It should be noted that there is an access road to Benmore OEC for the delivery of LPG and it is deemed appropriate in the delivery of biomass wood fuel also.

9.2.3 <u>Spatial Requirements</u>

Based on a 500 kW plant (see breakdown in Alternative Fuel Study Section which follows) the spatial requirements for LPG, woodchips and pellets are as follows:-

a) LPG storage would require 21 m3 net plus 23 m2 for plant space.
b) Woodchips at 30% moisture content would require 66 m3 net plus 50 m2 for plant space.
Woodchips at 50% moisture content would require 75 m3 net plus 50 m2 for plant space.
c) Pellets would require 30 m3 net plus 50 m2 for plant space.

For all of the above fuel types, adequate road access is required.

9.3 <u>Fuel Handling Systems</u>

It is advisable that the suitable fuel handling systems for a plant of this size are:-

a) Auger
b) Pneumatic delivery
c) Gravity feed, combined with pneumatic delivery

Whatever delivery system is utilised, it is important with pellets to minimise the number of handling stages to prevent the physical degradation of the pellets to, effectively, sawdust which means that the fuel store would require to be adjacent to the boiler house.

9.4 <u>Boiler Plant Types</u>

Boiler plant types:-

a) Overfeed stokers, which are designed to handle large fuel eg logs, which are not appropriate to this study.

b) Underfeed stokers which can handle small chips or pellets which feed into the boiler combustion chamber via a screw conveyor (auger) and which, in conjunction with abatement technology, result in lower emissions. Some manufacturers incorporate abatement technology within the boiler whereas in other cases this would be fitted external to the boiler. By the requirements of the Clean Air Act 1993 it is likely that some form of abatement technology will be required.

c) Moving grate, which can be vibrating, inclined, horizontal or travelling, all of which can handle a wide variety of chip quality and pellets. This type of grate is generally used on larger applications (in excess of 2 MW).

It should be noted that, although most modern biomass boilers are designed to operate down to around 30% of maximum output, they are not well suited to this mode of operation and if long periods of low or medium load and the provision of summer domestic hot water are required then it may be that the biomass boiler sized for minimum base load, supplemented by an LPG boiler for peak load and summer domestic hot water, would be appropriate, particularly as there is a contract for LPG supply already in place at Benmore OEC.

9.5 Procurement Mechanisms

There are two appropriate procurement mechanisms.

1) Traditional

In the traditional procurement method, the system is fully designed and specified and put to competitive tender to selected contractors. Generally it would fall to the user to source a suitable fuel supplier though this requirement could be incorporated into the contract.

Following installation and commissioning the responsibility for scheduling fuel deliveries in good time and ensuring quality of fuel delivered would be the responsibility of the user.

Basic maintenance of the plant could be contracted to the fuel supplier.

2) Energy Services Company (ESC)

In this mechanism the ESCO is contracted to supply heat rather than fuel and is paid on the basis of heat delivered, which is measured on the basis of water flow rate and temperature differential between boiler flow and return lines. Such metering equipment is readily available. The advantages to the user lie in the fact that, if the ESCO chooses to provide a fuel with a lower energy content, then it is their responsibility to provide sufficient fuel to maintain the contracted heat output.

Some energy services companies can also provide capital funding for the installation in which case they would own and maintain the equipment and the user would enter into an appropriate long term agreement which would be reflected in the charges made for heat supplied.

Highland Wood Energy were contacted over the phone and confirmed estimated charges of an energy supply contract, charges would be around 4.6 p/kWh to 5 p/kWh based on a 15 year contracted period.

This would cover supply and fit of all biomass plant and associated equipment and annual maintenance, call outs on a supply of heat basis as explained above.

This is the preferable option for Benmore OEC as there is no plant attendant nor anyone with suitable experience or knowledge of boiler plant to task with the day to day management of the biomass boilers or other boiler types for that matter. Use of an ESC will give peace of mind to the site manager, Andy Beveridge and his Administrators that occupancy comfort levels will be maintained and ensure business continuity.

Costs associated are therefore based on the annual consumption calculation:-

703500 kWh x 5 p/kWh x 15 years = £527,625

9.6 Ash Removal

With regard to ash removal, this was discussed with the site manager, Andy Beveridge, during our initial survey. Ash removal would normally involve removal from site but given the somewhat unique location of Benmore OEC compared to other Council buildings, it was thought more appropriate that the ash residue could be reused by the Royal Botanical Gardens for composting. The fuel will require to be checked for anything toxic in the pellets beforehand and technical standards referred to. This agreement is yet to be finalised at time of writing.

10.0 BIOMASS WINTER LOAD STUDY

The building has a net usable area of 2625 m2 multiplied by an average ceiling height of 3.5 m means the heated volume is 9200 m3.

The calculated heating load is 36 w x 9200 m3/1000 = 335 kW.

10.1 Domestic Hot Water (DHW) Load

Calculation allows for 120 people showering for an average of 5 minutes each allowing 6 litres/minute. This equates to 120 people x 5 mins x 6 litres = 3600 litres. Allowance for heat up period is 2 hours (5-7 am and 4-6 pm) or 4 to 6 hours twice a day = 118kW.

10.2 Catering

Allowing 4 litres per meal. This equates to 4 Litres x 120 (meals) = 480 litres and half hour heat up = 63 kW.

Allowing for time differences when loads are applied DHW heat up is 4 am to 6 am.

Low Temperature Hot Water (LTHW) Heating is required from 6 am to 9 am (or more on wet days for drying clothes in the drying areas) and 5 pm to 9 pm.

Catering DHW is calculated at 7 am to 9 am and 5 pm to 7 pm (electrically heated dishwashers).

Allow for total biomass boiler capacity of 335 kW (168 kW per boiler) based on 2 boilers which will be zoned according to time and system needs.

10.3 Fuel Consumption

I have used the base load figure previously of 13434 kWh (July 2010) consumption and multiplied this by 12 to get an annual electricity consumption figure of 161208 for general lighting and power only. This figure will be added to the various biomass operation scenarios in the sections that follow to detail total annual consumption.

10.3.1 All Year Round Operation – Biomass Only

LTHW heating boiler = 335 kW
Operational hours 6 am to 9 am, 5 pm to 9 pm plus 1 hour = 8 hour day
Allow 7 days per week and 50 weeks per year.
Boiler combustion efficiency = 80%
Annual energy consumption =
8 hr x 7 days x 50 weeks x 335 kW x 0.6 weather factor/0.8 (efficiency) = 703500 kWh/annum.

Total Annual Consumption 161208 kWh + 703500 = 864708 kWh

Savings in kWh – Subtract 161208 – 434169 (electricity 12 months ending 2011) = 272961

272961 kWh = heating proportion of electricity at present, equivalent to 148824 kg of carbon. Add the LPG annual consumption 16008 kWh (2261 litres x 7.08 kWh/Litre conversion factor from the Carbon Trust) 272961 + 16008 = 288969 kWh

10.3.2 <u>All Year Round Operation – Biomass and LPG</u>

Heating season taken as 30 weeks out of the year and using biomass to match demand. Using LPG to match DHW demand the calcs are:-

8 hr x 7 days x 30 weeks x 335 kW x 0.6 Weather factor/0.8 (efficiency) = 422100 kWh/annum.

Total Annual Consumption 161208 kWh + 422100 = 583308

10.3.3 <u>All Year Round Operation – LPG Only</u>

8 hr x 7 days x 50 weeks x 335 kW x 0.6 weather factor/0.8 efficiency = 703500 kWh/annum.

For 20 weeks summer load. Showers, DHW 120 people, 2 x 5 min showers/day @ 6 litres/min/shower, heat up 2 hours = 118 kW.

Catering 4 litres per meal, as mentioned in 4.3 above equates to 63 kW twice per day.

Total summer load = 180 kW Maximum.
Seasonal energy usage = (118 + 63) x 2 hrs x 7 days x 20 weeks/0.8 = 63350 kWh/season.

For 2 weeks at full load (Winter)

8 hrs x 14 days x 335 kW/0.8 efficiency = 46900 kWh/2 weeks.

Total Annual Consumption 161208 kWh + 703500 = 864708

10.4 <u>Savings in Carbon Emissions</u>

Table 8 Summary of Environmental Savings – Different Operating Plant Options

	Biomass	Electricity (baseload) kWh	Heating (electricity) kWh	LPG (2261 litres converted) Conversion factor 7.08/kWh) kWh	Total kWh (to be converted to CO2)	Total CO2 Emissions kg	CO2 Savings Kg using Biomass
Present Situation Elec & LPG		161208	272961	16008	450177	245445	n/a
Biomass Only	703500 (saving)	161208	n/a	n/a	161208	87893	383562
Biomass and LPG	422100 (saving)	161208	n/a	16008	177216	96622	230137

10.5 <u>Fuel Storage</u>

All fuel storage calculations are based on a Winter full load usage with a 2 week storage capacity.

Biomass for 2 weeks at full load = 46900 kWh heat energy
LPG for 2 weeks at full load = 46900 kWh heat energy
Table 9 Energy Density per Fuel Type

FUEL	ENERGY DENSITY KWH/M3
Woodchip 30% Moisture Content	870
Wood Pellet	3100
LPG	6600

Source: Biomass Centre, Forestry Commission, Scottish Government

Storage requirements:-

Woodchip at 30% moisture content = 46900 kWh/870 = 54 m3
Pellets = 46900 kWh/3100 = 16 m3
LPG = 46900 kWh/6600 = 7 m3

Allow 15% over capacity for filling when not completely empty:-

Woodchip = 54 m3 x 1.15 = 62 m3 (4m x 4m x 4m deep)
Pellets = 16 x 1.15 = 19 m3 (3m x 3m x 2.5m deep)
LPG = 7 x 1.15 = 8 m3 (6.9 m x 1.2 x 1.2 deep)
(plus clearances).

10.6 Installation Costs

Installation costs were provided to assess the project viability and payback periods.

10.6.1 Capital Costs

In order to be able to factor in the reductions in electricity costs, taxes etc and include the RHI (renewable heat incentive), the cost of the wet system has to be included.

10.6.2 Biomass LTHW Heating System

Space heating and air treatment for affordable housing is £40-£60/m2, excluding heat source. (Note: upper end includes cooling, sprinklers etc). Using £40/m2 plus 10% “complexity” factor for a listed building of this type = £44/m2.

Floor area = 2625 m2 x £44/m2 = £115,500 which is common to all options. Note that costs do include BMS (Building Monitoring System).

10.6.3 Heat Source

Biomass is £250/kW, LPG is £45/kW, excluding flues, plant room installation and boiler house/fuel store.

Biomass is £110/kW and LPG is £60/kW which includes flues, control, plant room installation and for biomass includes the accumulator vessel. Note, LPG tank is excluded and the wood fuel store is excluded.

The cost of a below ground wood fuel store is around £40,000 and allow cost of LPG tank as £25,000.

10.6.4 Biomass Electrical and BMS Services

The above figures exclude electrical costs and BMS. Electrical costs = £15,000 (in-house estimate or Council labour).

BMS costs = £1000/boiler LPG; £1500/boiler biomass (2 boilers).

Additional costs are therefore:-

Biomass electrical £15,000 + BMS £3000 = £18,000
LPG electrical £15,000 + BMS £2000 = £17,000

10.6.5 Boiler Plant Heat Source

Plant costs – Biomass, use £265/kW; LPG use £115/kW

Cost of boiler plant installation is as follows:-

		£	
Biomass £265/kW x 335	=	88,775	
Add fuel store	=	15,000	(note £40,000 for underground)
		103,775	
LPG £115/kW x 335	=	38,525	
Add fuel store	=	10,000	(note £20,000 for underground)
		48,525	

10.6.6 Summary of Capital Costs

Biomass

		£
LTHW Heating System	=	115,500
Electrical & BMS Services	=	18,000
Boiler Plant/Heat Source	=	103,775

		237,275

LPG

LTHW Heating System	=	115,500
Electrical & BMS Services	=	17,000
Boiler Plant/Heat Source	=	48,525
		181,025

Note – add £40,000 for biomass underground fuel store
Add £20,000 for LPG underground fuel store

10.6.7 Cost of Building works

Allow for £300/m2.
Biomass – boiler house 10m x 7m x 4m = 70 x 300 = £21,000
LPG – boiler house 6m x 4m x 4m = 24 x 300 = £7,200

Biomass £237,275 + £21,000 = £258,275 (for pellets £250,275)
LPG £181,025 + £7200 = £188,225

10.6.8 Biomass and LPG Co-Firing

a) Woodchips

	£
Biomass and LTHW heating system	= 258,275
LPG boiler plant installation	= 48,525
Total capital cost of co-firing woodchips	= 306,800

b) pellets

Biomass and LTHW heating system	= 250,275
LPG boiler plant installation	= 48,525
Total capital cost of co-firing pellets	= 298,800

10.7 Fuel Costs

Woodchip 1.5 to 2.5p/kWh – average of 2p/kWh assumed
Pellets 3.0 to 4.5 p/kWh – average of 4p/kWh assumed
LPG 48p/litre – equates to 7.2p/kWh

10.7.1 Operation over 50 Weeks (Year Round Consumption)

Table 10 Year Round Consumption Biomass vs LPG

Fuel	Annual Consumption (kWh)	Unit Rate (p/kWh)	Annual Cost (£)
Woodchip	703500	2.00	14,070
Pellets	703500	4.00	28,140
LPG	703500	7.20	50,652

10.7.2 Operation over 30 weeks (Biomass Only) Heating Season

Table 11 Operation over 30 weeks Biomass Only

Fuel	Annual Consumption (kWh)	Unit Rate (p/kWh)	Annual Cost (£)
Woodchip	422100	2.00	8442
Pellets	422100	4.00	16,884

10.7.3 Operation over 20 weeks (Summer Load)

Table 12 Operation over 20 weeks LPG Only

Fuel	Annual Consumption (kWh)	Unit Rate (p/kWh)	Annual Cost (£)
LPG	63350	7.20	4561

For a 30 week biomass/20 week LPG operation the costs are as follows:-

Woodchip + LPG = £8442 + £4561.00 = £13003/annum.

Pellets + LPG = £16884 + £4561 = £21445/annum

10.8 Maintenance Costs

Estimated maintenance costs based an external maintenance company, does not include an on site engineer/plant operator. Costs confirmed as follows:-

10.8.1 <u>Operation over 50 Weeks – Year Round Operation</u>

Table 13 Maintenance Costs over 50 Weeks – All Fuels

Fuel	Annual Consumption (kWh)	Unit Rate (p/kWh)	Annual Cost (£)
Woodchip	703500	4.00	28,140
Pellets	703500	3.00	21,105
LPG	703500	2.00	14,070

10.8.2 <u>Operation over 30 Weeks – Summer Load, Biomass Only</u>

Table 14 Maintenance costs over 30 Weeks (Summer) Biomass Only

Fuel	Annual Consumption (kWh)	Unit Rate (p/kWh)	Annual Cost (£)
Woodchip	422100	4.00	16,884
Pellets	422100	3.00	12,663

10.8.3 <u>Operation over 20 Weeks – Summer Load, LPG Only</u>

Table 15 Maintenance costs over 20 weeks, LPG only

Fuel	Annual Consumption (kWh)	Unit Rate (p/kWh)	Annual Cost (£)
LPG	63350	2.00	1267

For a 30 week biomass/20 week LPG scenario, the annual maintenance costs are as follows:-

Woodchip + LPG = £16884 + £1267 = £18151/annum

Pellets + LPG = £12663 + 1267 = £13,930/annum

Cost of plant operative = £22,000/annum x 2.3 (see note) = £50,600/annum (biomass only)

Note – 2.3 is the overhead factor for National Insurance, pensions, holiday pay etc.

10.9 <u>Plant Replacement Costs</u>

The only things requiring replacement would be:-

a) Solid fuel handling – replace at 10 years (pessimistic)

b) Chimneys – replace at 10 years (modestly pessimistic)

Estimated Capital Cost of Fuel Handling = £16,000
Estimated Capital Cost of Chimneys = £10,000

11.0 SAVINGS IN OPERATIONAL COSTS/GRANTS

11.1 Reductions in Electricity Consumption

The total electricity costs for Benmore OEC for financial year 2009/10 as £60,973. In the July of that financial year, electricity costs were £2356 (incl DHW) and so as a conservative estimate and allowing for new mechanical plant, electrical heating costs were taken as 85% of £60973 = £51,800.

11.2 Reductions in (CCL) Climate Change Levy

CCL rates for Year 2012 are, gas 0.177p/kWh and electricity 0.509 p/kWh. Payment reductions are therefore:-

Biomass = 0.509 p/kWh, LPG = 0.332 p/kWh

Table 16 Cost Savings on CCL per Fuel Type

Fuel	Annual Consumption (kWh)	CCL Rate (p/kWh)	Total Cost Savings (£)
Biomass Year Round	703500	0.509	3580
Biomass 30 Weeks	422100	0.509	2148
LPG 20 Weeks	63350	0.332	210
Biomass 30 Weeks/LPG 20 Weeks	n/a	n/a	2358 (2148 + 210)
LPG Year Round	703500	0.332	2335

11.3 Reductions in Carbon Reduction Commitment (CRC) Costs

The City of Edinburgh Council will pay £12/Tonne of CO_2, emission rates per fuel type, savings using wood chip compared to electricity is explained below.

First we note emission rates per fuel type.

Table 17 Emission Rates per Fuel Type

Fuel Type	Kg CO2/kWh
Woodchips	0.005
Pellets	0.016
LPG	0.234
Electricity	0.46

Then assess CO2 emissions by fuel type over a 50 week operation.

Table 18 Total CO2 Emissions - 50 Week Operation

Fuel	Annual Consumption (kWh) (a)	Kg CO2/kWh (b)	Kg/Annum (a) x (b) (c)	CRC Rate (£/Tonne) (d)	Total Cost (£) (c) x (d)/ 1000	Cost Savings Compared to Electricity (£)
50 Week Operation						
Woodchips	703500	0.005	3517	12	42	3840
Pellets	703500	0.016	11256	12	135	3748
LPG	703500	0.234	164619	12	1975	1908
Electricity	703500	0.46	323610	12	3883	n/a
30 Week Operation						
Woodchips	422100	0.005	2110	12	25	
Pellets	422100	0.016	6753	12	81	
20 Week Operation						
LPG	63350	0.234	14824	12	177	

Then a summary of figures for 30 weeks biomass use and 20 weeks LPG as seen below:-

Woodchips 2110+14824 = 16934 kg/annum = Annual cost of 16934 x 12/1000 = £203
Pellets 6753+14824 = 21577 kg/annum = Annual cost of 21577 x 12/1000 = £259

Savings using woodchips and pellets compared to electricity:-

Woodchips - £3883-£203 = £3680
Pellets - £3883-£259 = £3624

11.4 RHI Payments

The current RHI tariff rates are as follows:-

Tier 1 = 4.7 p/kWh, Tier 2 = 1.9 p/kWh
Tier 1 charge is applicable up to a threshold of 1314 kWh

It is worthwhile noting that co-firing with fossil fuels does not quality for RHI.

Medium biomass attracts payments of:-
1314 hours x 335 kW = 440190 kWh @ 4.7 p/kWh = £20688
703500 kWh-440190kWh = 263310 kWh @ 1.9 p/kWh = £ 5002
Total payment of £25690 (per annum)

11.5 Cost Summary and Paybacks

Please refer to appendix 1.

12.0 NPV (NET PRESENT VALUE) CALCULATIONS

NPV has been used to appraise the project given the proposed ESC and has been calculated based on a) 5 years and b) 15 years based on 5% (r) basis.

The basis of the calculations that follow are:-

a) 5 Years, n = 5, r = 0.05, used in the formula below:-

$$C = \frac{(1-(1+0.05)^{-5})}{0.05} = 4.329$$

b) 15 Years, n = 15, r = 0.05

$$C = \frac{(1-(1+0.05)^{-15})}{0.05} = 10.379$$

For 10 years replacement date

$$F = \frac{1}{(1 + 0.05)^{10}} = 0.614$$

12.1 NPV Calculations (excluding savings and incentives)

Table 19 NPV Calculation Summary

Item Capital Cost	**Expenditure (£)**	**"C" or "F"**	**Present Value (£)**
Woodchips 5 Year			
Heat source & LTHW Heating System	258,275	1.0	258,275
Energy Costs	14,070/annum	C = 4.329	60,909
Maintenance & Operating Costs	78,740/annum	C = 4.329	340,865
Repair Costs (10 year)	Nil	n/a	n/a
		NPV =	**660049**
Woodchips 15 Year			
Heat source & LTHW Heating System	258,275	1.0	258,275
Energy Costs	140,070	C = 10.379	146,032
Maintenance & Operating Costs	78,740/annum	C = 10.379	817,242
Repair Costs (10 year)	26,000	F = 0.614	15,964
		NPV =	**1,237,513**
Pellets 5 Year			
Heat source & LTHW Heating System	250275	1.0	250,275
Energy Costs	28,140	C = 4.329	121,818
Maintenance & Operating Costs	71,705/annum	C = 4.329	310,411
Repair Costs (10 year)	Nil	n/a	n/a
		NPV =	**682,504**

13 OTHER MEASURES TO LOWER CARBON EMISSIONS

As part of my role as Energy Officer at the City of Edinburgh Council, I was advising on ways on which to reduce energy consumption in operational buildings across the Council estate. This included various items of works of which are listed below and information on estimated annual savings. Information on the measures and on annual cost and environmental savings are taken from the Energy Saving Trust's (EST) website.

13.1 Roof Insulation

Insulating a roof or attic space reduces heat loss and therefore reduces energy consumption and carbon emissions.

EST state "Heat will always flow from a warm area to a cold one. The colder it is outside, the faster heat from your home will escape into the surrounding air". This effect will happen in outdoor education centres as well as in the home. "Insulation makes it much more difficult for heat to pass up through your roof by providing a layer of material which has lots of air pockets in it. These pockets trap heat, cutting what is known as the U value of the loft. The U value measures how quickly it loses heat so the lower the U value, the less energy you need to keep your home warm. Loft insulation cuts your loft's U value from around 2.3 W/m2K (for an un-insulated loft) to 0.16 W/m2K, a reduction of around 95%. An R value is a measure of thermal resistance and is the inverse of a U value so the higher the R value the better. The NIA (National Insulation Association) recommend lofts should be insulated to an R value of between 6.1 Km2/W and 7 Km2/W. The R value is usually displayed on the packaging of insulation. R values can be added together to reach the total required".

There may be some outdoor education centres who have flat roofs and the EST advise that you can insulate flat roofs, from the outside and the inside. They advise that "The best time to think about insulating a flat roof externally is when you come to renew its waterproof covering (or decorating the room)". It will be less disruptive and more cost effective to carry out both items of works at the same time.

EST go on to state "Insulating the outside of your roof involves laying boarding backed with insulation material either on top of or under the water proof layer. Insulating the inside of a flat roof is also achieved using insulation backed boards and is very similar to internal solid wall insulation". To be carried out by a recommended installer.

Unfortunately, I could not locate typical savings for roof insulation in an outdoor education centre, however I have used the EST's table on typical savings including carbon for a 3 bedroom semi-detached house to illustrate the potential cost and environmental savings as detailed:-

Table 20 Typical savings (based on 3 bed semi-detached house)

	Increase in Loft Insulation Thickness (0 – 270mm)	Increase in Loft Insulation Thickness (50 – 270mm)
Annual saving per year (£)	Around £145	Around £40
Installed cost (£)	Around £250	Around £250
Installed payback	Around £2 years	Around 6 Years
DIY cost	£50 - £350	£50-£350
DIY payback	Up to 3 years	1 to 9 years
CO2 saving per year	Around 730 kg	Around 210 kg

Source: Energy Savings Trust Website

13.2 Cavity Wall Insulation

The EST state that properties suitable for cavity wall if the following items are applicable:-

a) External walls are unfilled cavity walls
b) The masonry/brick work of the property is in good condition
c) The cavity is at least 50 mm wide

In the case of outdoor education centres, the building construction would have to be assessed to assess if the buildings are appropriate.

In the case of Benmore OEC, the construction was of solid stone and did not have a cavity, however other outdoor educations may be suitable.

Again, due to lack of information on cavity wall insulation savings in outdoor education centres and for consistency reasons, I have used EST's information to illustrate cost and environmental savings using cavity wall insulation in a 3 bed semi-detached house below.

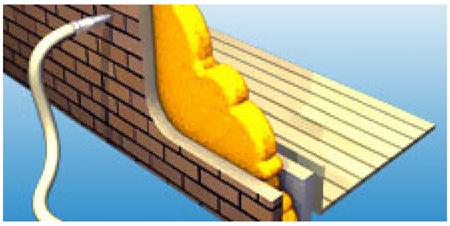
Table 21 Typical Savings in a 3 bed semi-detached house

Measure	**Annual saving per year (£)**	**Installed cost (£)**	**Installed payback**	**CO_2 saving per year**
Cavity wall insulation	Around £110	Around £250	Around 2 years	Around 560 kg

Source: The Energy Savings Trust Website

I have included below a graphic from the EST website to illustrate cavity wall insulation.

Image 5 Displaying Cavity Wall Insulation



Source: The Energy Savings Trust

In the case of solid walls however, these can be insulated according to the EST. They advise that if a property was built before or around 1920 then the likelihood is that it will have solid walls. In cavity walls, the cavity acts as barrier to reduce heat flow through the wall and so solid walls allow more heat to pass through them. The EST advise state "solid walls have no such gap and this allows more heat to pass through them than through cavity walls. In fact, twice as much heat can be lost through an un-insulated solid wall as through an un-insulated cavity wall". However, solid walls can be insulated from the inside or the outside preventing heat loss. This is relevant in the study as this could apply to Benmore OEC and other solid wall construction centres.

13.3 Glazing

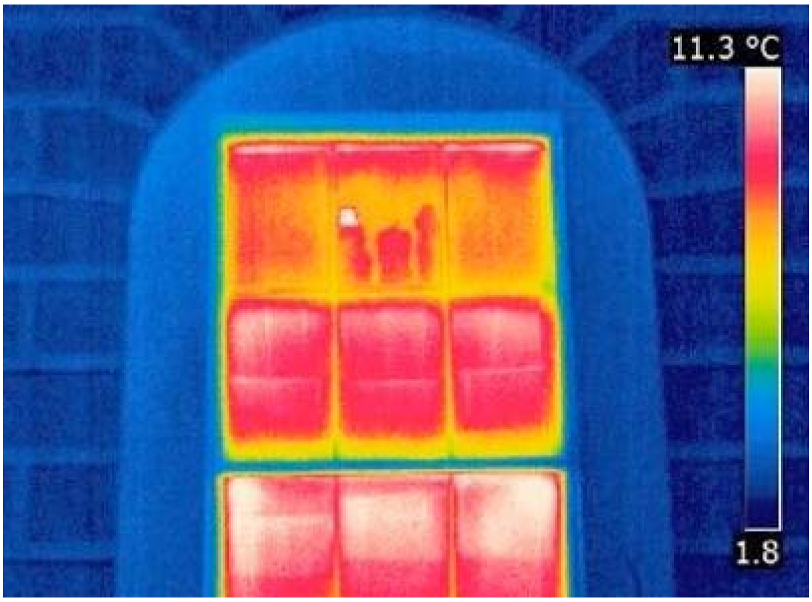
The EST (information available on their website) state that "all properties lose heat through their windows. Installing energy efficient glazing is an effective way of reducing your energy bills and keeping your home warmer and quieter".

"Changeworks" also backs up this argument with their study into "Double Glazing in Listed Buildings" (2010). The document was produced in partnership with Lister Housing Co-operative and Edinburgh World Heritage on behalf of the City of Edinburgh Council. The project started in March 2009 until March 2010 involving retro-fitting of slim-profile double-glazing units into 'A' and 'B' listed buildings located in Edinburgh's Old and New Towns (also conservation areas and UNESCO World Heritage Site).

The interesting fact the report stated was "nearly 40% of pre-1919 dwellings have single-glazed windows. 72% of heat lost through a window is lost through the glazing. Single glazing has very poor energy efficiency, with a U-value of around 5.5 W/m2K. Heat loss through a single glazed window is roughly double the heat loss through a double-glazed window built to Scottish Building Standards". (Page 6)

I have included a copy of their thermal image below displaying areas of heat loss through a single glazed window. This would be typical of the scenario at Benmore OEC and other single glazed buildings across the Council estate and other similar centres.

Image 6 Thermal Imaging of Single Glazed Window – Listed Building



Source: Changeworks, Double Glazing in Listed Buildings (2010)

Double glazing is recommended because of the insulation qualities it has using the air gap between two sheets of glass as an insulation barrier, with triple glazing the same applies but has three sheets of glass.

The EST website information says that “Double glazed windows use two sheets of glass with a gap between them which creates an insulating barrier, whilst triple glazed windows have three sheets of glass. Both options can deliver a high level of energy efficiency. It is not the case that you have to use triple glazing to gain the most energy efficient window.

Energy efficient windows are available in a variety of frame materials and styles. They also vary in their energy efficiency, depending on how well they stop heat from passing through the window, how much sunlight travels through the glass and how little air can leak in or out around the window”.

Through seminars I have attended through work, I have noted that some window manufacturers are now using a window energy rating scheme to display the energy efficiency of the windows.

This is helpful in reducing carbon emissions through reductions in heat loss and particularly useful at Benmore OEC where a large proportion of wall space is covered by single glazed units (see Appendix 2).

13.4 Variable Speed Drives

Variable speed drives can be fitted to pumps, fans and air compressors if all three are already installed at outdoor education centres. This would benefit Benmore when new heating plant is installed and could be fitted to heating zone pumps, domestic hot water pumps, and the flu fan in order to reduce energy consumption and carbon emissions. The Carbon Trust backs this up with their document available on their website called "Variable Speed Drives – Introducing energy saving opportunities for businesses".

The Carbon Trust document, technology overview (page 2) explains how the technology works and how it saves on energy as stated below:-

"Electric induction motors run at fixed speeds and are ideally suited to applications where a constant motor output speed is required. However, there are some applications where varying motor output speeds are preferable, better meeting the requirements of the load. While equipment like conveyors may be fine for a fixed speed, there are some applications which are better suited to running at variable speeds, such as fans, pumps, winders and precision tools. Historically, there have been a number of different methods of controlling processes without changing the fixed speeds of the motors driving them. For example: The flow rate produced by fans and pumps can be controlled by opening and closing dampers and valves. The speed of winders and stirrers can be controlled by gears and pulleys. Although the flow or speed is reduced by using these methods, the consequent power reduction of the motor is small and so the method is not as energy efficient as it could be".

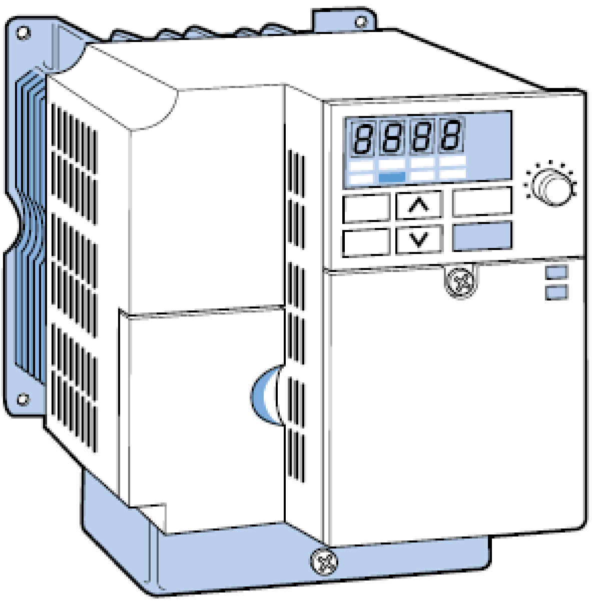
"A variable speed drive (VSD), also known as a frequency converter, adjustable speed drive or inverter, is an electronic device that controls the characteristics of a motor's electrical supply. Therefore, it is able to control the speed and torque of a motor, achieving a better match with the process requirements of the machine it is driving. So in applications where variable control is desirable, slowing down a motor with a VSD does reduce energy use substantially".

"A VSD works by converting the incoming electrical supply of fixed frequency into a variable frequency output. This variation in frequency allows the drive to control the way in which the motor operates — a low frequency for a slow speed, and a higher frequency for a faster speed. The output can also be changed to enable the motor to generate more or less torque as required. So, the motor and drive combination might be used for turning a large load at fairly slow speeds, or turning a lighter load at high speeds, maximising efficiency".

"VSDs are supplied in a wide range of sizes from 0.18kW through to several MW and may be optimised to suit particular applications. VSDs are typically 92–95% efficient with 5–8% losses being due to additional heat dissipation caused by the high–frequency electrical switching and the additional power required by the electronic components. The losses are usually more than compensated for by the savings at the motor. The motor itself also has various internal losses and, if it is attached to a transmission system of some sort (for example, a gearbox or pulley), then this introduces further losses in the form of friction. So, typically, only 75–80% of the energy supplied to the motor system is transmitted to the end–use equipment. The majority of these losses appear as heat. A drive can be located inside an enclosure, some distance away from the motor itself, or it can be directly attached to it. One thing to remember is that if equipment is located in a particularly dirty or badly–ventilated area, then it is advisable to relocate the drive to a suitably protected area. This should be an area which is clean, dry and of a suitable temperature to allow adequate cooling. Larger drives can generate quite a lot of heat, and this needs to be removed or the unit will eventually overheat and fail".

These are points for consideration by Mr McKeown, Mechanical Design Engineer for Benmore, particularly ensuring that the VSD's are not overheating and to protect from failure.

Image 7 A Typical VSD



Source: Carbon Trust, Variable Speed Drives, Introducing energy saving opportunities for businesses.

14.0 CONCLUSIONS

It is important to understand the political drivers involved in reducing carbon emissions including the legislation, particularly CRC energy efficiency scheme where emitters of carbon will effectively be taxed per tonne.

Wood fuel for biomass boilers should be sourced from a sustainable source to ensure that the technology is indeed “carbon neutral”. This includes ensuring that trees are planted to enable the carbon capture as part of the carbon cycle.

A biomass heating system is more expensive than an equivalent capacity fossil fuel fired system and so it is important to determine the optimum sized boiler to match a site’s requirements. This study has investigated how, due to the physical properties of the fuel, the system footprint is also larger for biomass plant than an equivalent capacity fossil fuel fired system. It is important to evaluate the space requirements for fuel delivery, storage and transfer to ensure the efficiency over the system’s lifetime.

The study ascertains the importance of fuel use, one which is available, reliable, accessible and appropriate for the job. This relates to the moisture content (which effects calorific value), energy efficiency and particle size or grade. The costs for fuel vary, dependent on quality and proximity of fuel source to point of use. Local suppliers are recommended to reduce carbon emissions as transporting wood fuel over larger distances compared to shorter distances emits more carbon. A map of fuel suppliers in Scotland has been included in this study and confirmed viable for use in supplying wood fuel for Benmore OEC.

Currently in the UK forests and woodlands are a source of wood fuel along with energy crops. Fast growing systems (SRC) include willow and poplar and SRC systems use eucalyptus species. Co-products are a source of wood fuel too, saw mill, amenity tree waste. “Waste” wood can be used such as unpainted pellets. Benefits are seen in the reduction of waste going to landfill and savings on landfill tax.

Wood logs, wood chips and wood pellets have around 85-90% burning efficiency in modern boiler systems, similar to gas and oil boilers but the advantage is that wood fuels have lower carbon emissions.

The case study on High Ashurst demonstrates how converting oil fired plant to biomass boilers saved 50 tonnes of CO_2 per year compared to oil with a payback of 9 years on capital investment. It proves that biomass is worthwhile in environmental terms and also financial terms as after 15 years of operation the biomass system will have cost 30% less than compared to operation under oil fired plant. If oil prices were the same or lower than wood fuel though, the financial savings may not be realised. Awareness and analysis of wood fuel vs fossil fuels price is advised.

In the case study of Pinkery OEC, which was off grid, used a combination of diesel, a 6 kW wind turbine and a PV array to generate on site electricity. However, they found that the electricity demand used in the centre could not be matched by the wind turbine and the diesel engine had to step in to meet demand. This highlights the importance of assessing the requirements of the site vs the design and specification of renewable technologies. The centre is now looking to install a bigger wind turbine which will add to capital costs and initial paybacks will not be realised.

Energy services contracts are a good option as in the Culloden Visitor Centre example compared to traditional procurement mechanisms. It has been used to ensure heat is available via the biomass boiler. Other centres or rural buildings of this nature should consider this if they have no plant attendant, no on site expertise, time allowance to look after plant. Having such a contract in place is convenient and is easy to pay for on a heat supply basis over a contract term. Future cost analysis will be required to ensure best value should wood fuel increase.

Biomass standards are in place to ensure quality in the supply of wood fuel and are used to describe both combustion equipment and wood fuels for consumers. The minimum standards for moisture, ash content and calorific value help wood fuel users purchase with confidence and help to ensure trouble free operation of plant, minimising failure and ensuring continuity of service. This is advisable for outdoor education centres and other buildings with similar circumstances. Informative and normative specifications for wood fuel should be looked at in order to assess minimum standards, the origin of the wood, chemical content and bulk density.

It is necessary to use a suitably qualified and experienced installer for the design and/or installation of renewable technologies including biomass as investigated through discussion with Inverness College. To ensure problem free running of the appliance and that it is also compliant, safe and deliver expectations.

It is necessary to monitor energy consumption to evaluate energy wastage in order to reduce carbon emissions. An M&T system is a tool that can carry out functions such as 2 year comparison reports as illustrated, benchmarking, producing league tables and degree day analysis. It is advisable to use an M&T system to list priority projects which can help reduce carbon emissions such as biomass installations, BMS control, insulation measures and other renewable projects.

Energy surveys can also identify energy wastage and perceived problems from staff can help in this exercise too for possible areas of improvement. This will all help drive down carbon emissions.

The alternative fuel study confirmed that storage of wood fuel can either be fully or partially underground or in a containerised unit. It is important to consider this at the earliest stage of design. Tipping is the best and easiest option into a silo wholly or partially underground, however there are problems associated with the provision of drainage for the build up of inadvertent water and the provision of ventilation to combat condensation to prevent moulds and spores which effect health if inhaled. In both cases, it would affect the moisture content of the fuel and calorific value. These problems are less likely but still possible with pelleted fuel. It is important that the silo allows fuel to flow freely so it reaches the boiler problem free.

The spatial requirements for a 500 kW plant at Benmore OEC was higher than that required for LPG. The higher the moisture content, the more storage space required.

The suitable fuel handling systems for a biomass plant for Benmore OEC are auger, pneumatic delivery or gravity feed, combined with pneumatic delivery

It is important to locate the fuel store adjacent to the boiler house to cut down the number of handling stages of pellets which helps prevent physical degradation of pellets at any building.

Boiler plant types suitable for wood fuel are overfeed and underfeed stokers and moving grate. Modern biomass boilers are designed to operate down to around 30% of maximum output, they are not well suited to this mode of operation. If long periods of low or medium load and summer domestic hot water are required then it is advisable to size for minimum base load supplemented by an LPG boiler for peak load and summer domestic hot water.

The cost summary for the alternative fuel study, confirms that taking into account all capital costs, operating costs, reductions in operating costs/incentives etc, the payback for wood pellets is most viable at 2.96 years, followed by LPG at 3.36 years, then Woodchip at 3.44 years. In co-firing plant the payback for wood pellets/LPG was slightly better than that of woodchip/LPG at 5.18 years compared to 5.25 years.

The current CO2 emissions for Benmore are 245445 kg or 245 tonnes. The CO2 savings for biomass only is 383562 kg or 383.5 tonnes, for biomass and LPG 230137 kg or 230 tonnes. The biomass only option, will be best in reducing carbon emissions.

Some of the other ways of reducing carbon emissions are to install VSD’s, secondary glazing, attic insulation and alternative renewable technologies such as wind turbines (if applicable and if there is enough wind) and solar PV arrays.

15.0 REFERENCES

Biomass Energy Centre (Contact Email Address), Forestry Commission, Scottish Government. biomasscentre@forestry.gsi.gov.uk

Biomass Standards, (date unknown) available at http://www.biomassenergycentre.org.uk/portal/page?_pageid=77,19836&_dad=portal&_schema=PORTAL (Accessed 1/9/11)

British Listed Buildings, (date unknown) available at http://www.britishlistedbuildings.co.uk/sc-95-benmore-botanic-garden-benmore-house-benmore/map (Accessed 28/7/11)

Carbon Trust

a) Biomass Technology Advice, (date unknown) available at http://www.carbontrust.co.uk/cut-carbon-reduce-costs/products-services/technology-advice/renewables/Pages/Biomass.aspx (Accessed 12/8/11)

b) Variable Speed Drives – Introducing energy saving opportunities for businesses, (2007) available at http://www.carbontrust.co.uk/Publications/pages/publicationdetail.aspx?id=CTG006 (Accessed 7/9/11)

c) Conversion Factors, (2010) available at http://www.carbontrust.co.uk/cut-carbon-reduce-costs/calculate/carbon-footprinting/pages/conversion-factors.aspx#Energy%20units%20into%20kWh (Accessed 7/9/11)

Changeworks, Double Glazing in Listed Buildings, (2010) available at http://www.changeworks.org.uk/uploads/Double_Glazing_In_Listed_Building_-_Project_Report_(Changeworks_2010).pdf (Accessed 7/9/11)

City of Edinburgh Council (2007) Climate Change Framework available at http://www.edinburgh.gov.uk/info/202/sustainable_development/694/climate_change/2 (Accessed 28/7/11)

City of Edinburgh Council, Clean Air Act (1993), available at http://www.edinburgh.gov.uk/info/1116/environmental_health-pollution/862/air_quality_in_edinburgh/3 (Accessed 8/8/11).

Department of Energy and Climate Change (DECC), (date unknown) Carbon Reduction Commitment, available at http://www.decc.gov.uk/en/content/cms/emissions/crc_efficiency/crc_efficiency.aspx (Accessed 8/8/11)

Energy Lens, Degree Days Handle with Care!, (date unknown) available at http://www.energylens.com/articles/degree-days (Accessed 7/9/11)

Energy Savings Trust

a) Loft and Flat Roof Insulation Advice, (date unknown) available at http://www.energysavingtrust.org.uk/Home-improvements-and-products/Home-insulation-glazing/Loft-insulation (Accessed 7/9/11)
b) Cavity Wall Insulation Advice, (date unknown) available at http://www.energysavingtrust.org.uk/Home-improvements-and-products/Home-insulation-glazing/Cavity-wall-insulation#Findouthowcavitywallinsulationworks (Accessed 7/9/11)
c) Wood Fuel Heating, (date unknown) available at http://www.energysavingtrust.org.uk/Generate-your-own-energy/Wood-fuelled-heating (accessed 7/9/11)

Forestry Commission, Woodfuel Meets the Challenge (2006), available at http://www.forestry.gov.uk/pdf/Woodfuel_meets_the_challenge.pdf/$FILE/Woodfuel_meets_the_challenge.pdf (Accessed 5/9/11)

Highland Wood Energy, (date unknown), available at http://www.hwenergy.co.uk/ (Accessed 6/9/11)

National Insulation Association (NIA) as quoted by The Energy Savings Trust, (date unknown) available at http://www.nationalinsulationassociation.org.uk/ (Accessed 7/9/11)

Pinkery Outdoor Education Centre, Low Carbon Case Study, (date unknown) available at http://www.exmoor-nationalpark.gov.uk/communities/sustainable-exmoor/sdf-projects/pinkery-outdoor-centre-low-carbon-case-study/Pinkery-Low-Carbon-case-study.pdf (Accessed 7/9/11)

Renewable Heat Incentive (RHI) (2011), available at http://www.decc.gov.uk/en/content/cms/meeting_energy/Renewable_ener/incentive/incentive.aspx (Accessed 25/8/11)

Security of Supply Report (2010), available at http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/resilience/803-security-of-supply-report.pdf (Accessed 25/8/11)

Sustainable Scotland (date unknown), available at http://www.sustainable-scotland.net/documents/5229_SSN%20Quarterly.pdf (Accessed 8/8/11)

The Scottish Government (2010), Energy Efficiency Action Plan, available at http://www.scotland.gov.uk/Publications/2010/10/07142301/2 (Accessed 18/8/11)

VILNIS VESMA Degree Days (date unknown), available at http://www.vesma.com/ddd/whatthey.htm (Accessed 28/7/11)

16.0 APPENDIX 1

17.0 APPENDIX 2

Cost Summary

Fuel Option	Capital Costs Heat Source & LTHW System (£)	Operating Costs (£)			Operating Cost Reductions / Incentives (£)				Operating Cost Reductions (£)	Net Operating Costs (£)	Simple Payback Period (Yrs)
		Fuel (1)	Maintenance (2)	Plant Operator (3)	Electricity (4)	CCL (5)	Carbon Tax (6)	RHI Payments (7)			
Wood Chips	285,725	14,070	28,140	50,600	51,800	3,580	3,840	25,690	84,910	7,900	3.4
Wood Pellets	250,725	28,140	21,140	50,600	51,800	3,580	3,748	25,690	84,818	15,027	2.96
LPG	188,225	50,652	14,070	N/A	51,800	2,335	1,908	Not Payable	56,043	8,679	3.36
Woodchip / LPG Cofiring	307,250	13,000	18,150	50,600	51,800	2,358	3,680	Not Payable	58,558	23,912	5.25
Pellets / LPG Cofiring	299,250	21,445	13,930	50,600	51,800	2,358	3,624	Not Payable	57,782	28,193	5.18

(1) Fuel costs based on costs and unit prices researched
(2) Maintenance costs are for specialist maintenance by external contractors
(3) Plant operator costs are based on a salary of £22,000.00 ea x overhead factor of 2.3
(4) Electricity costs are based on information provided by the energy & water management dept of CEC
(5) CCL charges are based on current published prices by DECC
(6) Carbon tax charges are based on information provided by the energy & water management dept of CEC
(7) RHI payments are based on published rates