Potential of Renewable Energy in the North Harris Trust area

A study by SESAM students 2005:

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SESAM - Sustainable Energy System and Management

International Institute of Management

University of Flensburg, Germany

September 2005

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List of Abbreviations

BHA	= British Hydro Association
CO2	= Carbon Dioxide
dB	= Decibels
GBP	= Great Britain Pound
GSHP	= Ground Source Heat Pump
HICEC	= Highlands and Islands Community Energy Company
HIE	= Highland & Island Enterprise
IRR	= Internal Rate of Return
LECs	= Levy Exemption Certificates
MHP	= Micro-hydro project
NASA	= National Aeronautic and Space Administration
NGR	= National Grid Reference
NHE	= North Harris Estate
NHT	= North Harris Trust
NPPG	= National Planning Policy Guideline
NPV	= Net Present Value

pH	= Negative logarithm of hydrogen ion
RE	= Renewable Energy
ROC	= Renewable Obligation Certificate
ROS	= Renewables Obligation Scotland
SCHRI	= Scottish Community and Householder Renewables Initiative
SDC	= Sustainable Development Corporation
SNH	= Scotland National Heritage
SPF	= Seasonal Performance Factor
Spp	= Specific Plant
SWH	= Solar Water Heating
WIE	= Western Isles Enterprise

List of Units

adt	= air dry ton
GW	= Gigawatt
ha	= hectare
kg	= kilogram
km^2	= Square kilometer
kV	= Kilovolt
kVA	= Kilo Volt ampere
kW	= Kilowatt
kWh	= kilo watt hour
l/s	= liter per second
m	= meter
m^3	= cubic meter
m^3/s	= cubic meter per second
MW	= Megawatt
MWh	= Megawatt-hour
odt	= oven dry ton

List of Currencies

1 Canadian $ = 0.446 Great Britain Poundsterling

This document is the result of a students exercise during the International Classroom 2005 of the SESAM Course at the University of Flensburg. The University of Flensburg is not to be held responsible for the application or use of the contents of this report.

Acknowledgements

In carrying out this study we received support of various forms from several individuals and organizations. We thus would like to express our sincere gratitude to the following individuals and institutions for their support extended to us in terms of organization, making contacts and providing the necessary information to prepare this report: Donnie Macaulay; Iain Morrison; Archie Macdonald and Norman Macdonald of Western Isles Enterprise, Calum Iain Maciver of Economic Development, Alastair Banks of Planning Commission, Ken Mackay of Aline Forest Development, Steven Liddle of Western Isles Woodland, Ms. Shara from 3G Energy.

Thanks are also extended to Frank Rennie of Lewis Castle College, Sandy Matheson, Donald Mackenzie of SSE, Ian Cairns of SAC, David Maclennan Scottish National Heritage, Eric Dodd, Marion O'Hara and Jon Priddy from HICEC, Donald MacRitchie and Vuorenmaa Tiina from Western Isles Council, Kevin Murray of AMEC and Justin Busbridge of Moorland Against Turbines.

Special thanks must be extended to David Cameron, Mary C. Maclennan and Alistair Macleod of North Harris Trust and Henk Munneke of HICEC for their friendly and tireless cooperation in coordination of various institutions and individuals who were involved in the study and to the residents in our study area for their warm welcome and their patience during the interviews. Without them this study would not have been completed.

Our gratitude goes to David Green, the Principal of Lews Castle College and also the Staffs for the support and the facilities provided for us during our study.

We would also like to thank our lectures from the University of Flensburg, Dr. Dieter Klein and Dip.Ing. Wulf Boie, for their proper administrative arrangements and academic guidance before and during the study.

Lastly, this study would not have been possible without the funding from the Deutscher Akademischer Austausch Dienst (DAAD, German Academic Exchange Service) which deserves our gratitude (goes to DAAD) for its financial support.

Executive Summary

This study has been carried out to identify the potential of using biomass, heat pumps, hydro power, solar water heaters and wind energy to meet the whole or a part of the energy needs for heating and electricity in the North Harris Trust area from Bunaveanadar to Hushinis. The data have been collected by reviewing literature and the internet, conducting a questionnaire survey in 33 households of the area and the Cliasmol school, doing direct field visits and measurements, and having discussions with specific expert as well as email and telephone conversation. Students of the department of Sustainable Energy Systems and Management (SESAM), University Flensburg have conducted this research during August-September 2005 under the academic guidance of 2 lecturers.

FINDINGS OF THE SURVEY

From the survey it was found that from the various renewable energy sources (RES) the respondents are most familiar with hydropower followed by wind energy, solar thermal and tidal energy, whereas there is only little knowledge about biomass, wave energy, solar photovoltaic and geothermal energy (heat pump). On the average ¾ of the respondents are convinced that the generation of energy from renewable sources has positive climatic and environmental impacts. Even more than 80% are of the opinion that more investments should be made in RE projects. And nearly half of the sample population is willing to pay more for energy produced from renewable sources.

Especially hydropower and wind energy is much favored to be exploited, and the energy to be exported to the mainland. Heat pumps – although not as much as the before mentioned sources - are also seen as an option, whereas the potential use of solar thermal energy and biomass is more in doubt with the majority of the sample population. This shows, however that there is still some need for more awareness of the people about the various options of renewable energies e.g. through demonstrative projects.

Electricity is commonly utilized for lighting and appliances in 33 residential homes and one school building of the study area. Presently most of the households use electricity for space and water heating (61-70%) respectively. For these households and the remaining ones, still using oil, coal or peat, there is quite some potential to satisfy their energy needs from renewable sources.

A good start could be those households who showed interest to change their space or water heating system and with those 46% of the respondents who are even willing to pay more for their energy if it came from renewable resources.

RENEWABLE ENERGY POTENTIALS FOR NORTH HARRIS ESTATE

Wind Energy.

It is noted that the North Harris Estate is endowed with abundant wind resources. For instance, the National Aeronautic and Space Administration (NASA) data reveal that Aide Mor has an average annual wind speed of 9m/s at a height of 50m. This speed is indeed higher than the recommendable economically feasible speed of 6m/s for wind turbine investment. Hence the Aide Mor site was the centre of our study for wind energy.

The upgrading of roads towards North Harris will be in completion very soon, this which would make it easier to transport wind turbines parts to proposed sites. The Western Isles is being envisaged as an energy innovation zone and feasibility work for upgrade of sub sea cable links to the mainland is being considered. This upgrade would enable private, community or commercial owners of wind turbine to feed their generated power into the national grid, North Harris Trust inclusive. With all the structures and strategies put in place will make the Lewis and Harris Islands stand to become the centre of excellence in terms of wind energy development in the near future and contribute positively towards reduction of CO_2 emissions.

Small Hydro Power. The topography situation of North Harris Estate helps the presence of hydro potentials in the area. The hilly terrain provides high head while high rainfall rate provides significant amount of flow in the river. In addition, impermeable soil and the absence of vegetation lead the precipitated water to flow directly to the stream. The study team found some potential for the development of small hydro power plants in the area. Three potential sites have been identified for feasibility study. Whereas, Bunavoneadar and Govig are technically and financially feasible, hydro power is not a feasible option for the electricity demand of the Fish Hatchery near the Castle.

Biomass Energy. Presently there are no relevant biomass sources in the study area that could be used as fuel. Some residents and the Amhuinnsuidhe Castle owner have planted some trees around their houses, which grow well. This indicates that tree plantation is possible in the area. The Aline forest, north of the North Harris Trust area on the road to Stornoway, was planted in 1970 by the Forestry Commission at an area of 625 hectare. The owner of this forest is committed to removing areas of conifer and replacing them with hard woods within the coming ten years, which would generate at least 14 GWh energy over this period. The experience of Aline forest shows that biomass growing is possible in the area. By investigating the soil survey map of the study area and also by visiting the sites it was found that in total about 305 ha have a similar soil type as the Aline forest, namely (Aird Chathanais, Gleann Mhiabhaig and Cleit nan Uan) plus 20 ha at Hushinis with another soil type. Willow Hookers (*Salix hookeriana*), Willow ogier (*Salix viminalis*) and Crack Willow (*Salix fragilis*) can be grown in this type of soil.

At individual household level, there is no immediate potential of biomass energy use for space heating. However, if the oil fired boiler of fish hatchery would be replaced with a wood fired boiler, there would be a significant biomass energy consumer in this area.

Solar Thermal. Despite the common opinion the weather conditions are still favorable to install Solar Water Heating (SWH) systems in the NHT area. Some households show interest to change their actual hot water system, so they were selected as study cases.

Due to the weather in North Harris, evacuated tube collectors are the appropriate technology for SWH system. We found that solar water heating technology is technically feasible in the area but still requires a considerable amount of grants to be economically attractive. This is partially caused by the high cost of solar water heating systems in Scotland, compared to other European countries. It is important to mention that the use of solar energy can achieve considerable CO_2 savings and it is encouraging that the North Harris Trust and some households are seriously interested in contributing to the environmental conservation.

Heat Pump. Heat pumps increase the efficiency of electrical heating and they can provide CO_2 free heating if they are operated with electricity from renewable resources. Therefore heat pumps are popular today in various developed countries. Different types of heat pump technologies are suitable for different places according to specific demands, convenience and availability of heat sources as well as local prices.

The study has found that sea water or ground source heat pumps (bore hole type) could be a suitable solution for North Harris Trust houses, a planned holiday home in Govig and the Marine Harvest hatchery.

Heat pumps are technically feasible in the area, although this study concludes that they are financially only viable with a considerable grant for the initial investment.

RENEWABLE ENERGY OPTIONS FOR SPECIFIC AREAS

Fish Hatchery Plant

The study team investigated the potential of micro-hydro, small-scale wind turbine, a heat pump, a biomass boiler and combinations of these technologies for the energy supply of the hatchery. These energies are locally available and have the potential to reduce the fuel cost by replacing furnace oil.

However, the study found that among these technologies a biomass boiler is technically the most feasible one, as the other alternative could only contribute to the energy consumption of the hatchery with a small percentage. Financially a biomass boiler would be feasible without any grant. Combined with a heat exchanger that recovers a part of the heat energy contained in the waste water of the plant the project could be very profitable with an internal rate of return (IRR) of 25%.

North Harris Trust House

The North Harris Trust intends to completely renovate the residential and workshop building and convert it into a ‘show-case’ of use of renewable energies. To get the best alternative, we analyzed five possible options namely the combinations Biomass and solar water heater, Heat pump and a solar water heater, and the singular use of Biomass, Heat pump and Solar water heater for the house.

From the analysis we got that only Biomass is financially viable with a grant of 50% or above.

However, as a first step to introduce the solar water heating technology in the area we propose a combination of biomass and solar water heating for the NHT house, although this requires a grant of above 50%. The implementation of such a project could also be used to train and inform plumbers in the area. If the biomass supply can not be guaranteed in the near future, we propose the combination of a heat pump and solar water heater as the second best option.

Gobhaig Houses

The generated electricity from a micro-hydro plant in Govig could best be used for heating purposes (both space heating and hot water) for all households and the planned holiday home. A micro hydro power plant can be installed with a capacity of 8 kW and about 6000 kWh/month electricity could be generated from this proposed plant. The total cost of the scheme is expected to be £ 45,565 and the project would be financially viable with an Internal rate if return (IRR) of 6.5 %, considering 30% subsidy from the Scottish Community and Household renewable Initiative (SCHRI).

Bunavoneadar Small Hydropower

This study assessed two alternatives for a small hydro project at Bunavoneadar, Whaling Station. The small-hydro power plant there would be an option to generate income for the North Harris Trust. A small scale hydro scheme with a capacity of 75 kW (1st option) or 153 kW (2nd option) can be developed in Bunavoneadar. The total cost of the scheme is expected to be approximately £ 320,000 (1st Option) and £ 590,000 (2nd option) respectively. Both schemes seem to be financially viable.

Wind Energy at Airde Mor

Three sites of Aide Mor (NGR 102750, 907750); Loch Leosail West (NGR 104970, 908640) and Loch Leosail South (NGR 106200, 907700) were evaluated based on various factors like impacts to birds, proximity to road and 33kV transmission line, distance from the human settlements to the sites and discussion with NHT. Aide Mor with average speed of 8.8m/s was then selected as the reference site for our survey with the technically better site being the Sidhean Mor, approximately 1.85km away from the main road. This distance is necessary to avoid the noise and flickering effect to nearby house and the road. During the survey the wind data available for the site, wind speeds and roses had to be taken from the European Wind atlas due to the absence of long-term data for the site. Thus the energy yield and consequently in the economic calculations are subject to certain acceptable approximations of the results. For the calculations, two (2) Vestas V47 660kW with 50 m hub height have been selected.
Within Aide Mor site, two options have been considered: the first option is that the wind turbine is situated about 1.85 km away from the B887 road and the second option is for the wind turbine to be put on top of the mountains with a distance of about 2.3km from the B887 road. The energy output from the two turbines is 5,008,000 kWh per year with total investment costs of **£**1,614,790.00. The net profit before tax per year is around £159,100 with payback period of 6.7 years. The second option is to place the turbine at the top of the Sidhean Mor hill with a distance from the road to site being 2.3km with the annual energy output for two turbines is 5,263,000 kWh. The total investment at for this option is **£**1,770,940 with profit before tax per year being £161,800 and payback period of 7.1 years. In both options the CO_2 saving is around 2,516 tons/year.
The small differences between the two options in financial evaluations mainly depend on the cost of road construction and grid connection as well as the energy output of the turbines at

the two different sites. Due to the fact that the investment costs were assumed within reasonable limits and that the wind data resource used being only the estimations of the European Wind Atlas then it is recommended that wind measurements are carried out on the site to allow a proper calculation of the energy yield.

Chapter 1: Introduction

1.1 Purpose and Background of the Study

The purpose of the this research project is to identify the potential of using the locally available renewable energy sources such as biomass, heat pump, hydro, solar and wind, to meet the whole or a part of the energy needs for heat and electricity of the North Harris Trust (NHT) area in a sustainable way.

The study was done on the invitation of NHT with the assistance of the Highlands and Islands Community Energy Company (HICEC) during August – September 2005 by students of the department of Sustainable Energy Systems and Management (SESAM) at the University of Flensburg/Germany. The research project is part of the SESAM study concept providing a practical research task to prepare students doing their Masters Degree

The study area is an ideal region for research, as there is a large potential of renewable energy and the NHT is an organization which is keen in implementing renewable energy projects across its Estate. The aim of the NHT is "…..to manage, develop and conserve the assets of North Harris in a sustainable manner for the benefit of the community and the enjoyment for the wider public".[1]

Under the guidance of the representatives of the NHT and in consultation with Highland and Island Energy Company (HICEC) the area from Bunaveanadar to Hushinis was identified for the study (see Figure 1.1).

Figure 1.1: Map showing the study area

[1] http://www.north-harris.org/aimsandobjectives.htm, date 03.09.05

1.2 Study Objectives

The ***General Objective*** of the study is to explore the potential sources of different renewable energy sources and find out the possibilities of using this energy at a local level for electricity and heat generation as well as providing surplus electricity to the grid.

Specific Objectives of the study are:

- To analyze the technical and economical possibilities of the establishment of hydro and wind power plants.
- To analyze the resource availability and possible use for solar water heaters, heat pump and biomass
- To find out the accessibility and acceptance of the various technologies in the local community.
- To check the possibility of grid connections of the generated electricity.
- To investigate the existing heat energy situation
- To study the economic feasibility for heat energy use from renewable sources

1.3 Methodology

The assessment of the present situation of energy use and the opinion of the local people about renewable energy was done using a questionnaire in face to face interviews. The research group of 11 students did their work in five sub-groups according to the technical subject areas biomass, heat pump, hydro, solar and wind. The following methods and tools were used to collect and analyze data and information:

1. Survey Interview

A survey questionnaire (see Appendix 1.1) was designed to get some basic information about the houses in the study area, identify the average energy demand and the types of energy presently used. Furthermore questions were asked about knowledge and preferences of the local people about renewable energy.

2. Literature Review

Technical research papers, books, Internet sources and local maps were reviewed.

3. Personal contact and discussion

Lectures and guided discussions with experts from various organizations and relevant disciplines such as renewable energy policy, woodland management, agriculture etc. were attended and conducted. Still missing information and data were retrieved via

Email and telephone conversation. Excursions to various sites with already established renewable energy projects gave a practical insight into their performance and viability.

4. Data Analysis

1. TsoL (a solar thermal software) and WindPro software were used to analyse data and design technologies for solar water heating systems and wind generators, respectively.
2. Excel software was used to analyze the surveyed data and do financial analysis
3. Economic indicators such as Net Present Value (NPV) and Internal Rate of Return (IRR) were used in a dynamic analysis to assess the feasibility of proposed alternatives.

5. Limitation of the study:

The study had two major limitations:

1. Shortage of time did not allow more detailed survey and research, especially on some time consuming measurements and calculations in the area of hydro power and wind energy.
2. Lack of sufficient data made it necessary to do calculations based on some assumptions e.g.
   a. in calculations about the biomass plantation and energy consumption of the hatchery
   b. in the estimated figures of the river flow due to rainfall data from 2 years only
   c. the European Wind atlas had to be used for the wind energy resource simulation as there were no long-term wind data for the site at Airde Mor

This study is to assist the North Harris Trust in their regional development of generation electricity using renewable energy resources.

1.4 Structure of the Report

Chapter one of the report deals the background of the study and also gives the objective, methodology, limitation and significance of the study.

Information about renewable energy policy as well as over all situation of renewable energy development in the Scotland and the Western Isles are presented in the Chapter two. Chapter three of the report presents the detail analysis and findings of the survey which was collected form the household questionnaires. General information related to the different renewable energy technology has been dealt in the Chapter four. It gives the information about potential of hydro power, wind power, biomass, heat pump and solar thermal in the North Harris area.

Chapter five mainly focuses on the development of the different renewable energy technology in the project specific area. It gives the detail information about technical and financial aspects of the various energy projects in the particular area.

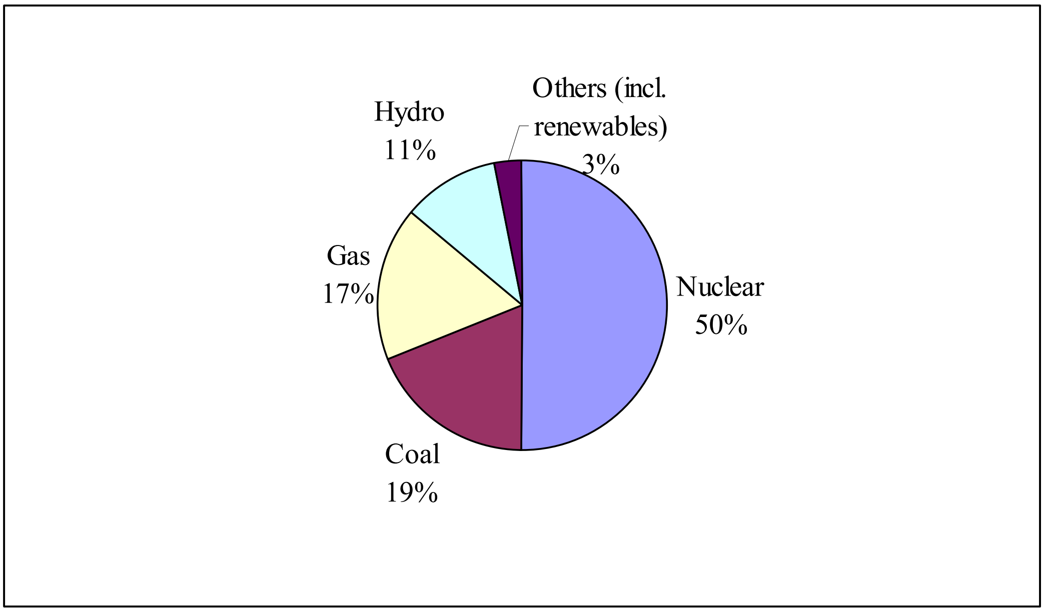
Chapter six gives the concluding remarks and recommendations drawn from the study.

Chapter 2: Energy System in Scotland and the Western Isles

2.1 Status of Renewable Energy in UK and Scotland

The following figure shows that the nuclear is the major source of energy in Scotland. Among the renwable sources of energy hydropower is the major one whereas other renewables were not so much exploited untill 2000.

Figure 2.1: The energy mix of Scotland (1999/2000)



Source: Plotted from data available in http://www.unison-scotland.org.uk/, Printed on 20.04.05

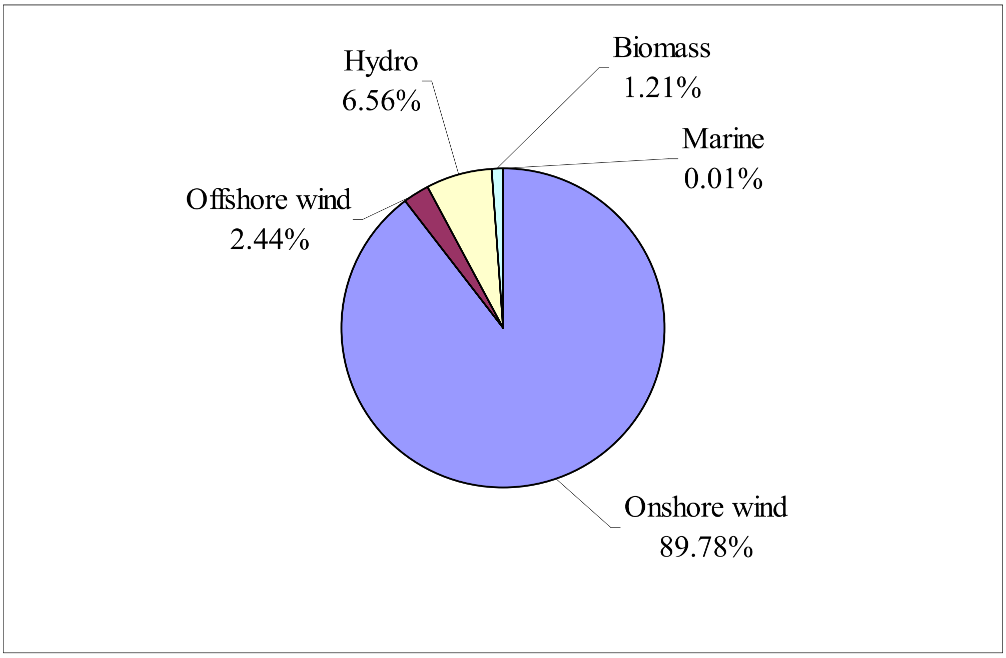
Although the renewable energy sector has high potential in Scotland, only about 8 GW (14%) out of approximately 59 GW has been exploited. Whereas the energy demand of Scotland is about 10.5 GW. There is a huge demand in UK, especially the southern part. Therefore there is a large potential for exporting energy, especially from renewable sources from Scotland.

In Scotland most of the renewable energy proposals are wind turbines and hydro power plants, others technologies are so far negligible. Howerver, there is also potential for biomass and geothermal, solar water heating and photovoltaic, wave and tidal energy and the interest in such applications is increasing.

Among the renewables, the genereation capacity could be splited as shown in Figure 2.2[1].

[1] (http://www.scottish-enterprise.com/sedotcom_home/news-se/key_summaries/press_energy.htm?siblingtoggle=0, Printed on 20.04.05)

Figure 2.2: Generation Capacity (6158 MW) of Renewables Obligation Scotland (ROS) Eligible Schemes Installed or within the Planning System



Source: Scottish Natural Heritage, 2003, p.11 certainly on small hydro

Renewable Energy Obligations (ROS)

Regarding the climate change signed in the Kyoto Protocol, UK Government is committed to reduce CO_2 emissions by 12.5% up to 2010 and 60% by 2050 in comparison with 1990 levels. To contribute to this, the Scottish Executive also has set a target to produce electricity from renewable sources by 18% until 2010 and 40% by 2020. To achieve these targets, a statutory obligation (ROS) has been placed. Based on this all electricity suppliers have to supply at least 10% electricity from renewable sources by 2010. The Scottish Executive has recently extended this obligation to 15% by 2015. (Scottish Natural Heritage, 2003, p.4)

In order to achieve these targets, both UK and Scottish Government have launched *climate change programs* and policies through different institutions and programs like Highlands & Islands Enterprise (HIE) and its Community Energy Units, Western Isles Enterprise (WIE), Scotland Community and Household Renewables Initiative (SCHRI), Community Energy Companies like as North Harris Trust and so on. To promote the renewable technology, the British and Scottish governments have implemented certain financial incentives. Some of the most relevant are:

a. **Grants**:[1]
   - Clear Skies offers grant of up to 50% of project costs not exceeding £100,000. The household grants for all renewables is 30% of the capital cost;
   - In Scotland, the Community and Household Renewables Initiative (SCHRI) has also similar grants for community and household schemes.

b. **Renewable Obligation Certificates (ROC):** Electricity generated from renewable sources can be used to obtain certificates which have a market value in the range 4,5 p/kWh. (BHA, 2005, p.17)

c. **Levy Exemption Certificates (LECs):** The electricity generated from renewable energy sources is levy exempt which is 0.43p/kWh per consumption, (IPA Energy Consulting, 2003, p.15)

Constraints for the development of Renewable Energies (RE)

The major constrains for the development of RE is lack of sufficient capacity of transmission lines in Scotland. Besides that there are a number of environmental issues **to be considered** along with the development of RE schemes, such as international natural heritage designations, Special Protection Areas and Special Areas of Conversations, National Scenic Areas, Sites of Special Scientific Interest, cultural heritage sites etc. There are also interests and obligations in relation with the local community. As the development of renewable energy projects is likely to have significant effects on the environment, careful planning and an Environmental Impact Assessment is necessary according to the Regulations of the Scottish Executives. (Adapted from: Scottish Executives, 2000, National Planning Policy Guideline-NPPG 6, "Renewable Energy Developments")

2.2 Renewable Energy in Western Isles

The Western Isles possess huge potential for producing energy from wind, and hydropower. There are also opportunities for energy from biomass, geothermal and solar. In the longer term, wave power and offshore wind may provide further sources of renewable energy. Upon this background the Western Isles have the ambition to become a global player in renewable energy generation and manufacturing.

Renewable energies are already used on the Western Isles including the commercially run hydroelectric power station at Chilostair, with two 0.6 MW sets and Gisla with a 0.75 MW set. Some non-commercial renewable energy applications are also–introduced, such as the excellent community-based SIR E SCOTT School project, which uses a solar water heating

[1] BHA, 2005, P.18

system to meet part of the heating demand of the swimming pool and a solar PV system to generate electricity. Other show cases are the community-based Gearrannan project, which uses a ground source heat pump to meet 100% of heating demand of seven Blackhouses; and the wind generator at the community center at Lac a Lea.

There are several plans of developing renewable energies on the Western Isles, such as large-scale wind farms on Lewis, (234 turbines with totally 712MW), another large-scale wind farm at Beinn Mahor(133 turbines with totally 399 MW).

However, the limited capacity of the transmission and grid system especially of the sub-sea cable to the mainland is the main constraint towards the development of future wind farms, hydropower plants and wave generators. Scottish and Southern Energy (SSE) has started the planning process to upgrade its transmission system and the cable connection to the mainland, but the expected completion data is not before 2010. Besides the technological aspect, the public discussions about wind farm between the individuals, local communities and the developer are still going on. The focus issues are noise, visual impact, construction traffic, interference with telecommunications (including TV reception) and driver distraction.

In general environmental issues play a major role in the planning process of renewable energy systems, namely their impacts on fishery, protected animals, natural scenery and heritages.

Small scale renewable energy projects could provide a limited but valuable contribution to energy requirements and CO_2 emission reduction both locally and nationally .Technologies such as heat pumps, community wind turbines, biomass, solar thermal and solar PV technology could contribute a considerable part of the electricity and heating demand of local communities.

The Scottish Community and Household Renewables Initiative (SCHRI) and the Western Isles Council give strong financial and political supports for renewable energy developments in the Western Isles. The concept of a ‘Western Isles Energy Innovation Zone’ promotes the islands as a test field. Communities can apply for funding for technical assistance, capital grants and start-up grants for renewable energy projects from SCHRI, the grants cover 50% of project investment up to £100,000.The Western Isles Enterprise also provides the grants as 40% of the capital cost of the total grants from two organization would be up to 80% of investment cost for community renewable energy projects. For household projects, the grants cover 30% of the investment up to £4,000. For the big scale renewable energy projects communities can apply to the Highlands and Islands Community Energy Company.

Chapter 3: Findings of the Survey

3.1 Introduction to the Survey

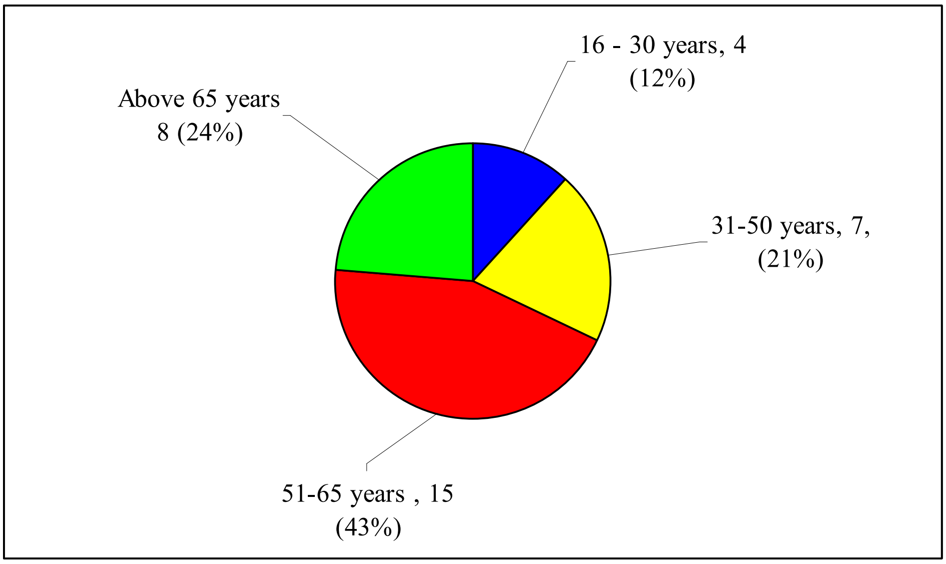
The survey was carried out by administering a questionnaire to 50 households as discussed, agreed with and identified North Harris Trust (NHT). However, 4 from these households rejected to answer the questionnaire and 12 were holiday homes, where either the tenants could not answer the questions or the owner could not be traced. NHT managed to get a filled in questionnaire from 2 holiday homes which were treated in the analysis separately from the continuously occupied houses. Additionally, some information pertaining to electricity consumption and space heating related to 8 households were availed by NHT to complement various evaluations. The following analysis and findings are based solely on 33 households plus Cliasmol school, from which the team got full responses.

3.2 General Profile of the Respondents

3.2.1 Demographic Profile of Respondents

From the 34 respondents of the survey 20 (59%) were male and 14 (41%) female. 23 (70%) of them were above 51 years of age and only 11 (30%) belong to the age group of 16-50. The detailed numbers per age group are shown in Figure 3.1

Figure 3.1: Respondents' Age Distribution

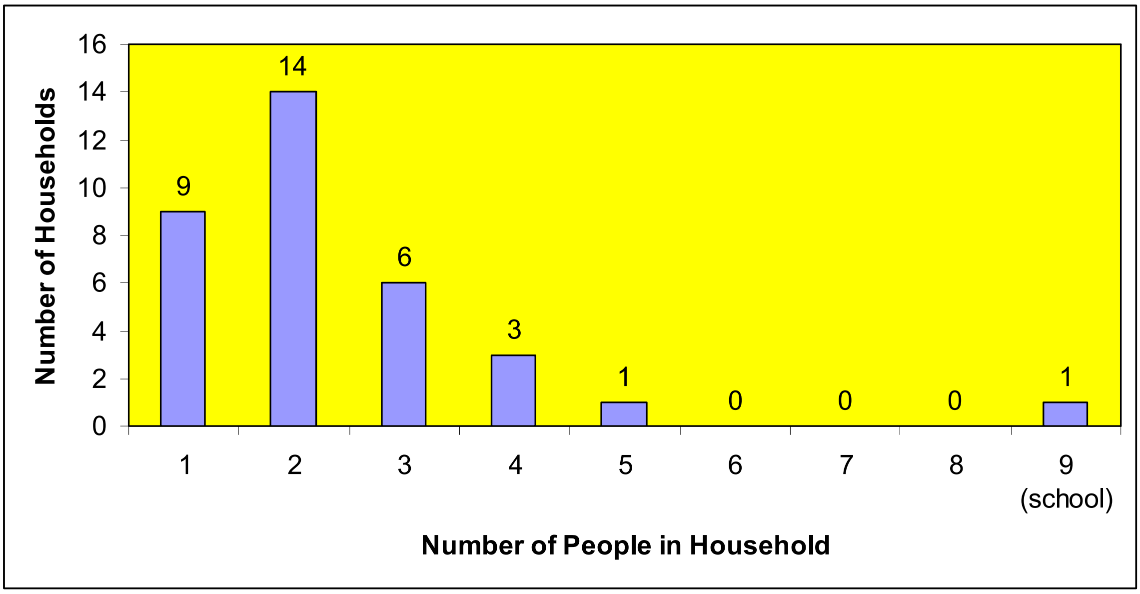


Source: Energy Demand Survey by SESAM, 2005

3.2.2 Profiles of the Households

Figure 3.2 shows that most of the households are occupied by 1-3 persons with an average of 2.2 people per household.

Figure 3.2: Number of People per Household



Source: Energy Demand Survey by SESAM, 2005

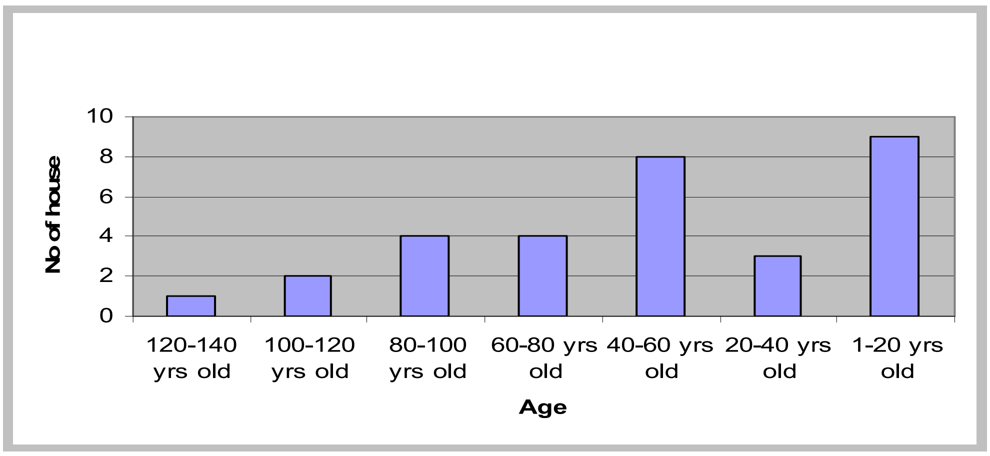
20 (59%) respondents indicated they are the heads of the particular family, while 14 (41%) were members of the respective households. 24 (71%) of the houses in the study area belong to the families living in them, while 10 (29 %) of the respondents are not the owner of the house.

3.3 Information about the Houses

3.3.1 Age of houses

Among the 34 houses (including school), 3 houses have no available information about the age of houses. The oldest one was built in 1865 and the newest one in 2004. Most of them (20) are post war houses, but there is still a good number of 11 houses which are older than 60 years as shown in detail in Figure 3.3

Figure 3.3: Number and age of houses

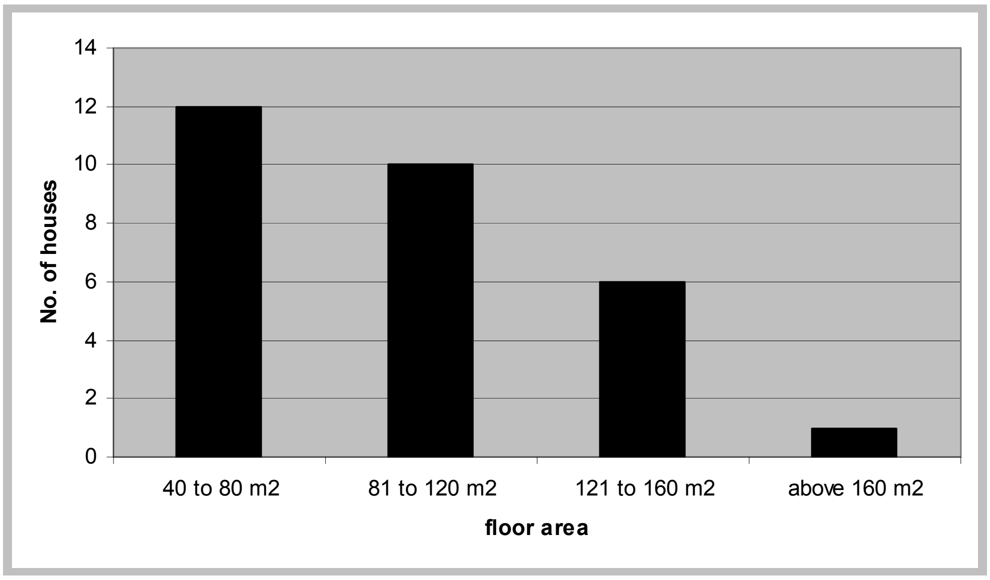


Source: Energy Demand Survey by SESAM, 2005

3.3.2 Floor Area

Information about the floor area was received from 29 out of 34 houses only. Their floor area varies from 40 to 272 m^2, with an average of 100 m^2 as shown in figure 3.4.

Figure 3.4 Number of houses and range of floor space



Source: Energy Demand Survey by SESAM, 2005

3.3.3 Window system

25 houses (74%) have double glazed windows and the rest 9 (26%) use single glazed window. The houses which are built or renovated last 10 year, 14 have double glazed windows and one has single glass window. So the trend of savings heat loose by using double glazed window is appreciable. 4 respondents don't know the changing time of the windows, and 3 households gave no answer. So, we recommend to change all the houses which have still single glazed windows with double glazed ones.

3.3.4 Roof insulation

Among the surveyed households, 23 houses (68%) have roof insulation, and 10 houses (30%) have none. In 1 (3%) household nothing is known about roof insulation. The roof insulation thickness varies from 25 mm to 120 mm. The houses with no insulated roof, can insulate their loft 200 mm which is recommended also by Communities Scotland (Fuel poverty in Scotland, 2002)[1] for better heat savings.

3.3.5 Wall Insulation

21 (62%) houses have wall insulation and 12 (35%) have none. From one house it is not known whether the walls are insulated. Mainly old houses, whose walls are made by stone,

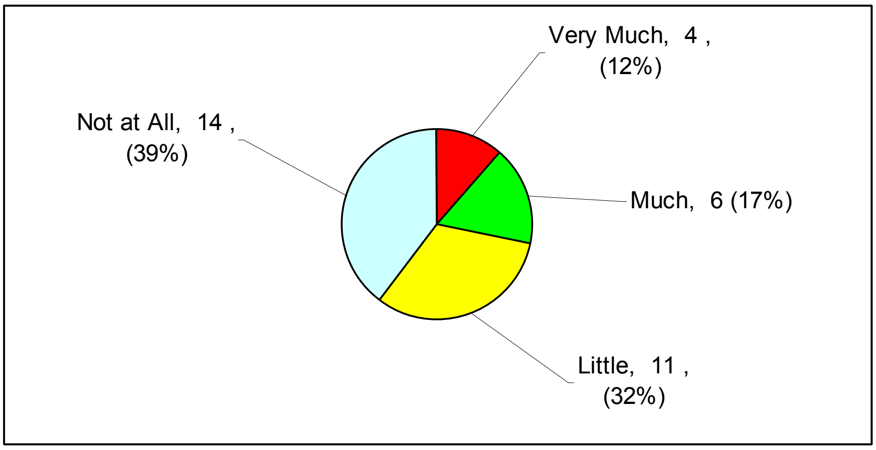
[1] http://www.communitiesscotland.gov.uk/stellent/groups/public/documents/webpages/cs_008713.pdf page; 60

have no wall insulation. As proper wall insulation reduce heat losses and such safe energy, it is recommended to insulate all houses according to the Communities Scotland by 50 mm cavity wall insulation (Fuel poverty in Scotland, 2002).

3.4 General Knowledge on Renewable Energy Sources (RES)

Respondents were asked to rank their awareness on various sources of renewable energies such as biomass and hydropower, wind, tidal, wave or geothermal energy (heat pump), solar thermal and solar photovoltaic. Surprisingly 24 (71%) of the 34 households asked, are not at all aware or have only very little knowledge about sources of renewable energies. Only 10 (29%) of the respondents are very much or much knowledgeable as shown in Figure 3.5.

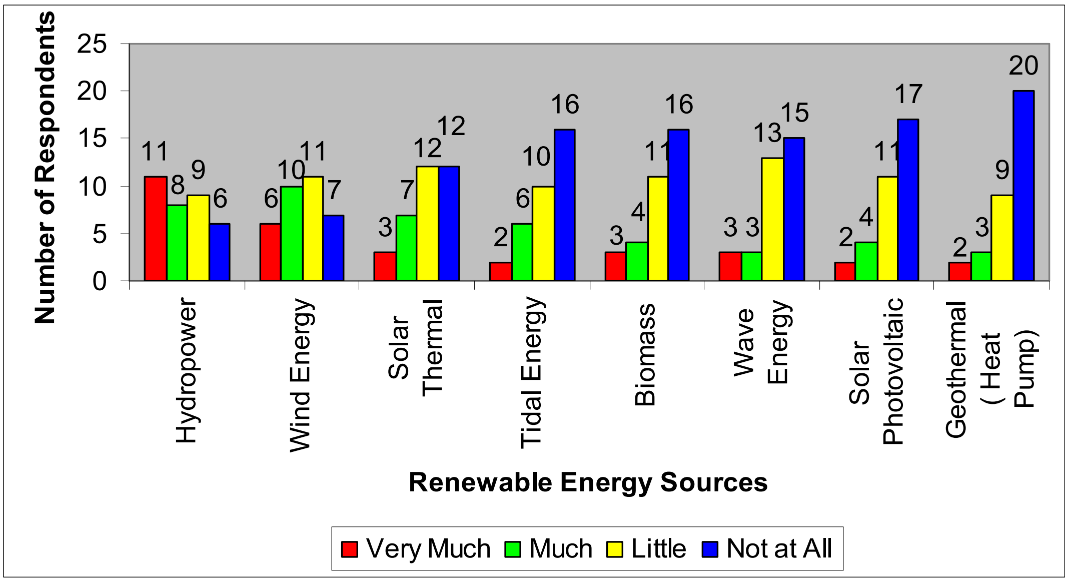
Figure 3.5 Results for Knowledge on Renewable Energies



Source: Energy Demand Survey by SESAM

It was established that from the various RES the respondents are most familiar with hydropower followed by wind energy, solar thermal and tidal energy. Whereas there is only little knowledge about biomass, wave energy, tidal energy, solar photovoltaic and geothermal energy (heat pump) as shown in detail in Figure 3.6

Figure 3.6: Knowledge of Respondents on RES



Source: Energy Demand Survey by SESAM, 2005

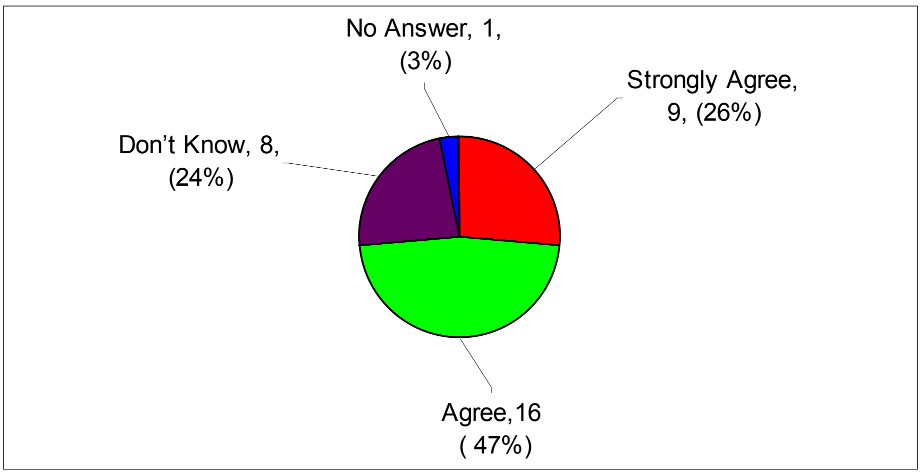
3.5 General Attitude and Views on Renewable Energy Sources

Respondents were asked to rank their attitudes and views about Renewable Energies towards a total of nine statements.

3.5.1 *"Renewable Energy is a solution to problems related to climatic changes"*

It is an encouraging finding that nobody of the sample population disagrees obviously with the statement that "Renewable Energy is a solution to problems related to climatic changes". In fact, nearly ¾ of those questioned support this opinion more or less. However, there are still more than ¼ of undecided persons, who do not know whether they should be for or against the statement or who do not have an answer at all.

Figure 3.7: Renewable Energy is a solution to problems related to climatic changes

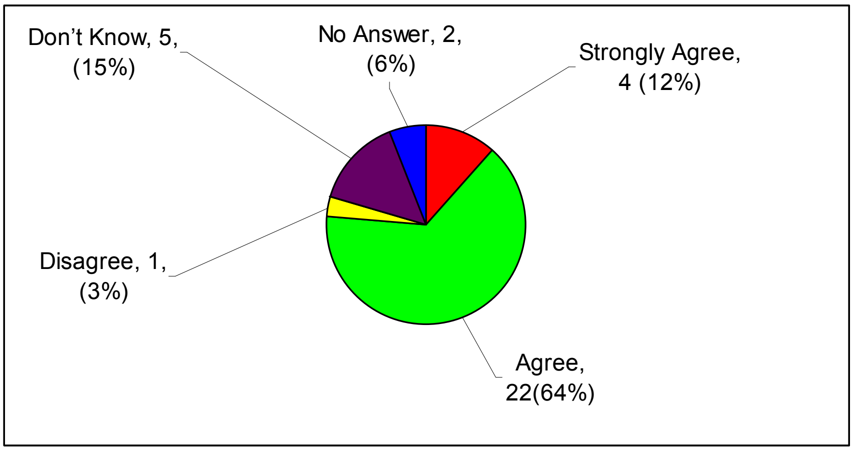


Source: Energy Demand Survey by SESAM, 2005

3.5.2 *"Renewable energy can contribute to sustainable development"*

The same high percentage of people as in 3.5.1, are of the opinion that renewable energy can more or less contribute to sustainable development. It is obvious however, that far less support such a statement strongly as compared to the potential of RE being a solution towards climatic change. Whereas there is only one person who disagrees with this statement, there is about 1/5 which "don't know" or have "no answer" on it.

Figure 3.8: Renewable energy can contribute to sustainable development

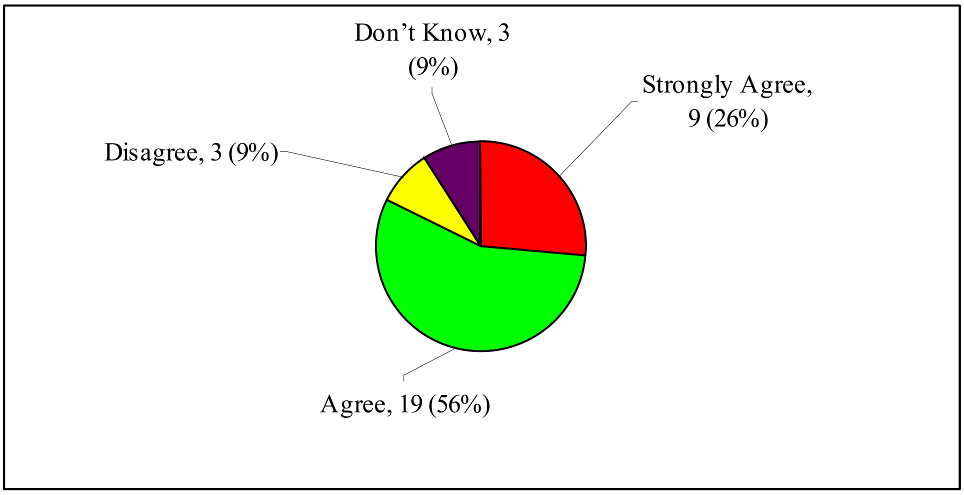


Source: Energy Demand Survey by SESAM, 2005

3.5.3 *"Generally speaking, I fully support development of RE projects on the islands"*

Figure 3.9 shows that 28 (82%) of the participants of the study support the development of renewable energy projects on the islands. Only 3 (9%) do not support this, and another 3 (9%) is undecided about an answer on this question.

Figure 3.9: Generally speaking, I fully support development of RE projects on the islands

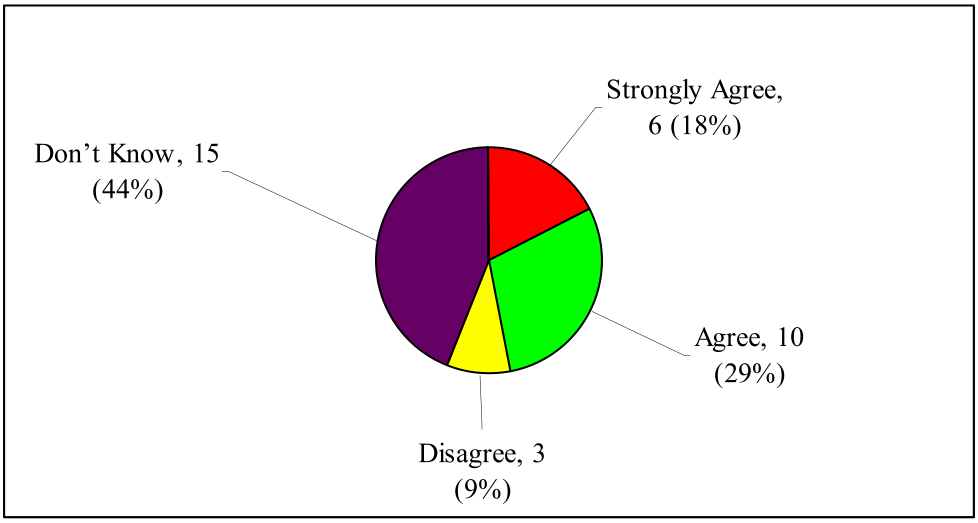


Source: Energy Demand Survey by SESAM, 2005

3.5.4 *"Solar Thermal energy can contribute considerably to water and space heating requirements for the island"*

Figure 3.10 shows that although 16 persons (47%) agree with the statement above 15 (44%) are uncertain (don't know) and 3 (9%) disagree with the statement. This shows in fact that the majority of the sample population is not convinced that solar thermal energy can contribute to water and space heating in this are.

Figure 3.10: Solar Thermal can contribute considerably to water and space heating requirements of the island

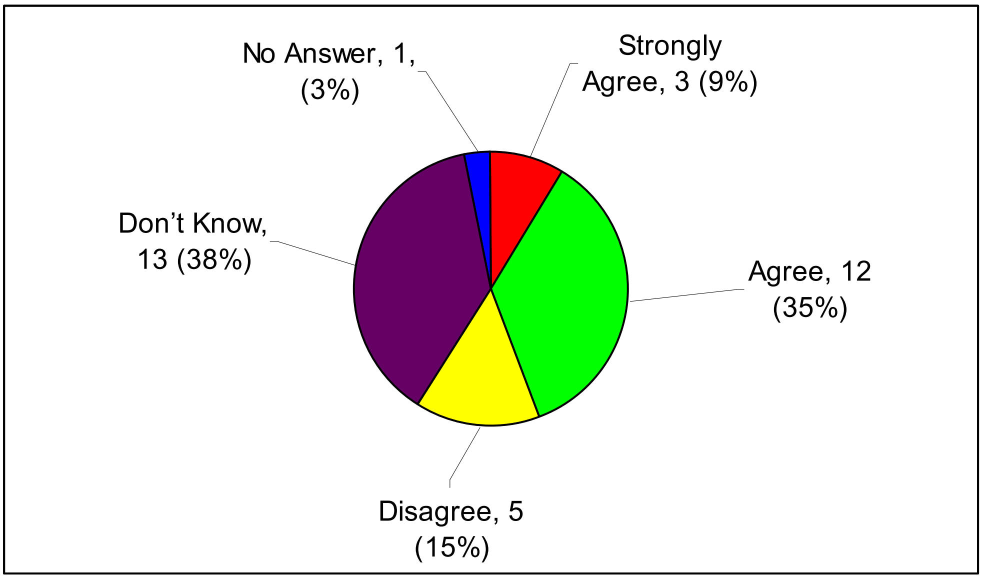


Source: Energy Demand Survey by SESAM, 2005

3.5.5 *"Biomass Energy can contribute considerably to water and space heating requirements for the island"*

As shown in Figure 3.11 15 respondents (44%) are of the opinion that Biomass Energy can contribute considerably to water and space heating. However, 13 persons (38%) don't know, 5 (15%) disagree with the statement and 1 (3%) has no answer. From these figures it is evident that although quite a number of people are aware of the role of biomass, the majority of the respondents do not consider biomass as a potential energy source for water and space heating in the area.

Figure 3.11: Biomass Energy can contribute considerably to water and space heating requirements for the island

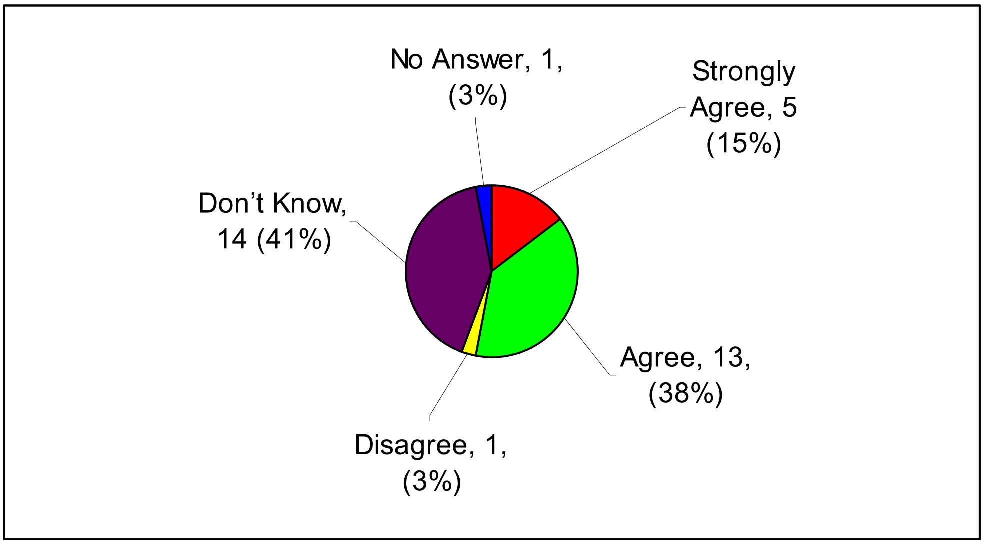


Source: Energy Demand Survey by SESAM, 2005

3.5.6 *"Heat Pumps using sea water as a source of energy can contribute considerably to water heating requirements for the island"*

From Figure 3.12 it is evident that the majority of the respondents (18 or 53%) are of the opinion that Heat Pumps can contribute considerably to water heating requirements for the island. However, 16 (47%) are not sure, disagree or have no answer about the above statement

Figure 3.12: Heat Pumps using sea water as a source of energy can contribute considerably to water heating requirements for the island

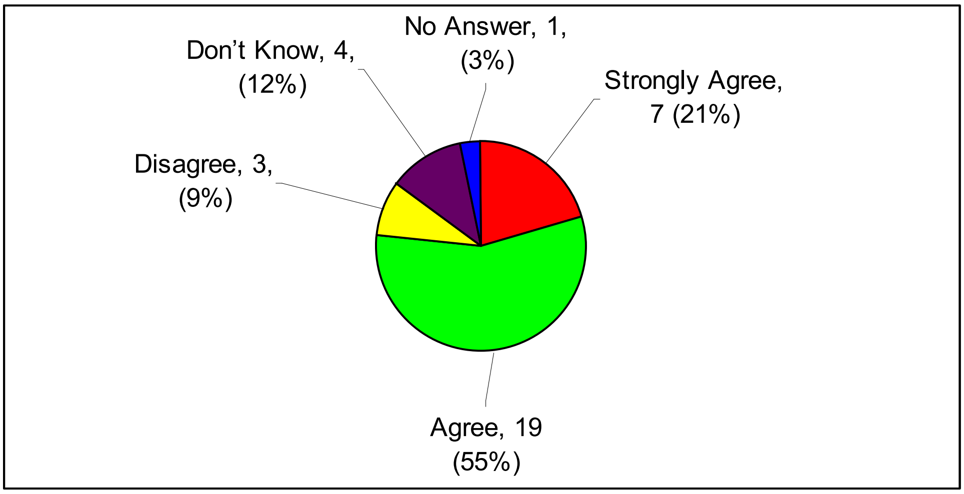


Source: Energy Demand Survey by SESAM, 2005

3.5.7 *"Hydropower should be more exploited to export electricity to the mainland"*

It is quite obvious from fig.3.13 that most of the respondents (26 or 76%) prefer Hydropower to be more exploited for electricity generation. Only 3(9%) disagree with this option and 5 (15%) have no opinion or answer on this statement.

Figure 3.13: Hydropower should be more exploited to export electricity to the mainland

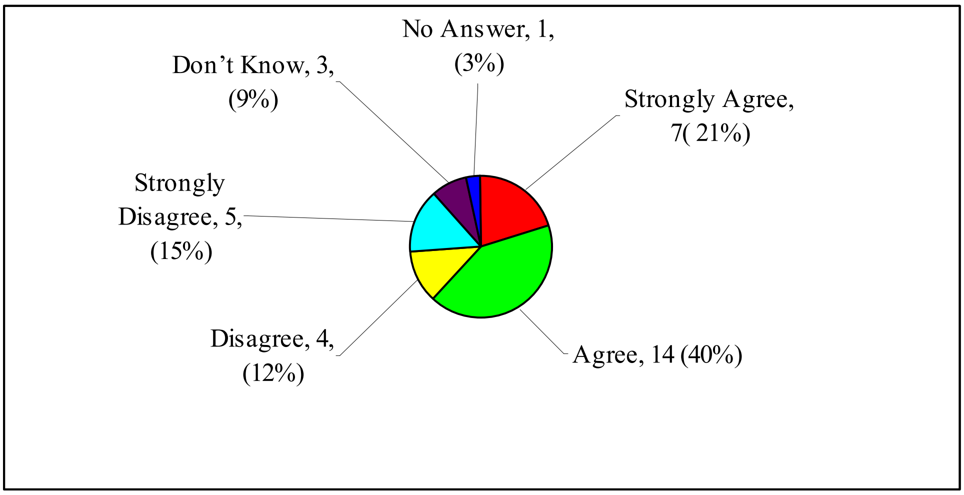


Source: Energy Demand Survey by SESAM, 2005

3.5.8 *"Wind Energy should be more exploited to export electricity to the mainland"*

Despite the controversial discussion about wind energy on the island 20 (61%) of the sample population are of the opinion that wind energy should be more exploited to export electricity to the mainland. Only 9 (27%) are against this option and 4 (12%) are not decided or have no answer as shown in Figure 3.14.

Figure 3.14: Wind Energy should be more exploited to export electricity to the mainland

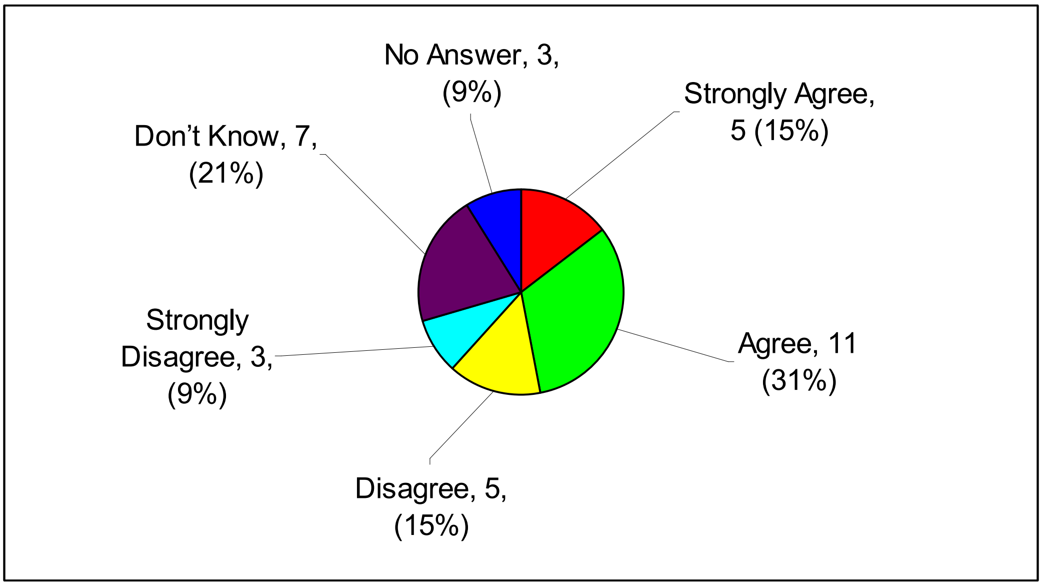


Source: Energy Demand Survey by SESAM, 2005

3.5.9 *"I am willing to pay extra for energy generated from RES in order to serve the environment"*

It is an encouraging finding that nearly half of the respondents (16 or 46 %) are willing to pay extra for energy generated from RES. Only 8 (24%) reject such an option. while 10 (30%) don't know about or have no answer on this statement as shown in Figure 3.15.

Figure 3.15: Willingness to pay for extra energy generated using RES



Source: Energy Demand Survey by SESAM, 2005

3.5.10 *Summary*

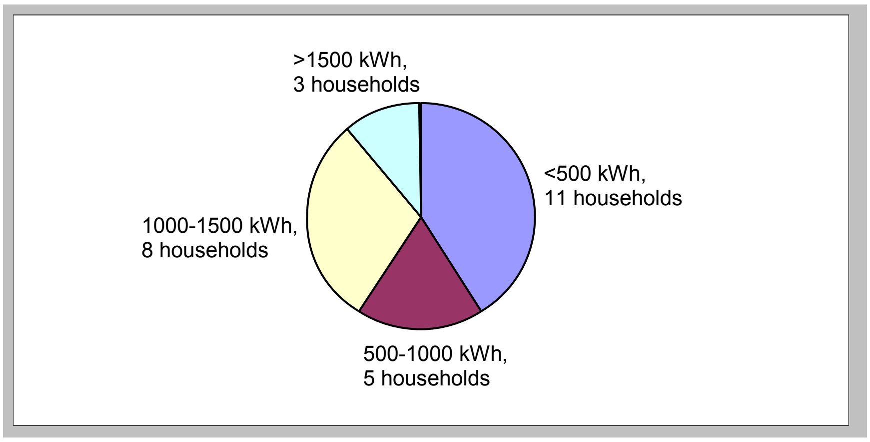
It can be summarized that on the average ¾ of the respondents are convinced that the generation of energy from renewable sources has positive climatic and environmental impacts. More than 80% support investment to be made in RE projects. Especially hydropower and wind energy is much favored to be exploited, and the energy be exported to the mainland. Heat pumps – although not as much as the before mentioned sources - are also seen as an option, whereas the potential use of solar thermal energy and biomass is more in doubt with the majority of the sample population. The high number of people who are undecided about solar energy, heat pumps and biomass is an indicator for the lack of knowledge and awareness in the area about these technologies.

3.6 Electricity Consumption for the Study Area

Electricity is commonly utilized for lighting and appliances in 33 residential homes and one school building of the study area. 18 Households use electricity for space heating and hot water. The rest uses either a combination of electricity and other fuel such as oil, coal, and peat (6 households), or they use only other fuel (8 households).

Electricity bill information is available from the school and 27 households. Based on the information gathered, the monthly electricity consumption falls between the ranges of 93 – 1761 kWh per household.

Figure 3.16: Distribution of households based on monthly electricity consumption in kWh



Source: Energy Demand Survey by SESAM, 2005

From the houses using electricity to provide space heating and hot water, the average electricity consumption is 1157 kWh/month. The typical consumption is quite high compared to households which are not using electricity for both purposes, as the average consumption there is 375 kWh/month.

Looking into the correlation between the electricity consumption and the number of persons living in these houses and their floor area, results show an average electricity consumption of 474 kWh per month per person. The average electricity consumption per m^2 of building is 10 kWh per month. The average electricity consumption for the buildings which are using electricity for space heating is 13 kWh per m^2 per month, while those which are not using electricity for space heating have an average electricity consumption of 6 kWh per m^2 per month.

Furthermore the survey revealed that the school has an average electricity consumption of 815 kWh per month. Total electricity consumption of the study area based on available bill information is 21,860 kWh per month, out of which an estimated 11,740 kWh are used for heating.

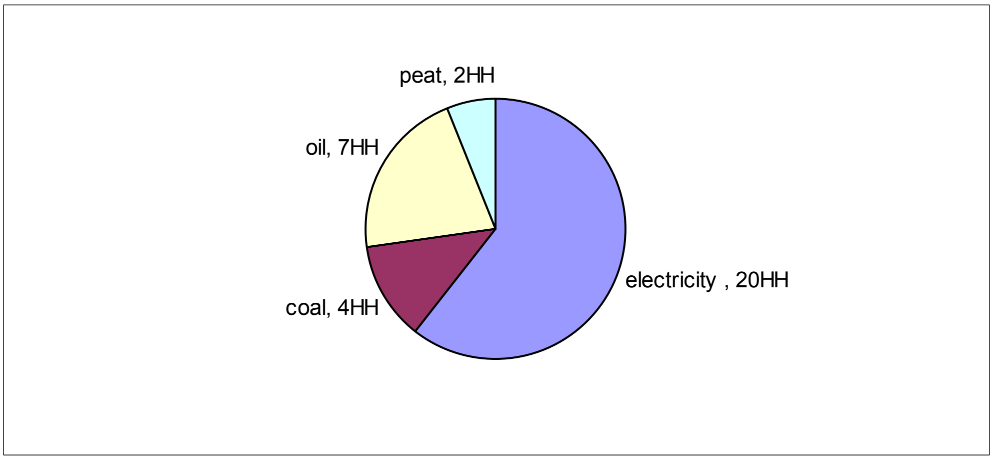
Apart from the surveyed households and school, there are some residential houses, holiday houses and Amhuinsuidhe castle which also use electricity, but no information is available about their monthly consumption.

3.7 Hot Water and Space Heating

3.7.1 Type of Energy used for Hot Water and Space Heating

The following figure presents the type of energy that the households use as main source for space heating. The survey shows that 20 of the 33 households (61%) use electricity, while 7 (21%) use oil, making these two energy sources the most important ones. Coal and peat are used for the most traditional and old houses.

Figure 3.17: Type of Energy used for Space Heating

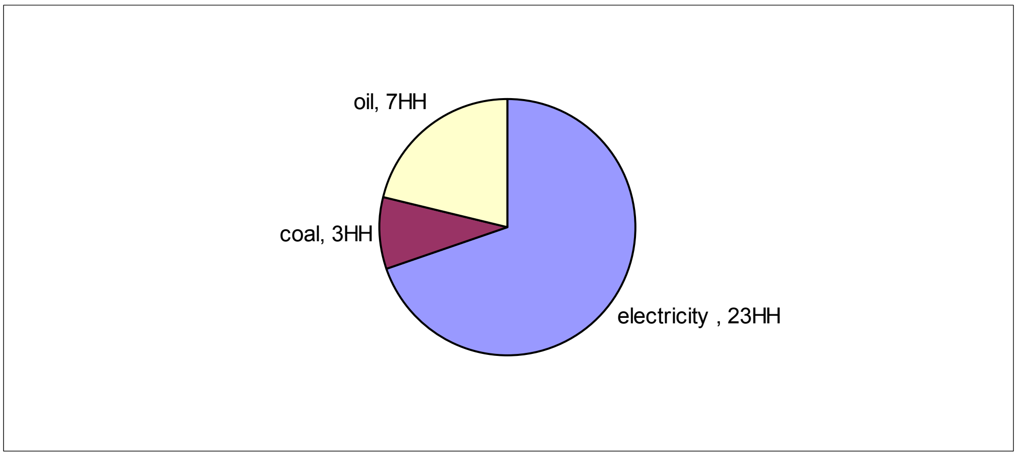


Source: Energy Demand Survey by SESAM, 2005.

In the case of water heating, 23 households from the total interviewed use electricity for this purpose, which represents 70%; as Figure 3.18 shows; 7 households (21%) use oil and only 3 households (9%) use coal.

In most households the system for space and water heating is different, 17 of the 33 households (52%) have separate systems for each purpose; and 16 households (48%) have the same system for both purposes. From these 16 households, 14 have a central heating system for the whole household and only 2 have single-room heater systems. 7 of the households which have the same system for space and water heating, have installed them in the last 10 years, 6 between 1995 and 1985, and 3 more than 20 years ago.

Figure 3.18: Type of Energy used for Water Heating

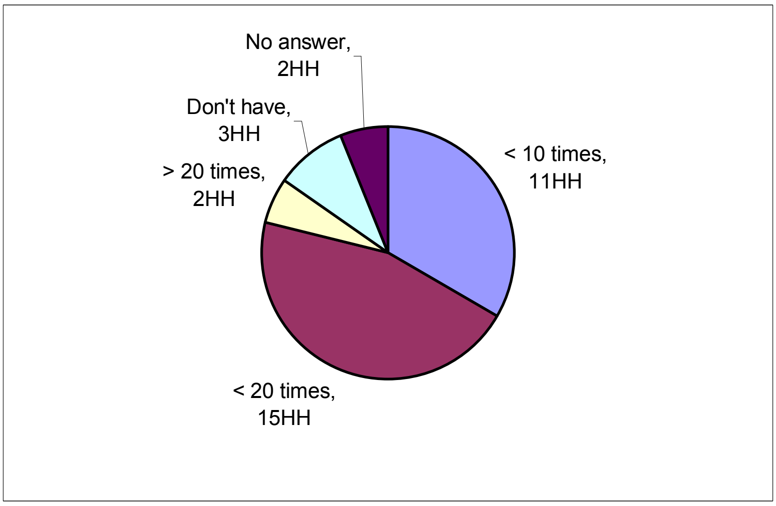


Source: Energy Demand Survey by SESAM, 2005.

<u>Hot Water Consumption</u>

The survey shows that 46% of the interviewed households use the shower between 10 and 20 times per week; while 33% uses it less than 10 times per week, and 6% more than 20 times (Figure 3.19). This consumption depends on the number of family members, and particularly on the number of children. From the 33 interviewed households, only 27% uses to have baths frequently apart from the shower.

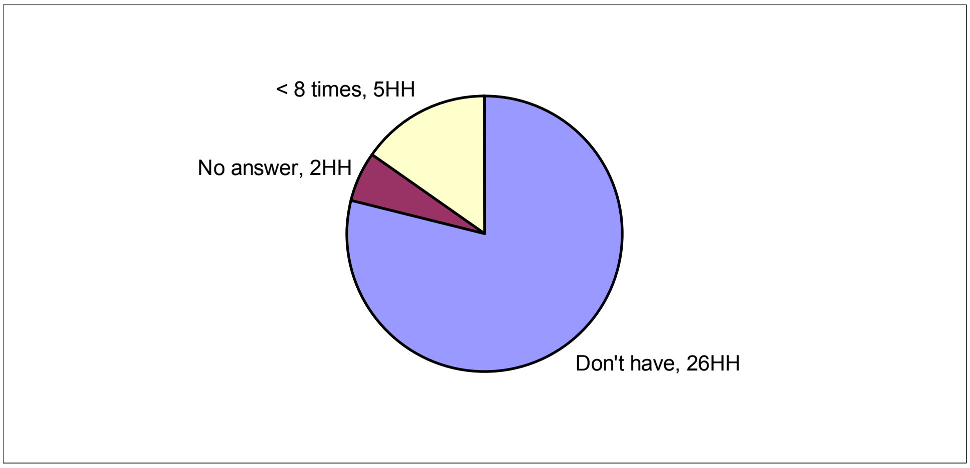
Figure 3.19: Use of Shower per Week per Household



Source: Energy Demand Survey by SESAM, 2005.

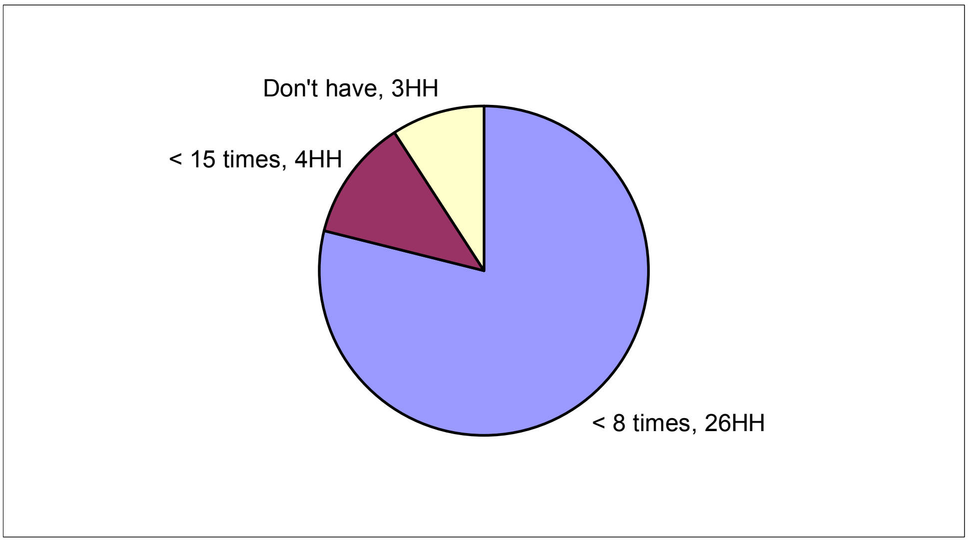
The following figures (3.20 and 3.21) present how often the interviewed households use the dish washer and the washing machine, respectively. For the first one, 26 of the houses don't have dish wash machine; while 5 households (15%) use their dish wash machine less than 8 times per week. For the second machine, 4 of the houses (12%) use it between 8 and 15 times per week, while 26 (79%) use the wash machine less than 8 times per week.

Figure 3.20: Use of Dish Wash Machine per Week per Household



Source: Energy Demand Survey by SESAM, 2005

Figure 3.21: Use of Wash Machine per Week per Household



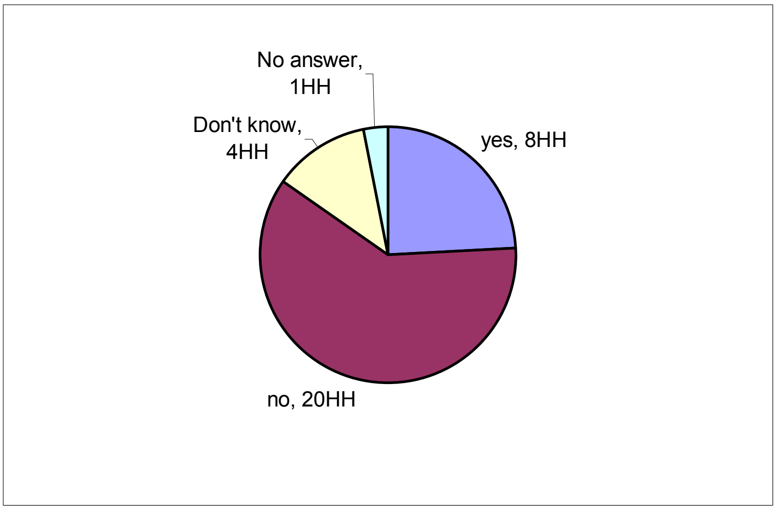
Source: Energy Demand Survey by SESAM, 2005

From the results, the requirement of hot water for any of the 33 interviewed households can be considered as the average standard for domestic houses, which is between 30 and 40 l/person*day. This consumption includes the use of the wash machine and also eventual baths.

3.7.2 Interest in Use of Solar Energy for Space and Water Heating

From the total 33 houses, 8 are interested in using solar energy for space heating (Figure 3.22). The principal reasons revealed by the survey are the environment for 2 households and 4 households only would use solar energy if it is cheaper than the one they use actually, mostly electricity and oil.

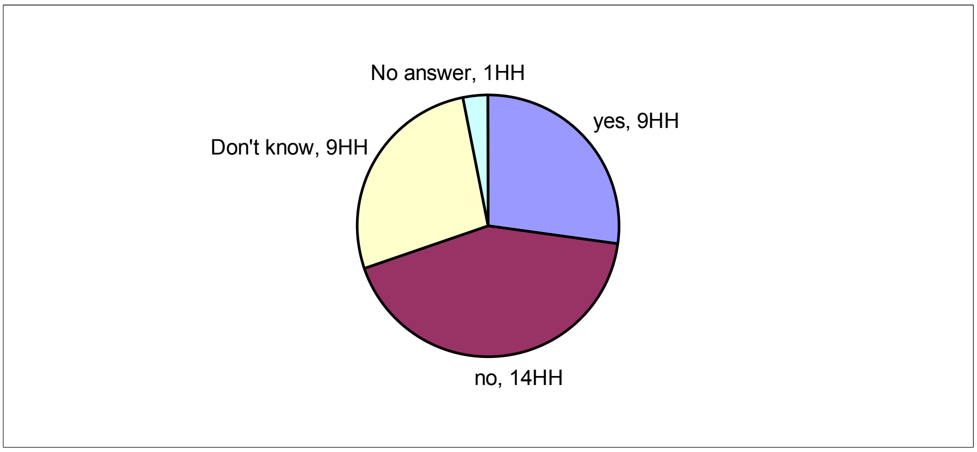
Figure 3.22: Interest in Using Solar Energy for Space Heating



Source: Energy Demand Survey by SESAM, 2005.

The survey shows that 9 households of 33 are interested in using solar energy for water heating. The reasons given are also the environment (3 households), and if this energy could be cheaper than the actual one 6 households would be interested.

Figure 3.23: Interest in Using Solar Energy for Water Heating



Source: Energy Demand Survey by SESAM, 2005

The interest in using solar energy depends mainly on its cost; therefore some cases will be selected to compare this cost with the costs of oil and electricity, which are the two main sources of energy for space and water heating in the interviewed households.

Chapter 4: Renewable Energy Potential for North Harris Estate

4.1 Introduction

In this chapter, various renewable energy development options in North Harris Estate are addressed. Five possible renewable energy options have been studied by our team i.e. small-scale wind power, micro/small-hydro, solar thermal, biomass, and heat pump. General description of the study results have been presented in the following sections.

4.2 Electricity Generation: Wind Energy

North Harris Estate is endowed with abundant wind resources. The NASA surface metrology shows an average annual wind speed of 9m/s at a height of 50m for our research site at Airde Mor. This speed is higher than the recommended economically feasible speed of 6m/s for wind turbine investment.[1]

The Highlands and Islands Enterprise Network has invested £ 11million in infrastructure at Arnish Point at Stornoway.[2] This has resulted in refurbishment of the 12,000m^2 fabrication workshop, upgrading of services and access road.[2] The Arnish Point is envisaged to be the hub for manufacturing parts of wind turbine for Lewis, North Harris and other parts of the Western Isles. Most roads are also being upgraded to dual status which would make it easier to transport wind turbine parts to the proposed sites. The Western Isles is being envisaged as an energy innovation zone and feasibility work for upgrade of sub sea cable links to the mainland is being considered.[3] This upgrade would enable private, community or commercial owners of wind turbines to feed their generated power into the national grid. There is also a grant from the Highland and Islands Community Energy Company (HICEC) for community owned small to medium scale wind farms.[2]

4.3 Electricity Generation: Small-Hydro Power

4.3.1 <u>Hydro Potentials in North Harris</u>

The topography of North Harris area has quite some potential for the use of hydro power. The hilly terrain provides high head while high rainfall rates provide significant water flow. In addition, impermeable soil and the absence of much vegetation lead the precipitated water to

[1] Source: http://eosweb.larc.nasa.gov/cgi-bin/sse/retscreen.cgi?email=rets%40nrc
[2] Source: Hebridean Renewable Energy Partnership, News 2005
[3] Source: Energy innovation zone, p4

flow directly to the stream. However, this situation is also unfavorable as it causes unsteady flow of stream, i.e. high water flow after the rain fall and low water flow in dry days.

A previous study by West Coast Energy Ltd. indicates some potential catchments in the Estate. The best option was found in Bunavoneadar with a potential generation capacity of 309 kW. The study was done by defining the catchment area with digital terrain model and calculating the flow based on statistical model (WCE, 2004, p.18).[1]

Presently, Scottish and Southern Energy (SSE) is running one hydropower plant located in Chliostair with a generation capacity of 1.2 MW. Apart from this plant, there was another small-hydro scheme located in Bunavoneadar. The power house was situated near the Whaling Station but it was washed away by a big storm. The dam and pipeline can be still seen there however all components have completed their life span. There was one small-hydro scheme built in Govig by a resident to supply the households nearby. However, the construction of the scheme was not completed and the remains of the pipeline are still there.

The study was carried out to re-evaluate both schemes (Bunavoneadar and Govig) and to analyze another site in Lochan Beag (nearby the fish hatchery). In the next section, the general description of the study is presented.

4.3.2 Result of Study on Possible Small-Hydro Power Schemes

The aim of the study is to evaluate several possibilities of small-hydro power potential sites in North Harris. The preliminary study focused on identifying potential sites, by collecting information from North Harris Trust (NHT), analyzing the topography of the area from a map and visiting likely sites to check their potential. In addition, an assessment of energy demand from the households or industry nearby was done. The consideration study resulted on three options of a potential hydro power development site i.e. the Fish Hatchery, Gobvig, and Bunavoneadar, described in Chapter 5.

The Bunavoneadar site is considered for a feasibility study as it has significant potential i.e. a combination of high head and continuously substantial flow of water. The proposed use of electricity generated from this site is to supply the grid.

The Govig site is located near a cluster of six households and one holiday house is planned to be built there. Therefore, development of a micro-hydro power plant there is aimed to supply a part of the energy demand of those households.

[1] a model which is used to define the catchment area based on the digital topography map

A study on a possible micro-hydro scheme has also been carried out for the Fish Hatchery site, to provide heating energy for the demand of the hatchery.

The following environmental issues have been considered for the proposed schemes:

1. For fishery conservation purpose, sufficient flow has been considered for continuous flow in the river in the driest months.
2. None of the proposed hydro schemes is situated in the special protection area (SPA) of the Scottish Natural Heritage

The study was carried out on the basis of the following assumptions:

1. The flow of the river has been analyzed based on the rainfall data of North Harris area, which are available for the last two years.
2. The overall efficiency of the schemes is considered to be 60% in calculation of maximum electrical power output.
3. Unit cost of different components of small/micro-hydro scheme has been derived from the RETScreen – a standardized renewable energy project analysis software of Canada, from British Hydro Power Association and also from a previous feasibility study report by Renewable Heat & Power Ltd for Clear Skies program in the Wye Valley region[1].
4. Interest rate of loan is fixed at 6.4% per year and project life is set at 20 years.
5. Subsidy for the proposed hydro scheme is taken as 50% of the capital investment for the community projects and 30% of the capital investment for the household's projects.

4.4 Potential of Biomass Energy

4.4.1. Present situation of study area

The parent material of the North Harris soil is "Drifts derived from Lewisian gneisses". The soil is composed of different materials such as peaty podzols, peaty gleys, peaty rankers, peat subalpine podzols, alpine soils etc. At a small area at Hushinis point there are shelly sands and a component of brown calcareous soils[2].

The soil contains less phosphorus in this area with an acidic ranging form 5.0 to 5.7 pH. The peat soil contains lot of moisture causing the water logging. The soil can be developed applying lime. About 6 tons of lime is needed per hectare land to improve the pH from 5.3 to

[1] http://www.clear-skies.org/communities/FeasibilityStudies.aspx printed on 5 Sept 2005
[2] Soil Survey of Scotland 1982: Sheet 2, The Outer Hebrides Soil

6.0. Lime has to be added every 5 years, however, as it is not available in this island it has to be imported from main land. Due to the shipment cost lime is quite costly at about 50 GBP per ton.

The hard wood plant can grow in this soil condition, but there is a need to identify the proper species. Also short rotation energy crops can be grown in this area. Willow, poplar and some hybrid species of willow crossed with local species may give the best results. The landscape is hilly, therefore it is not easy to transplant and harvest the trees. The harvesting machinery suitable in this condition is costly and also the work is labor intensive[1].

At present there are no biomass sources in the study area that can be used as energy fuel. Some residents and the Amhuinnsuidhe Castle owner have planted some trees around the house, which grow well. This indicates that tree plantation is possible in the area. A wood land of about 120 hectares has been planted at the hill side of Ardvourlie three years ago by the forestry commission to generate a habitat for the enjoyment of visitors and to provide a home for woodland wildlife. The land is all croft land and part of the Ardvourlie common grazings. 200,000 different trees like birch, rowan, alder, willow holy and juniper have been planted there[2].

Presently most of the people (61%) are using electricity for space heating, and the rest is using oil, coal and peat and for space heating, and only 8 (25%) households showed interest to change their space heating system if it is cheaper. Therefore, at individual household level, there is no immediate potential of biomass energy use for space heating.

However, there is a fish hatchery in the study area which needs quite an amount of heat energy during the winter season to warm the water for small fish breeding. Presently, an oil fired boiler is being used to heat the water. The data on oil consumption and hot water requirements which were available are contradictive. Nevertheless, even considering the smaller figures, a significant amount of oil (126,000 liters) is needed. If the oil fired boiler would be replaced with a wood fired boiler, there would be a significant biomass energy consumer in this area.

4.4.2. Potential of biomass energy supply from nearby sources

As the hatchery could be a potential big consumer of biomass energy, the need of a nearby source of biomass exists. There is the Aline forest on the road to Stornoway, which was planted in 1970 by the Forestry Commission at an area of 625 hectare (ha). Two types of trees

[1] Personal contact with Mr. Ian Cairns, Agricultural Expert, date: Monday 29 August 2005
[2] Field Survey, August-September 2005

are grown, 60% Lodgepole Pine and 40% Sitka spruce. There are no proper statistical data on the forest available. It has been sold to Erisort Trust in early 2005, and the Trust plans to make a survey for further development of the forest and consultants have already been appointed.

Out of the total 625 ha forest area, about 300 ha are not suitable for this type of forest due to the low quality of soil. The Trust is planning to clean these 300 ha. How much wood can be gained from this forest is not quantified yet, however it is expected that a significant amount of fuel wood can be harvested form this area. A part of the forest was affected by insects, namely the "Beauty Pine Moth" and white dead logs are standing in the forest[1].

In this forest the seedlings were planted very closely giving not enough space in between the trees. Even new seedlings could not grow in the forest to sustain the forest generation, due to the lack of a favorable environment for germination. Some seedlings can be found outside the forest, where sunlight and other favorable conditions for germination are available. About 2500 to 3000 seedlings were planted per hectare land; however, about 1500 plants per hectare are suitable for getting better yield of wood. There was a high competition among the trees for nutrition so that they could not grow properly over 30 years of life span. Since the forest is very dense, it is needed to thin it up.[2]

> "The areas to be replanted are still being discussed with Forestry Commission and our consultants. Until agreement is reached we can not give specific information. In general we are committed to removing areas of conifer and replacing them with hard woods. We are also establishing a series of paths for walking, cycling and horse riding. As part of the restructuring areas will be planted with rotation energy crops if a market for such can be established. The total works are programmed to take place over ten year period"[3].

From the above discussion it is clear that a significant amount of wood fuel could be obtained from the Aline forest given the clear fell of unsuitable 300 ha and replacing of the existing conifer with hard wood. Since the total restructuring process of the Aline forest takes place over ten years, every year some wood fuel can be obtained. Further analysis is needed to estimate the annual availability of woodfuel from Aline forest.

4.4.3. Wood fuel potential from Aline Forest

The Aline forest area is divided into two parts as follows:

PART I: 325 ha, to be replanted with hard wood

PART II: 300 ha, not suitable for forest , this part has to be clear felled

[1] Personal discussion with Mr. Ken Mackay who is working for the Aline forest, date: 25 August 2005
[2] Aline forest visit with Mr. Ken Mackay on 25 August 2005
[3] Information received by email from Ken Mackay on 5 September 2005

An approximation of the yield of wood fuel from the Aline forest was done based on some assumptions:

> The woodfuel harvest is divided into three types of outputs: Clear felling, thinning and Brash. As part of the management plan for the forest, existing conifers will be replaced by hard wood. The yield class for sitka spruce and lodgepole pine are considered as 10 and 4, respectively. The average wood volume for sitka spruce and lodgepole pine are considered as 143 m^3/ha and 26 m^3/ha, respectively[1].

4.4.3.1 Potential wood fuel harvest from PART I

Based on the above assumptions, the Clear Fell, Thinning and Brash harvest calculation are as follows (Baksh et al. 2002, p.17-18):

Equation 4.4.1: Thinning Harvest Volume, m3

*Thinning Harvest = Spp Area% * Total Forest Area * Spp[2] Yield Class * 0.7[3]*

Equation 4.4.2: Timber Harvest Volume, m3

*Timber Volume Harvest = Av. Vol. Timber/ha *Spp [4] Area% * Total Forest Area*

Equation 4.4.3: Clear Fell Harvest Volume, m3 for the First Year

Clear Fell First Year = Total Timber Vol. of Spp / Crop Cycle Period

Equation 4.4.4: Clear Fell Harvest Volume, m3 for all Years after the First Year

*Clear Fell n year = First Year Timber Harvest of Spp + (n * (Spp Yield Class * Spp Area% * Total Forest Area)) / Crop Cycle Period*

Equation 4.4.5: Formula to Calculate Brash Harvest

*Brash n year = number of Years of Clear Fell Timber Harvest * Spp Brash Factor*

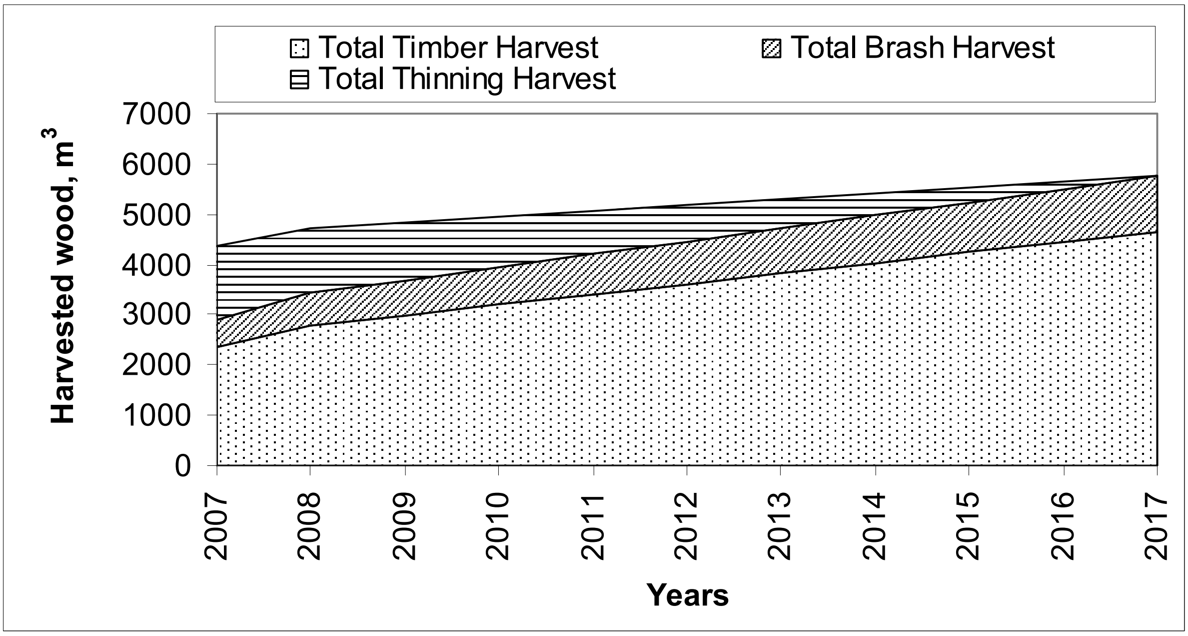
The estimated annual wood fuel harvest from Aline forest is shown in Figure 4.1 for a 10-year period. It is assumed that the first harvest to be in 2007 and the last in the year 2017. The estimated harvest quantity of wood fuel ranged from 4364 m^3 in the first year to 5754 m^3 in the last year with an average increase rate of 3.18% per year.

Total Timber Harvest volume ranges from 2366 m^3 in 2007 to 4654 m^3 in 2017 with an average annual increase rate of 9.7%. The average annual Brash Harvest volume ranges from 542 m^3 to 1100 m^3 with an average annual increase rate of 10.3% over this period. The

[1] Personal discussion on 5 September, 2005 and email contact on 6 September 2005 with Mr. Steven Liddle, Western Isles Woodland Project Officer
[2] Spp: specific plant
[3] 0.7 is an empirical factor used to calculate the thinning volume
[4] Specific Plant

thinning harvest volume decreases from 1456 m^3 to null over time with 10% decrease rate due to the reduction in area of trees with clear felling and re-plantation of hard wood.

Figure 4.1: Harvesting Pattern of wood fuel from Aline forest over 10-year period



Source: Author's calculation

On the basis of the calculated average Volume/Weight Ratio ***1.065m³/tonne*** (Appendix 4.4.1), the harvest quantity of first year, 4364 m^3 can be converted into tons as follows:

Equation 4.4.6: Volume/Weight Ratio of Conifer Wood

$$4364\ m^3/1.065m^3/tonne = 4097\ tons$$

The calorific value of wood fuel can be determined on the basis of the moisture content of the wood shown in Appendix 4.4.2 (Reforesting Scotland, Highland Birchwoods and TreeFest Scotland 2002 quoted in Baksh 2002, p.21 and own calculation).

Air-dried calorific value, which is 3.4 kWh/kg, was used to calculate the energy content of wood because the most practical method for acquiring wood suitable for producing energy is air dying. On the basis of this assumption, the estimated energy content of the wood harvested in the first year is:

Equation 4.4.7: Estimated Energy Content of Conifer Wood

$$3.4\ kWh/kg * 4097\ ton * 1000 = 13,929,800\ kWh$$

There is a plan to make walking paths, cycling and horse riding paths, therefore some area of the forest can be sacrificed for this enjoyment, but this area is not estimated. But based on the above calculated value of energy we can see that the harvested energy increases at 3.18% per year, therefore, it is calculated that at least 13,929,800 kWh energy can be obtained from this 325 ha forest every year for 10 year period.

4.4.3.2 Potential wood fuel harvest from PART II

The annual average wood fuel from the part of the Aline forest which is not suitable for forest to be completely clear felled was calculated as follows equation 4.4.8 and the results are shown in Appendix 4.4.3 based on the assumption (Section 4.4.3).

Equation 4.4.8: Timber volume harvested, m3

$$\text{Total harvest of wood fuel} = \text{Av. Vol. Timber } m^3/ha * \text{ Forest Area}$$

It is not yet decided how many years are needed to clear this 300 ha of forest. If we assume that this work also will be done during a 10 year period, then an additional 6,972,000 kWh of energy will be available per year. However, there is a part of this forest that was affected by Beauty Pine Moth. In this area, the dead trees start to rot and therefore can not be used as fuel woods.

It should be also mentioned, that the existing Aline forest clearly indicates the possibility of growing plants at the present soil conditions, although it is needed to find out the area specific species with trial basis where the plant can grow.

4.4.4. Possibility of biomass plantation

From the discussion about the Aline forest it is clear that biomass growing is possible in the study area. By investigating the soil survey map of the study area and also by visiting the sites we found about 305 ha (Aird Chathanais 50 ha, Gleann Mhiabhaig 130 ha and Cleit nan Uan 125 ha) which is similar to the soil type of the Aline Forest area and about 20 ha at Hushinis (Appendix 4.4.4). Steven Liddle[1] confirmed from the experience of the island of Shetland that Willow Hookers (*Salix hookeriana*), Willow ogier (*Salix viminalis*) and Crack Willow (*Salix fragilis*) can be grown in this type of soil.

The estimated cost for crop establishment is shown in Appendix 4.4.5. The total cost of crop establishment for 325 ha is 1,787,000 GBP for manual planting and 2437000 GBP for machine planting considering 10,000 seedlings per ha. Scottish Forestry Commission is offering grants/premium under the Scottish Forestry Grants Scheme (SFGS) for different types of tree plantation activities. Therefore, grants can be obtained for biomass plantation. The grants vary from 60% to 90% depending on the conditions[2]. If the sort rotation coppice are planted in this proposed area (Aird Chathanais, Gleann Mhiabhaig, Cleit nan Uan and

[1] Personal discussion on 5 September 2005
[2] Quick Guide to Applying for the SFGS, Version 1/ Mar 2005.

Hushinis) then more than 2000 oven dry ton (odt) fuel can be obtained per year (considering the average yield 6.5 odt/ha/year[1]). Space heat requirement of about 500 household can be served with this 2000 odt wood fuel (considering 100 kWh/m^2/yr energy consumption), therefore with this amount of biomass energy a district heating system for a small town like Tarbert can be operated.

4.5 Water Heating using Solar Thermal

4.5.1. Introduction

SWH (Solar Water Heating) is an established and reliable technology. It works with a coil in a hot water storage tank, linked to a collector on the house roof. The heat transfer fluid in the coil is pumped through the collector, where it absorbs the solar irradiance, and through the coil to the tank, where it exchanges the energy to heat up the water. This technology is not popularly used in Scotland, only a few hundred installations a year and an accumulative total of about 2,500 installations; while Netherlands, for example, has over 50,000 installations and its rate of installation is about 10,000 per year [2]. In North Harris, the Sir E. Scott School has installed at the beginning of 2005 a SWH system to supply hot water for the swimming pool, but there is no household using this system at the present.

In North Harris the solar insolation[3] from June to August is only approximately 10% lower than the one in Paris, due to the longer sunshine duration. A well designed SWH system could cover most of the hot water demand in summer, and between 10 and 30% of the requirement in winter. A domestic SWH system is simple to install and to maintain, reliable, and costs between £2,500 and £5,000, varying with collector size and type. System performance depends on the local weather conditions, hot water demand and the selected technology.

4.5.2. Weather Conditions

Solar energy consists of direct and diffuse radiation. Meteonorm software was used to interpolate the data from three different weather stations to find more precisely the required data for North Harris.

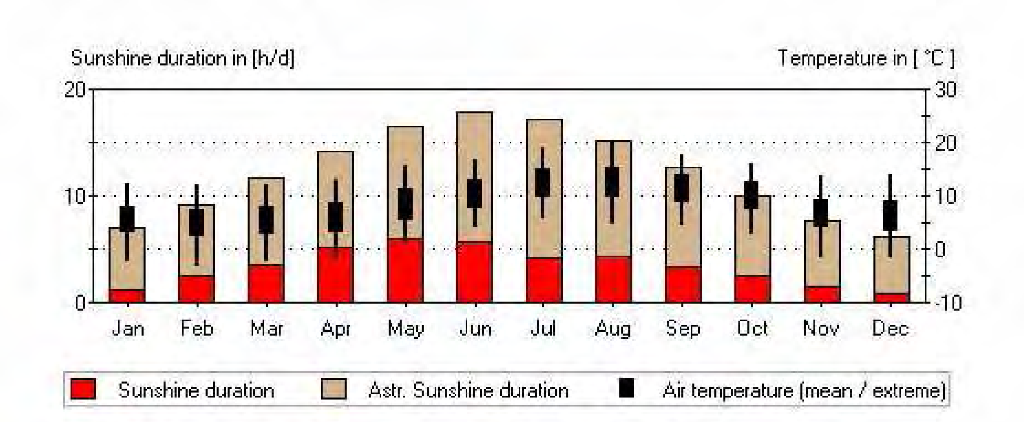
(1) Sunshine Duration

At this latitude, the length of daylight has a significant variation between summer and winter. From October to March, the sun only shines between 1 and 4 hours per day and the mean temperature is below 10 ºC. From April to September, the sunshine hours increase from 5 to

[1] Final Report of the Proposal for Biomass Demonstration Project for Western isles, 2004, page.8
[2] http://www.scottish.parliament.uk/business/committees/enterprise/inquiries/rei/ec04-reis-srf4.pdf
[3] Insolation: Energy of the solar radiation per area [kWh/m^2]

12 hours and the mean temperature goes up gradually from 6 to 13 ºC. This data is confirmed by the statistics found in the Met Office of UK for Stornoway.

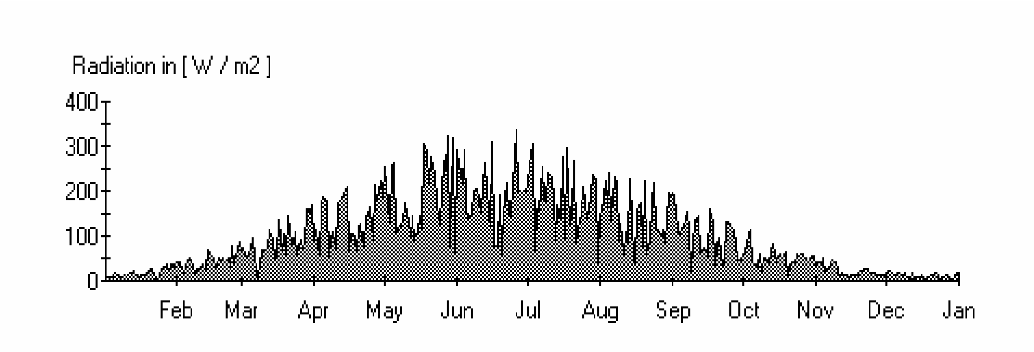
Figure 4.2: Sunshine Duration in North Harris [hours/day]



Source: Created by the author with Meteonorm, 2005.

(2) Solar Irradiance[1]

Figure 4.3: Irradiance in the North Harris Isle [W/m2]



Source: Created by the author with Meteonorm, 2005.

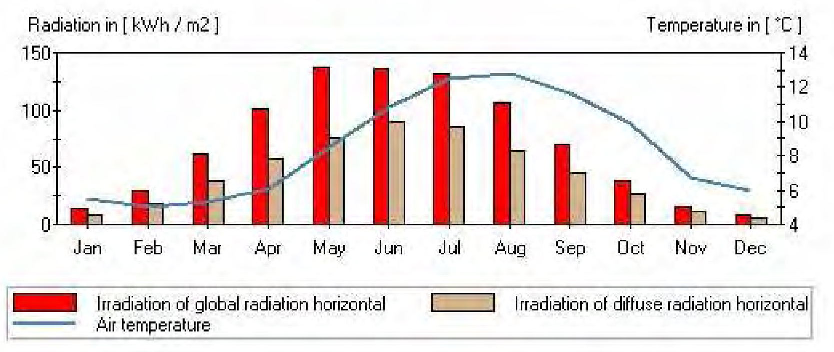
From Figure 4.3, the average solar irradiance available from October to March is below 100 W/m^2, but for the months between April and September this value is above 200 W/m^2.

(3) Solar Insolation

In the next figure, the red bars represent the Global Radiation, direct and diffuse radiation together, which is between 75 and 130 kWh/m^2 for the summer season (April – September) with the highest values for May, June and July.

[1] Irradiance: Power of the solar radiation per area [W/m^2]

Figure 4.4: Insolation in the North Harris Isle [kWh/m2]



Source: Created by the author with Meteonorm, 2005.

(4) Ambient Temperature

The ambient temperature is an important factor for the SWH system performance as the collectors are installed on the roof. Cold air temperatures can decrease the system's efficiency despite the insulation.

Figure 4.4 presents the temperature of the air, which is between 4 and 7 ºC from November to April, and between 8 and 13 ºC from May to October. These winter temperatures are not as cold as those measured in other countries of Northern Europe.

(5) Wind Speed

It is important to consider also the presence of wind, especially for the installation. With large wind speeds it is better to install the collectors attach to the roof, in order to avoid possible accidents. High wind speeds also increase the heat losses of the collector. In North Harris the average wind speed is approximately 8m/s.

Consequently, solar thermal energy is a suitable technology in North Harris if the appropriate type technology is selected.

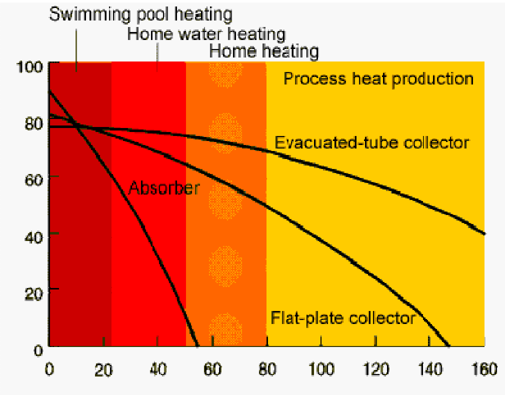
4.5.3. Solar Water Heating (SWH) System

The key component in a SWH system is the collector. For domestic SWH mainly two kinds of collectors are used, flat-plate collectors and evacuated tube collectors.

While flat-plate collectors are insulated with conventional insulation material such as mineral fiber, the absorber strip of a vacuum collector is located in an evacuated and pressure proof glass tube, which minimizes heat losses. In the heat-pipe type of the vacuum collector the pipe of the absorber is filled with a heat transfer liquid (methanol), which begins to vaporize even at low temperatures. The steam transfers the heat to the carrier fluid in the main pipe. The condensed liquid flows back into the base of the heat pipe. Several single tubes, connected to each other via manifold make up the collector.

The vacuum collector is recommended in North Harris, because evacuated tubes have the significant advantage that they work efficiently at low ambient temperatures and in areas with high wind speeds (See Figure 4.5). They also occupy a smaller area. The disadvantage of the evacuated collector is its high cost. The typical installation cost for a residential flat plate collector system is between £2,000 and £3,000 while for an evacuated tube collector system is between £2,500 and £5,000 [1].

Figure 4.5 Graph of efficiency and temperature ranges of various types of collectors (radiation: 1000 W/m²)



Source:http://www.solarserver.de/wissen/sonnenkollektoren-e.html#wel
(Note: vacuum collector is also known as evacuated tube collector)

Since in North Harris there are no local installers and domestic SWH users, it is necessary to initiate pilot projects of domestic SWH system installed by a professional installer from the mainland. This pilot projects will not only demonstrate the performance of SWH systems to local residents, but can also used to motivate and train local plumbing companies. If these companies advertise and popularize such technology for local residents; it will reduce the investment for SWH system by shorter transport cost and maintenance cost.

Other factors influencing the feasibility of a SWH system are:

- The area of a south facing roof,
- Obstacles on the roof and in the neighbors' houses, such as roof-windows, trees, etc.
- The existing water heating system which sometimes is not suitable to be combined with a solar system.

[1] http://www.est.org.uk/uploads/documents/ myhome/Solar_water_o_p.pdf

Solar energy is the most environment friendly energy, its CO2 emission is nearly zero. A SWH system does not produce any pollution and a typical 2 panel system can reduce CO2 emissions by 0.25-0.5 ton/year.

4.5.4. Local Situation in North Harris

- **Building Conditions.** The survey showed that 17 of the 33 households have their roof oriented to the south, 9 to the south-east or south-west, these buildings' roof orientations are suitable for installing collectors. 7 houses are facing to the east or west, so they are less suitable for solar collector installation. There are no houses where trees or buildings could produce shadow on the roof, and no other obstacles to install SWH systems were found.
- **Grants.** In Scotland the Scottish Communities and Householders Renewable Initiative (SCHRI) provides grants for the installation of solar collectors for water heating. These grants consist in 30% of the costs up to £4,000 for private households, and 50% of the costs for community projects. However, the grant for community projects in the Western Isles can be as high as 80% if the SCHRI grants are merged with grants from the Western Isles Enterprise.

Constraints

- **Few Manufacturers and High Investment.** There are only a few companies within Scotland which install solar collectors (between 6 and 10), and none of them in the Hebrides. In the absence of competition the technology requires a high investment, which increases still more because of the transportation costs to the island. Due to local weather condition, the evacuated tube collector is the best choice, but its cost is between £2,500 and £5,000. This same system in Germany costs nearly half of the price. All these factors lead to high investment cost for a domestic SWH system.
- **Low Energy Tariff.** 23 of the 33 interviewed households use electricity for water heating, and 7 households use oil. The night tariff electricity used for water heating is 0.039 £/kWh, which is almost 50% lower than the normal one (0.076 £/kWh). Also, some households of this 23 pay the "Staywarm" tariff which is special for households which have one of the family members over 60 years; this tariff is fixed for 12 months independent on the consumption. For this reason these households don't have much interest in saving energy and replacing their hot water system.

- **Average Age.** The average age of the residents in the studied area is relatively high and the payback time of SWH system is above 20 years; for these two reasons it seems not so attractive for these households to invest in such a system.
- **Low Confidence.** Also the solar energy available in North Harris is not much less than in other regions of Northern Europe, where SWH systems are more popular, most of the people think that this type of energy has no potential on the island due to the lack of sunny days. Lack of demonstration of SWH systems used in households also causes low confidence.
- **Interest in Environment.** Only 5 from 33 interviewed households mentioned the environment as a reason for using SWH systems, it seems that this concern is just beginning among the community. However, as ¾ of the respondents are of the opinion that RE can contribute to sustainable development and conservations of the climate and 46% are willing to pay more for clean energy, there is a fertile ground on which the interest for SWH can grow.

4.5.5. Conclusions

Solar thermal technology has been proven to be reliable and environment friendly. Solar domestic water heating systems can provide up to 50% of the water heating needs of a typical household in North Harris area. However to popularize this technology, economic factors will be the main obstacles. The main potential for cost reduction lies in the reduction of marketing costs and more encouraging policies, such as an increasing percentage of grants or low interest loan. Motivating the local installers is a useful method to reduce the cost. Another method to make this technology more popular is to improve the public awareness and knowledge of the technology through improved information, dissemination and model projects

4.6 Heat Pump as a Source of Energy

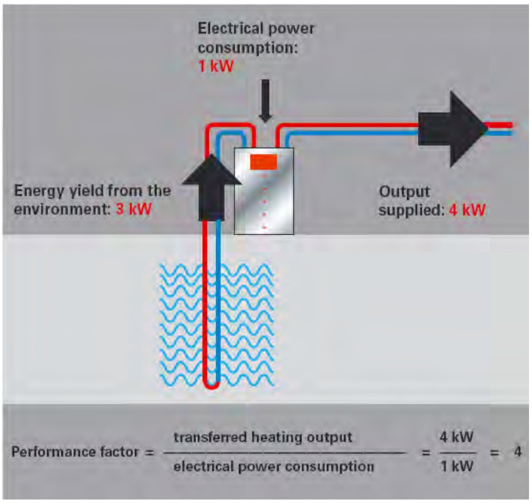
4.6.1. General description and Conditions

Normally 80% of the energy consumption is for space and water heating system[1]. Heat pumps can be used to provide heating of buildings as well as for heating water by using the environment as a heat source. Heat flows naturally from a higher to a lower temperature. Heat pumps, however, are able to force the heat flow in the other direction, using a relatively small amount of high quality drive energy (electricity, fuel, or high-temperature waste heat etc.). For example, in the best case the performance factor is 4, which means for every 4 kW of heat

[1] www.irishenergy.ie/uploads/documents/upload/publications/Hospital_pdf, page 1

provided, a heat pump will consume around 1kW of electricity. However, the practical figure for the performance factor is near to 3. Heat pumps can save electricity from fossil fuels where electrical heating cannot be avoided in the next future. They also allow to convert electricity from renewable energy into heat in a very efficient way, where this electricity cannot be fed into the electricity grid. If the electricity comes from renewable sources, then heat pump technology is free of CO_2 emission because heat pumps can transfer heat from a natural heat sources such as the air, ground or water to a building without burning fuels.

Figure 4.6: Performance factor of heat pumps



Source: www.viessmann.com

Today, heat pumps provide a reliable heating system, which operates in a numbers of countries. For example, in Switzerland, every third new building is equipped with an electrically operated heat pump; whereas in Sweden 7 out of 10 new buildings are using heat pumps. More over growth rates for the German market is substantial also (source: www.viessmann.com).

Scottish Government set the target to produce 40% electricity from renewable sources by 2020. So, using heat pumps in NHE could make a good contribution to electrical power savings and reduction of green house gases. The Scottish Community and Householder Renewables Initiative (SCHRI) has been derived from this government target and offers 30% grant for all renewable technologies including heat pumps for households and community organizations to accelerate renewable technologies in the Western Isles.

Despite heat pumps have various advantages, in North Harris Estate heat pumps are still not used. The Shawbost Old School and the Gearrannan Black House Village in the Western Isles three Ground Source Heat Pumps (GSHP) of 17 KW power are the first successful initiatives to introduce heat pumps in the Isle of Lewis.

4.6.2. Design Alternatives

Heat can be taken from a source of minimum 5°C and heat water to a temperature of 45 °C to 50°C. The heat source of a heat pump can be groundwater, seawater or ambient air. In the North Harris Estate (NHE), the potential for various types of heat pumps is considerable. Air-source heat pumps have a 10-30% lower seasonal performance factor (SPF) on average than water-source heat pumps. A high temperature fluctuation of air in winter and summer season results in a more fluctuated performance of air source heat pumps compared to water source heat pump, because the seasonal air temperature is less stable than the water temperature[1]. Ground water is available with stable temperatures (4-10°C) in many regions in Scotland[2] River and lake water is in principle a very good heat source, but has the major disadvantage of low temperature in winter (close to 0°C). Sea water is an excellent heat source under certain conditions, and is mainly used for medium-sized and large heat pump installations. At a depth of 25-50 metres, the sea temperature is constant (5-8°C)[3]. On the other hand, GSHP are used for residential and commercial applications, and have similar advantages as (ground) water-source systems, i.e. they have relatively high annual temperatures of the heat sink and can convert around 250% to 350% of the input energy into heat (seasonal performance factor SPF 250 to 350). In Scotland the ground temperature is 11-12°C [4]. For GSHP heat is extracted from pipes laid horizontally or vertically in the soil (horizontal/vertical ground coils). But for NHE, due to the rocky ground, vertical borehole systems are more preferable than horizontal loop systems.

Figure 4.7: GSHP with vertical loops

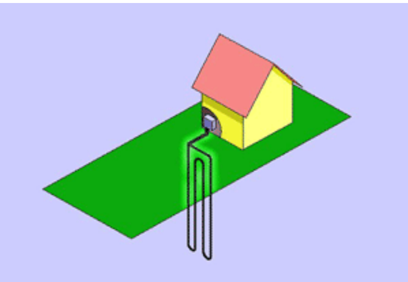
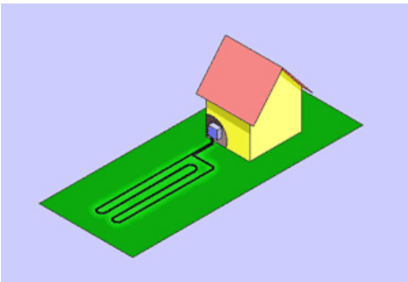


Figure 4.8: GSHP with horizontal loops



(Source: www.csep.co.uk/downloads/heat_pump_info_sheet.doc)

[1] www.irishenergy.ie/uploads/documents/upload/publications/Technical_heat_Pump.pdf Page 3
[2] www.csep.co.uk/downloads/heat_pump_info_sheet.doc
[3] www.csep.co.uk/downloads/heat_pump_info_sheet.doc
[4] www.renewscotland.org/sun/heatpump.html

The thermal capacity of the soil varies with the moisture content and the climatic conditions. Due to the extraction of heat from the soil, the soil temperature will fall during the heating season. In cold regions most of the energy is extracted as latent heat when the soil freezes. However, in summer the sun will raise the ground temperature, and complete temperature recovery may be possible. In addition, humid ground is preferable, because a light dry soil will require a much longer horizontal heat exchanger than a damp soil would. (Source: www.eco-hometec.co.uk/Heatpump.htm).

4.6.3. Economic Viability

Heat pumps are a cost effective, robust and preferable option to use electricity for heating. It consumes about 70% less electricity than direct heating with electricity and thereby produces two third less CO_2 (Source: www.csep.co.uk/downloads/heat_pump_info_sheet.doc). If the heat pump uses electricity from renewable sources its CO_2 emission is nil and the primary energy efficiency is 100%. Moreover for all kinds of heat pump, the maintenance cost is 20 to 40% of conventional heating systems only and 10 years warranty for heat pump and 50 years warranty for ground loops are available from suppliers here. In spite of many advantages of heat pump, its initial cost is 3 times higher than the cost for a conventional heating system. But in general, for large households or commercial cases, its pay back period is 5 years only.

4.6.4. Conclusion

In NHE area among 33 surveyed households, 28 house holders are not well informed about heat pumps, whereas some households are enthusiastic about heat pumps. 24 households are using electricity for space heating. By using heat pumps in these 24 households it is possible to save 122,416 KWh electricity yearly. That results in 52,639 kg/year less emission of CO_2 at 0.43 kg per kwh electricity generation[1]. 9 house holds are interested to change their current space heating system and among them 7 households have a potential for heat pumps using micro hydro and wind energy based electricity.

[1] Environmental Reporting-Guidelines for company reporting on green house gas emission, p. 27

Chapter 5: Renewable Energy Options for Specific Areas

5.1 Introduction

After conducting and analyzing the survey, the collection of secondary information and some visits to the potential sites for the different renewable energies, some specific options of possible sites of renewable energy projects came to light. These projects respond to the concerns and advice of the North Harris Trust and the Highlands and Islands Community Energy Company. Some of them combine diverse renewable energy sources to meet the energy demand for electricity, space and water heating, showing various options for such projects.

One of them is the Fish Hatchery located near Amhuinnsuidhe Castle which needs energy mainly to heat water for the fish basins. Renewable energy options checked for this project are biomass, heat pump, micro-hydro and wind.

The North Harris Trust houses near the castle were considered to involve solar energy, biomass and heat pump, to create a good example for the application of renewable energies.

The third project is located in Govig, a neighborhood of 6 houses, which is a potential site for micro-hydro to provide electricity combined with solar and heat pump for a future holiday house. Another option in Govig is a household which shows interest for solar water heating in combination with oil fuel.

Bunavoneadar is the fourth possible site which presents two alternatives for small-hydro power stations.

In Airde Mor, located 1.5 km west of Amhuinnsuidhe Castle, the possibility of installing a middle-scale wind project of 1.3 kW was analysed.

5.2 Fish Hatchery Plant

5.2.1 General Description and Energy Supply Options

In North Harris Trust area there is one fish hatchery, which breeds up millions of Salmon fishes per year. The hatchery takes the fresh water from Loch Leosaid to their fish basins. The basin temperature is kept more or less constant year around and consequently the demand for hot water increases during winter. From December to April the water temperature of the Loch is approximately 2 °C; whereas the hatchery needs to keep the water at 12°C - 16°C, so they use an oil boiler system to supply the heat energy.

The present system has two boilers of 425kW each. To improve the health and growth rate of the fish, the water in the basin has to be kept fresh and at a certain flow rate. Based on the information that we have received we assume that 437 m³ of water needs to be warmed each day which consumes approximately 6000 L oil per week. (The available data on oil consumption and hot water requirement are contradictive, here oil consumption data is selected to calculate other relative data) .The waste water is released to a concrete pool with ca. 450 m³ volume at a temperature of 14° C through an open concrete channel, and then to the river. There is presently no heat recovery system for the channel and concrete tank to reuse this heat energy from the waste water. The heat energy losses could be reduced by using well insulated pipes and covering the pool, as well as reusing part of the heat of the waste water with some heat exchange equipment such as a heat pump. These measures would reduce fuel cost significantly.

Figure 5.1: The Fish Hatchery Plant

Source: Photograph by SESAM study team

The potential renewable energies suggested for the hatchery are micro-hydro, small-scale wind turbine, heat pump and a biomass boiler. These energies are locally available and have potential to reduce the fuel cost by replacing or compensating for the present oil based heating system. The aim of the project is however, not only to reduce the fuel cost, but also to incorporate ideas of reducing CO_2 emissions and to reuse the energy from the discharged warm water.

5.2.2 Biomass energy use for hatchery

5.2.2.1 *Option 1- Biomass energy only*

Energy from biomass can be used for the hatchery as an alternative of the existing oil fuel. It is estimated that 1,160,320 kWh/year (equivalent to 342 air dry ton) wood fuel energy (considering 90% efficiency of new boiler) is needed to replace the presently required 126000 litre of oil per year. The calculated average required capacity of a wood chip boiler is found to be 296 kW. To ensure the peak energy demand (assumed to be 20% higher than the calculated average) a boiler with a nominal output range of 320-400 kW capacity has been selected (model: PYROT 400 of 3GEnergi, see Appendix 5.2.2.1). The specification of the boiler is shown in Appendix 5.2.2.3.

The results of the financial analysis shows, that the option-1 is viable and attractive. The NPV and IRR are found to be £74,785 and 11.8%, respectively, when air dry wood chip price is considered as 45 GBP/ton1. The sensitivity analysis shows that up to a price of 70 GBP/ton of wood chips the project is viable (Appendix 5.2.2.2).

It is estimated that from the Aline forest, at least 13,930 MWhyear (section 4.4.3.1) energy from biomass can be obtained for 10 years. Initially the required wood chips for running the boiler can be obtained for this period, if the authority of the Aline forest executes their plan for restructuring the existing forest (section 4.4.2). For the sustainable supply of the wood chips, a local biomass production program should be undertaken. It is calculated that if 43 ha short rotation coppice is cultivated the required amount of wood chips for the hatchery would be available.

5.2.2.2 *Option 2- Combination of biomass energy and heat pump*

A Heat pump can supply 648000 kWh/year energy which is 62% of the 1044288 kWh/year required, and the rest of the energy could be supplied from biomass. The financial analysis of this option shows however, that this combination is not financially viable. (Appendix 5.2.2.4).

5.2.2.3 *Option 3- Wood chip boiler and waste heat recovery*

The waste water is released from the basin to an open concrete canal and then the water enters the pool and finally water goes back to the river with a temperature of about 12 to 14 °C. The

[1] Sustainable Development Corporation (SDC) Scotland 2005, p.26

heat could be recovered from this waste water. For this purpose a PE pipe can be placed in the waste water pool as a heat exchanger and the fresh water (which runs into the boiler at a temperature of about 2 °C) is diverted through this heat exchanger. The heat exchanger can supply about 50% of the total heat requirement. The calculated surface area and the length of the pipe of the heat exchanger are 110 m^2 and 700 meter of pipe with 50 mm diameter, respectively. It is recommended that the open canal should be replaced by a pipe and the water pool should be covered to keep the maximum of heat.

To supply the remaining 50% of the heat needed the capacity of the boiler is calculated as 145 kW (Appendix 5.2.5.5) and the requirement of wood chips is about 168 air dry ton (571200 kWh). The boiler model Kob PYRTEC 200 with a nominal output of 150 to 200 kW is selected (see Appendix 5.2.2.6 and Appendix 5.2.2.7 for detailed specifications).

The result of financial analysis shows that this option is financially viable with NPV £208,385 and IRR 25% when air dry wood chip price is considered as 45 GBP/ton1. The sensitivity analysis shows that the project is viable up to 140 GBP/adt price of wood chip with NPV £94,942 and IRR 8% (Appendix 5.2.2.6).

If we make a comparison among the above three options, option 3 - biomass energy and heat recovery - system is more attractive from the financial point of view. But it is also mentioned that this option also saves half of the biomass energy and CO_2 emission (334 ton CO_2/year) by saving the fossil fuel.

5.2.3 Heat Pump

A heat pump of 180 KW capacity using a horizontal loop heat exchanger of 4500 m in the existing 450 m^3 volume water tank is considered in this study by partly using green electricity from a 20 kW micro hydro plant (section 5.2.4) or a 15 kW Wind turbine (section 5.2.5) at suggested for the same site. With an initial investment of approximately 120000 pounds for the heat pump system, it is possible to heat up 266009 liters of cold water per day. This could reduce the oil consumption by 62,548 liters/year and save 167,628 kg CO_2 emission per year (see Appendix 5.2.3.1 for detailed calculation).

5.2.4 Micro Hydropower Plant

5.2.4.1 *Introduction*

This report presents the findings and conclusion of the proposed micro-hydro project for the Fish Hatchery plant, by assessing different issues on the basis of various technical and

[1] SDC Scotland 2005, p.26

financial aspects. With the available gross head of 6 m, design flow of 500 l/s and overall efficiency of 60%, a micro-hydro scheme with a capacity of 17.6 kW could be developed for the hatchery at Lochan Beag. Presently the hatchery requires a significant amount of oil for heating purposes. Therefore this study assesses the possibility of using electricity from a small hydro scheme to provide a part of the heating energy demand.

5.2.4.2 ***Salient Features Of Lochan Beag Micro-Hydro Project***

Project	Lochan Beag Micro-Hydro Project
Location	Lochan Beag (near to fish hatchery)
Source name	Loch Leosaid
Measured Flow and Date	518 l/s, Aug 20, 2005
Catchment area (km^2)	16.72
Annual average flow (l/s)	815 (calculated from area rainfall method)
Design flow (l/s)	500
Intake location	NB 05668 BNG 08525
Power house location	NB 05634 BNG 08504
Gross head (m)	6
Installed capacity (kW)	17.6
Energy generated	65,900 kWh/year (for 5 months)
Overall efficiency (%)	60, using Kaplan
Penstock Pipe (m)	45 m mild steel, Ø 625 mm
Powerhouse	Stone masonry in cement mortar with slate roofing
Tailrace canal	10 m, open canal discharged to the river
Turbine	Kaplan, 22 kW shaft power
Generator	27 kVA, 3-Phase Synchronous Generator,
Transmission/distribution	400 m length, overhead low-tension
Beneficiary	Fish Hatchery plant
Total heat demand	208,857 kWh/month
End-Use	Supply part of plant's heating demand
Grid connection possibilities	Possibilities of grid connection
Ownership/Owner	The Fish Hatchery or North Harris Trust

5.2.4.3 ***Methodology***

The feasibility study of hydro is based on field survey and following methods were used during the study period to acquire the respective data and information.

1. ***Data Collection:*** The study team visited the site to collect the information regarding the energy demand of households and/or industries as well as discuss the end use possibility if the hydro scheme would be installed in the site.
2. ***Site Survey:*** Equipments like, GPS, Altimeter, Abney level and measuring tapes were used to undertake the technical survey. The listed procedures were followed to conduct the technical survey.

a. Flow measurement using weir or bucket method.
b. Site survey of different components e.g. intake, canal, powerhouse, transmission and distribution line.
c. Calculation of plant capacity and financial analysis

3. ***Data Analysis & Report Preparation:*** The technical findings and site data collected were finally compiled after rigorous technical verifications and calculations.

5.2.4.4 *Location and Topography*

The proposed site for the scheme is located at Lochan Beag, near to the Amhuinnsuidhe castle and the Hatchery plant. This site can be accessed with a gravel road from the secondary road (B 887) to the north east. It is situated on an altitude of about 49 meter above mean sea level. Source of the water is Loch Leosaid, where the water from the existing Chliostair hydro scheme is discharged. Another small river (Abhainn Leosaid) also supplies water to the Loch.

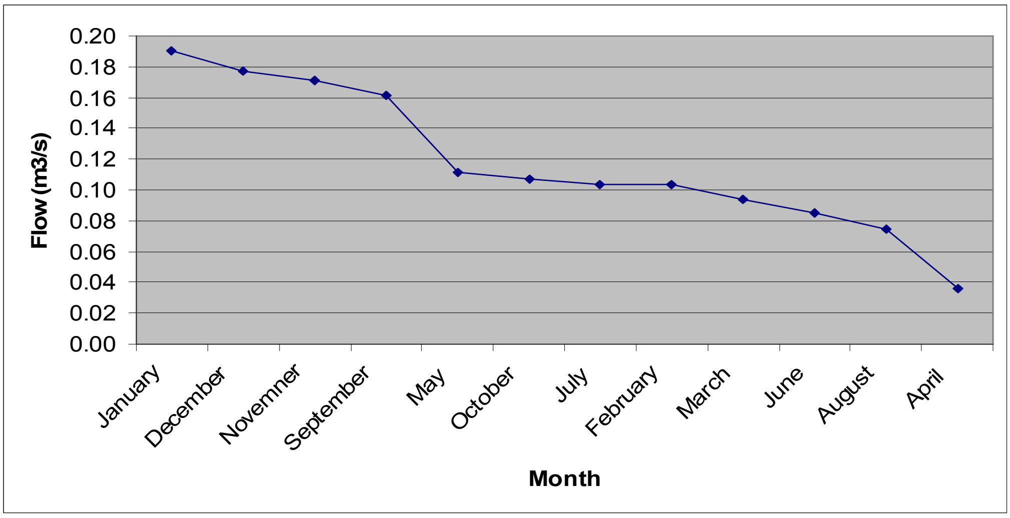
5.2.4.5 *Hatchery Power*

The proposed micro-hydro scheme would supply electricity for a part of heating demand at the fish hatchery. The electricity could drive a heat pump that recovers part of the heat energy of the hatchery waste water. However, the electricity supply from the hydro scheme could supply only a part of the required demand, as its generation capacity would only be approximately 13,000 kWh per month.

5.2.4.6 *Hydraulic Potential and Plant Capacity*

Flow*:* The source of the scheme is Loch Leosaid. The flow measured on the existing dam using weir method was found to be 518 l/s. This measured flow has also been compared to the average annual flow calculated by using the rain fall method which is 815 l/s. The design flow is fixed at 500 liter/sec.

Figure 5.2: Approximated Flow Duration Curve



Source: Calculation by SESAM Hydro Group

Head: The available maximum gross head was found to be about *6 m* downstream of the lowest possible powerhouse site from the intake.

Site Selection: This site is selected as it is the nearest hydro potential from the hatchery. The water intake can be located where the stream discharges from the lake. The power house can be located at the nearest downstream with the lowest possible position to give the maximum head, in order to minimize the penstock length. From the power house, the generated electricity can be transmitted to the hatchery through a 400 V transmission line.

Plant Capacity: The micro-hydro scheme could have a capacity of 17.6 kW and would generate approximately 139,000 kWh/year electricity for 11 months.

Figure 5.3 Scheme lay out of proposed micro hydro scheme

Source: Photograph by SESAM Hydro Group

5.2.4.7 ***Project Financial Analysis***

The proposed micro hydro could provide 139,000 kWh energy per year, however the Hatchery needs heating energy only five months. If the project runs only 5 months, it could not generate the positive revenue. Therefore the project does not seem financially viable. If the Hatchery gets 50% grant, the project would be marginally profitable with a NPV of £746 and IRR of 6.65%.

If this proposed project operates under the North Harris Trust, they could gain income by selling electricity to the grid. For £0.02/kWh (+0,045) selling price to the grid, this proposed micro hydro-project under NHT ownership does not seem financially viable without grant. If NHT gets 40% grant, the NPV, IRR and payback period would be £10,930, 9.5% and 14 years respectively. The details of financial analysis are presented in Appendix 5.2.4.1 and Appendix 5.2.4.2.

5.2.4.8 **Conclusion**

The proposed micro-hydro scheme can not provide the total heating energy demand of the hatchery, and it also needs energy only for five months period. Presently there is no provision to get subsidy to install micro hydro as a private business. Under these conditions, this project does not seem viable for the owner of the Hatchery. But NHT could develop this project to generate income by selling the electricity to the grid.

5.2.5 Small Scale Wind Turbine

5.2.5.1 ***General Description and Conditions***

The general conditions applicable for the site are shown in Table 5.1. The proposed site is about 65m from the hatchery with reference bearings as NB 105632 and BNG 908234.

Table 5.1: Site Conditions at Fish hatchery

Average Wind Speed at 45m height above ground[1] (source)	3.9 m/s
Wind shear exponent	0.16
Wind Speed at 10m height	3.1m/s
Average atmospheric Pressure	100 kpa
Annual average temperature	8.01 ^oC

[1] Source: West Coast Energy Ltd (2004) : Drawing 862/A1/2_5b

5.2.5.2 *Design Alternatives*

Based on the scale one Proven Turbine of 15kW is considered to be built on this site. The total Energy output at given conditions and based on RETScreen 9,311 kW per year.

The total CO_2 saving of this configuration is set at 5 tons/year. The Proven wind turbine can be used to heat water directly or via a heat pump and the cost estimates and evaluations are based on this configuration.

5.2.5.3 *Environmental Impacts*

a. Visual Impacts: The single turbine at 15m hub height can be seen from the road to the Castle. However, based on the size of the turbine this view will not distract or create a significant impact on tourists around the area.

b. Noise: It has been noted that the noise generated within the area is less than 48dB (Proven, 2005). Given that there is no residential house around, then this noise will have no significant effect.

c. Flickering: Given the rotor diameter of 9m and the fact that no residential hose are in the vicinity of the turbine the flickering effect is insignificant impact.

5.2.5.4 *Economic Viability*

The total investment for the turbine is £36,200 and is summarized in Table 5.2. Given the interest rate of 6.4 % and the inflation rate of 2% and various operation and maintenance costs, the calculated average after tax profit/loss per year is estimated at -£5,600 per year with a payback period of more than 26 years. These cost and profit estimates are based on the average values obtained from different sources and in particular to the manufacturer. The investment cost are estimated based on a stand-alone operation of the turbine to use the electricity for water heating in the hatchery, However only a part of the generation capacity could be used as the hatchery requires heat energy only during 5 months of the year. This will further increase the loss. On the other hand, a grid connection to feed electricity in the grid would increase the investment cost and thereby also increase the loss.

Table 5.2: Cost Elements for Proven 15kW Turbine

No.	Description	Percentage of Total Cost	Amount in £
1	Feasibility study	7%	2,400
2	Development	0	0
3	Engineering	0	0
4	Energy equipment	84%	30,600
5	Balance of plant		
6	Miscellaneous	9%	3,300
Total Investment Costs		100.0%	**36,300**

5.2.5.5 *Conclusion*

Based on the economic analysis it has been examined and found to be far from economic feasibility and hence it is concluded that it is not realistic to invest in such a small turbine under the site conditions.

5.3 North Harris Trust (NHT) Houses

5.3.1 General Description and Energy Supply Options

The Trust house is located at 57º57´Latitute and 6º59´Longitude. It presently belongs to North Harris Trust. The house consists of two flats, one intervening unused space, one workshop and one deer-larder. Each flat is presently occupied by two long-term residents.

The North Harris Trust intends to completely renovate the building and convert it into a 'show-case' of use of renewable energies. For this project, it is considered that 6 long-term residents will live in the building.

Figure 5.4: Houses owned by North Harris Trust

Source: Photograph by SESAM study team

The total required energy for space and hot water heating of the house is about 32.40 MWh per year, of which 4.08 MWh are for hot water. So, at the present condition the house has a specific heat index of 164 KWh/m^2. The energy can be supplied by choosing the different renewable energy options like solar thermal, biomass and heat pump. These technologies are more realistic and achievable in order to be a real showcase for the other residents.

We consider the two flats as an integrated unit to be supplied by a hot water and space heating system. The solar collector can then be installed on the roof of the workshop and deer-larder, with a roof area of $77.7m^2$. For fuel wood storage the existing workshop can be used. To get the best alternative, we propose five possible options to provide energy for space heating and hot water demand. The options are:

Option 1. Biomass and solar

Option 2. Heat pump and solar

Option 3. Only Biomass

Option 4. Only Heat pump

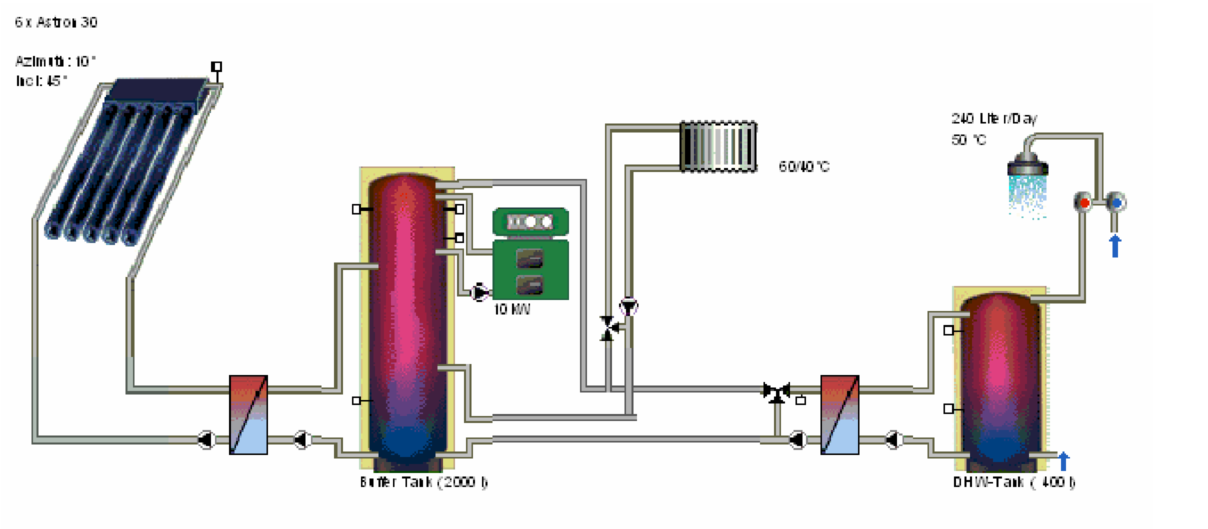
Option 5. Only Solar

For all the options, the distribution of heat for the two flats is done by a water bound central heating network. The space heating will be provided by using radiators. This cost, which also increases the quality of the heating system, is also included in the investment.

5.3.2 Option 1: Biomass and Solar thermal

There will be a central space heating and hot water system for the existing two flats by using solar and biomass together as shown in the chart 5.5.

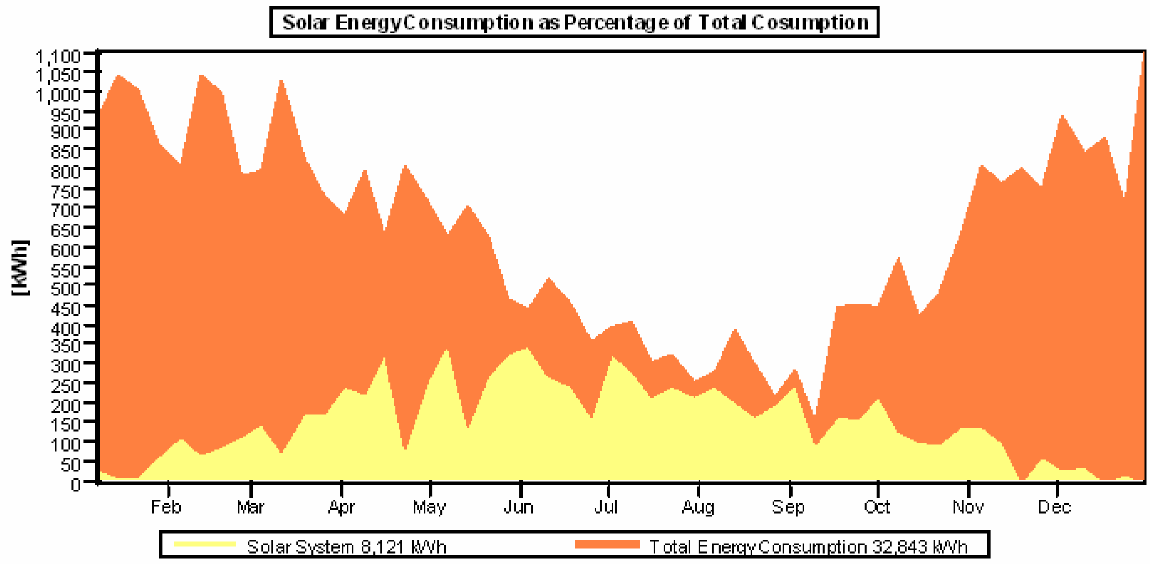
Figure 5.5: Combined Solar and Wood fuel boiler system for the NH Trust House,



Source : SESAM by using Tsol software

The total energy demand for hot water and space heating in the house is 32.4 MWh per year, of which 8.12 MWh will be delivered by a solar system and the rest will be covered by a wood fired boiler. For this purpose we use six 3 m^2 evacuated collectors and a 10 KW rated wood fired boiler. By using this system, Fig. 5.6 shows how the solar fraction is working in a year with the weather condition of North Harris Trust area.

Figure 5.6: Solar Energy Consumption of Total Energy consumption



Source : SESAM by using Tsol software

The total investment cost for this option will be £ 26030 . If we consider a grant of 50% then the investment cost would be £ 13015. For the 20 years of life time, our financial calculation shows that the NPV for this option is £-9084 (considering the grant 50%). This means that as a whole the option is not financially viable. But considering 80% grant, NPV, IRR and pay back period is £4104 ,15% and 8 years respectively, which would make the project financially feasible. This arrangement also saves 14.00 ton CO_2 per year. The detail of financial analysis is given in Appendix: 5.3.2.

5.3.3 Option 2: Heat pump and solar thermal

There will be a central space heating and hot water system for the existing two flats by using solar energy and heat pump together. 2.800 MWh is to be delivered by a solar thermal system and the rest of 29.60 MWh will be covered by a heat pump using the nearby sea water source. For this purpose two 3 m^2 evacuated collectors and a 12 KW rated heat pump are needed.

The total investment cost for this option is £15150. Considering a grant of 50%, the investment is £7575. For the 20 years of life time, and with 50% grant, our financial calculation shows that the NPV for this option is £-2242 .This means that as a whole the option is not financially viable. But if we consider a possible grant of 80%, then NPV, IRR and payback become £7165, 27% and 4 years. With replacing the electrical heating system by this combined system, it is estimated that about 9.70 ton CO_2 can be saved per year. The detail of financial analysis is given in Appendix: 5.3.3.

5.3.4 Option 3: Only Biomass

There will be a central space heating and hot water system for the existing two flats by using only biomass. To cover the total heat demand of 32.40 MWh per year we need a 15 KW rated wood fired boiler.

The total investment cost for this option is £7510. By considering a grant of 50%, investment becomes £3755. For the 20 years of life time and with 50% grant, our financial calculation shows that the NPV for this option is £1573, IRR is 12% and Pay Back period 10 years. These figures show that as a whole the option is financially viable. By replacing the existing electrical heating system, this option will also save 14 tons CO_2 per year. The detail of financial analysis is given in Appendix: 5.3.4.

5.3.5 Option 4: Heat pump only

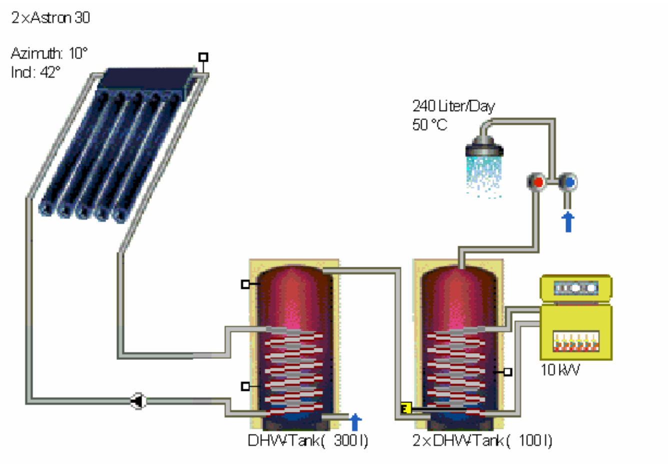
As the sea water is only 16 meter apart from the NHT houses, a sea water heat pump is considered for both space and water heating of NHT houses. The sea water depth at this site is 16 meters with an assumed minimum temperature of 5-6°C. (Source: Map from British Admiralty Surveys in 1971 and 1973, topography from Ordinance Survey).

A 15 KW heat pump can be considered for an annual energy demand of 32.4 MWh for space and water heating. The total investment cost is £19,300. If we consider a grant 50%, the investment cost would be £9650. Financial analysis shows that with 50% grant the project is not economically viable. However, with a grant of 80%, an NPV of £6083 and a payback period of 5 years indicate the economic feasibility. The heat pump would save 21576 kWh of electricity and 9.3 ton of CO_2 per year. (see Appendix 5.3.5 for detailed calculation.)

5.3.6 Option 5: Only Solar thermal

In option 5, a Solar Hot Water system is used to supply hot water for the trust house. 6m^2 evacuated heat-pipe collectors are installed on the roof of the workshop. One 300L central solar tank is installed in the workshop between two flats. The central solar tank is connected to the two existing small DHW-tanks with electrical immersion heaters as shown in the following sketch.

Figure 5.7 Solar Water Heating (SWH) system



Source: SESAM by using Tsol software.

The boiler (yellow) is part of the system configuration of the software, but not used for the simulation. The right tank symbolizes the two existing DHW-tanks
Total hot water energy demand is 4,080 kWh. The solar system could produce 2,780 kWh. Total SHW system investment is £6100 (see Appendix 5.3.6 for calculation). The community can get grants around 50% of the investment cost from SCHI, then the investment cost become £3050. The annual electricity saving is 3087 kWh (considered 90% efficiency of the electricity system), which is equivalent to 185£ per year. The energy cost is 0.10 £/KWh. The NPV of this system is £-556 and the pay back time is 27 years (financial calculation in Appendix 5.3.6). But if we consider an 80% grant, the NPV is £1274 and the payback period becomes 8 years, and also the unit cost of energy drops to 0.04 £ /KWh. So, this option becomes financially viable.

5.3.7 Conclusion

From the above options, only Biomass (opt. 3) is financially viable with a grant of 50%. A grant of 80% would also make all the other options economically feasible. Our survey has shown that the awareness for biomass, solar water heating and heatpumps is still low in the area. However, 46% of the people asked are willing to spend more money for energy, if it came from a renewable source as it serves the environment. Our survey also has shown that out of 34 respondents 9 were willing to change their current hot water heating system by a solar heating system.
The NHT-houses could play an important role as a showcase for the introduction of these technologies. As a heatpump for the NHT house would have to be driven with electricity from

the grid, we propose a combination of a biomass boiler and a solar water heater. The implementation of such a project could also be used to train and inform plumbers in the area. If the biomass supply can not be guaranteed in the near future, we propose the combination of heatpump and solar water heater as the second best option.

Table 5.3: Summary of options for NHT Housing project

Option	Investment, GBP	Unit cost GBP/KWh			NPV			IRR			Payback period, Year		
		Without grant	With 50% grant	With 80% grant	Without grant	With 50% grant	With 80% grant	With out grant	With 50% grant	With 80% grant	With out grant	With 50% grant	With 80% grant
Option 1 : Biomass and solar	26030	0.135	0.077	0.0415	-29327	-9084	4104	-	-5%	15%	>20	>20	8
Option 2 : Heat pump and solar	15150	0.139	0.069	0.023	-21163	-2242	7165	-	1%	27%	>20	>20	4
Option 3 : Only biomass	7510	0.068	0.0465	0.034	-4894	1573	5453	-3%	12%	47%		10	2
Option 4 : Only heat pump	19300	0.127	0.0635	0.0262	-17931	-2922	6083		2%	23%	>20	>20	5
Option 5 : only Solar hot water system	6100	0.19	0.10	0.04	-3606	-556	1274	-	-	-	>27	27	8
Existing system		0.0516*											

* The tariff rate is determined by assuming that for hot water and heating system, two third of the energy comes from night tariff and one third from day tariff.

5.4 Govig Houses

5.4.1. General Description and Energy Supply Options

There are six households in the Govig area. The total electricity and heating demand have been estimated, based on interviews with the residents during the survey. The major use of electricity is for domestic purposes especially space heating, lighting and electrical appliances. Out of six households, 5 use oil fuelled boilers for the central heating system for space heating and hot water, and only one household uses electricity for both purposes.

The total monthly electricity demand of the existing households is 2690 kWh, which is supplied from the grid. The total amount of oil and coal consumption is approximately 700 liters/month and 65kgs/month respectively. Future demand is likely to increase as a holiday home is planed by one family from Govig. This house will have 2 bedrooms, mostly occupied during the summer from April to October, so SWH system and heat pump would be possible solutions for hot water and space heating demand. The estimated heating electricity demand for this holiday home is 900 kWh/month (why is it more per m2 than for the NHT house?(for space heating and hot water), while electricity for lighting and appliances is approximately 200 kWh/month.

Considering the above facts, the following options of renewable energy supply could be a solution to replace the oil for the heating purposes:

Option 1: A micro-hydro scheme would be installed to supply electricity to meet the heating demand of the houses and holiday home, and therefore it would replace the oil. Electricity required to replace oil for heating purpose at the existing households is 5000 kWh/month.

Option 2: Two alternatives are proposed for the planned holiday house:

a. Heating demand would be supplied by a heat pump which would be powered by the grid.
b. Hot water demand will be partially supplied by solar thermal, and the rest heating demand would be supplied by electricity from the grid (or the micro hydro)

5.4.2. Option 1: Micro Hydropower Project

5.4.2.1 *Introduction*

A micro-hydro scheme with the capacity of 8 kW is proposed for development in Govig. The available gross head is 13m, the design flow would be 100 l/s and the overall efficiency is estimated at 60%. The topographical features of the project area appear to be favorable for the construction of a micro-hydro scheme. The community also showed high interest during our field visit and they seemed to be interested in installing a micro-hydro scheme. Previously they tried to install a 5kW micro-hydro scheme but the construction was not completed.

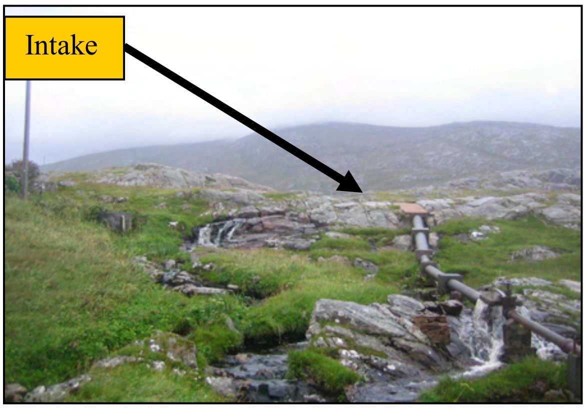
5.4.2.2 *Salient Features Of The Govig Micro-Hydro Project*

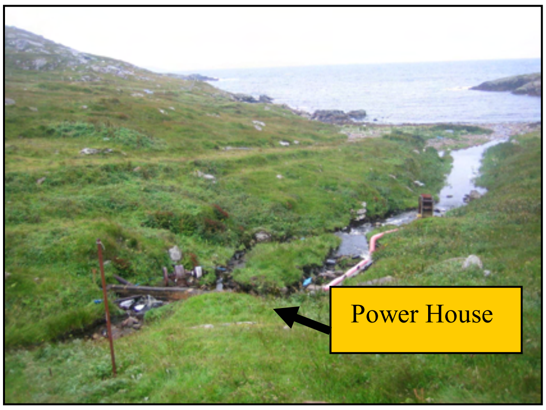
Project	Govig Micro-Hydro Project
Location	Govig
Source name	Loch Geodha Beag
Measured Flow and Date	75 l/s, Aug 22, 2005
Catchment area (km^2)	3.38
Average Annual Flow (l/s)	118 (calculated from area rainfall method)
Design flow (l/s)	100
Intake location	NB 01111 BNG 09243
Power house location	NB 01068 BNG 09175
Gross head (m)	13
Installed capacity (kW)	8
Energy generated	6,000 kWh/month (max.)
Overall efficiency %)	60, using cross flow
Penstock Pipe (m)	75.8 m mild steel, Ø 300 mm
Powerhouse	Stone masonry in cement mortar with slate roofing
Tailrace canal	10 m, open canal discharged in sea
Turbine	Cross flow, 9.5 kW shaft power
Generator	13 kVA, 3-Phase Synchronous Generator,
Transmission/distribution	400m length, overhead low-tension
Nos. of beneficiary households	5 households and 1 planned holiday home
Total electricity demand	2690 kWh/month (existing households)
Total oil & coal demand	700 liters/month and 65kg.month
Holiday home electricity demand	900kWh/month (heating) and 200 kWh/month (lighting + appl.)
Total Project cost: (£)	45,565
Cost per kW (£)	5,677
End-Uses	Space heating and hot water for all households and power for heat pump
Grid connection possibilities	Possibilities of grid connection
Ownership/Owner	Local households(Community)

5.4.2.3 *Location and Topography*

The proposed site is located at Govig in the western part of North Harris at the coastal area of the Atlantic Sea. This site can be accessed by a sealed road from the secondary road (B 887) to the south west. It is situated on an altitude of about 20 meter above mean sea level. The proposed scheme is located in the centre of the settlement with six houses. The topography favours the construction of a micro-scale hydro project. The terrain consists of gravel mixed soil and rock. Loch Geodha Beag is the source of water for the hydro scheme. The lake depth is approximately 2 meters at the center and 1 meter at the edge. It is about 800 meters long and 140 meters wide.

Figure 5.8: Proposed lay out of Govig Micro Hydro project





Source: photographs by SESAM study team

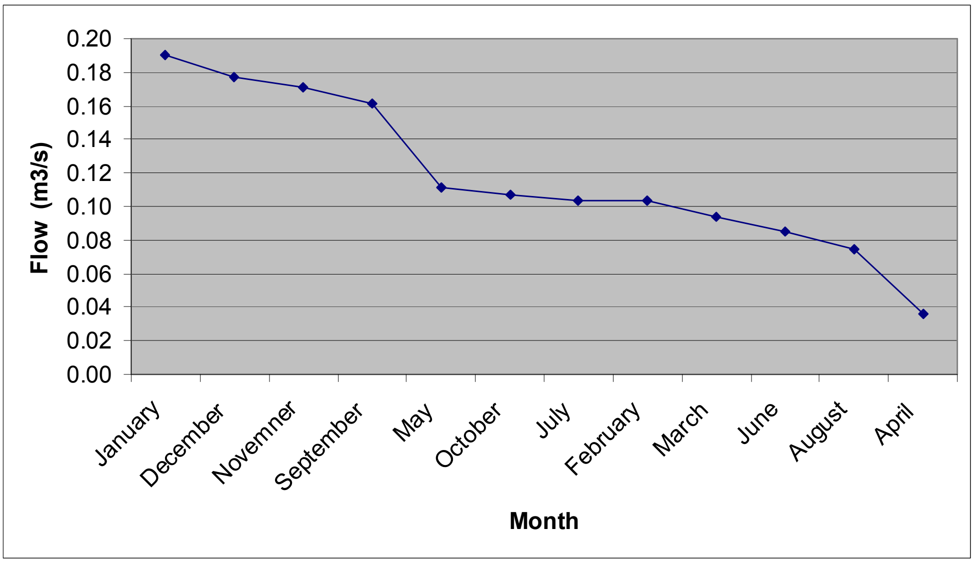
5.4.2.4 *End Use Possibilities*

The generated electricity from a micro-hydro plant in Govig could best be used for heating purpose (both space heating and hot water) and electricity to drive a Heat pump. The electricity supply will replace the use of oil as boiler fuel. With an efficiency of the electricity heated boiler of 90%, the community & holiday house need 5900 kWh/month electricity. This demand can be covered by the micro-hydro scheme which could supply 6,000kWh/month. The limited generation capacity restricts the use of hydro electricity to replace grid electricity for lighting and appliances in houses. It would also increase the investment cost to supply electricity with stable frequency and voltage as it would be required for electrical appliances.

5.4.2.5 *Hydraulic Potential and Plant Capacity*

Flow*:* The flow, measured at the nearby intake location using bucket method, was found to be 75 l/s in August. This measured flow has also been verified by calculating the annual mean flow with the rain fall method. This calculation resulted in 118l/s. The villagers involved in fishing works also revealed that reasonably good flow is available in the lake even in the driest months. In the winter season, flow is quite high and therefore the design flow is taken as 100 l/s which should be available for 8 months.

Figure 5.9: Approximated Flow Duration Curve for Loch Geodha Beag



Source: Calculation by the SESAM Hydro group

Head: GPS, Abney level, compass and measuring tapes were used for the site survey. The available maximum gross head between the lowest possible powerhouse site and the intake was found to be about ***13 m*** .

Site Selection: The intake location is fixed at the point of stream discharged from the lake, while the power house is located at the lowest point of the stream before discharge to the sea. Nevertheless, a distance should be maintained from the coastal line, to prevent damage on the power house when storm occurs.

Plant Capacity: Given the flow, the head and overall efficiency, the scheme can be installed with a capacity of 8 kW. About 6000 kWh/month electricity could be generated from this proposed plant.

5.4.2.6 ***Project Financial Analysis***

The proposed design features are aimed at arriving at a reliable plant with reasonable cost. The total cost of the scheme is expected to be £ 45,565 and per kW cost would be £5,677. Financial analysis has been worked out and concludes its viability with a positive NPV £146 and 6.5 % IRR, considering 30% subsidy from SCHRI and income from the sale of Renewables Obligation Certificates (ROCs) and Climate Change Levy Exemption Certificate (LEC). Without the grant, ROCs and LEC, the project does not seem financially viable.

Local contribution like voluntary labor to construct the Power house, intake and penstock support pillars could help to reduce the total cost. The amount of local contribution could be £6776. This reduction of capital investment would greatly increase the viability of the project, increasing the predicted Internal Rate of Return from 6.5 % to 8.5 %. Details of financial analysis are presented in Appendix 5.4.1 to 5.4.4.

5.4.3. Option 2(a): Heat Pump (holiday house)

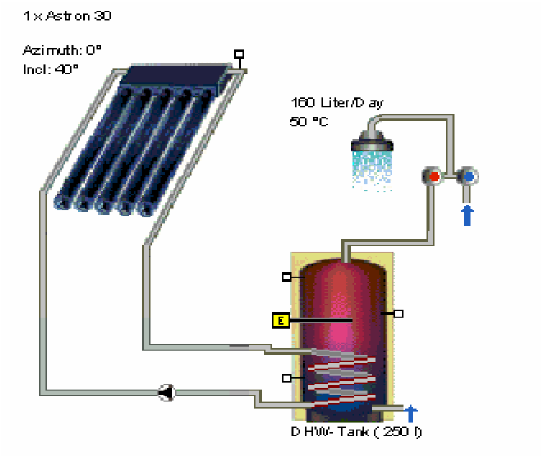
A heat pump for space and water heating would be a good opportunity for the new holiday home (under construction), if the micro hydropower plant was not be implemented. A 4kW Ground Source Heat Pump (GSHP) of the borehole type is considered in this study as appropriate. Due to rocky area and small yard space around the home, a horizontal loop type heat exchanger based GSHP is not applicable at this site. Two other alternatives of heat pumps using sea water and lake water as heat source are not viable due to the long distance from sea and the low temperature (2°C) of lake water in winter respectively. An air source heat pump is not considered here due to a 30% lower seasonal performance factor. With an initial investment of approximately £6500 (considering 30% grant) for a GSHP for the 54 m2 holiday home a heat pump is financially not viable and detailed financial analysis are presented in Appendix 5.4.6.

5.4.4. Option 2 (b): Solar Water Heating System (holiday house)

As the holiday house is mostly occupied during the summer, a SWH system will be an ideal solution for hot water demand due to its high performance in the summer months. An active system with electrical immersion is recommended (see figure5.4.3). One 3m^2 collector will be mounted at the south roof of the building, and kept at the same angle as the 40^o roof angle. A 250 liter tank is recommended to be installed in the loft. The total hot water energy consumption is calculated at 1,840kWh, considering that the holiday home is occupied for 6 month/year from spring to autumn. 1,465kWh comes from SWH system, accounting for 80% of hot water energy demand. The total investment cost is expected to be 4000£ (Appendix 5.4.5). Considering its 20 years life time and 30% of investment grant, NPV (Net Present Value) of the SWH system will be -1858£, the unit cost of Solar energy will be 0.18£/ kWh (Economic parameters and calculation see Appendix 5.5.3 and Appendix 5.5.4).

Due to the high investment cost, this project is not economically feasible but it can help to save CO2 emission approximately 791kg/yr. If there would be higher percentage grants or the investment could be reduced, SWH will be a good option for supplying hot water to holiday houses in North Harris area.

Figure 5.10: Solar Water Heating system



Source: SESAM by using TSol software

5.4.5. Conclusion

The Micro hydro scheme seems technically feasible and financially viable when considering the grant, income from renewable obligation certificates (ROCs) and climate change levy exemption certificate, and it carries all potentialities for implementation. The residents also showed interest in the implementation of Govig Micro Hydro project. Local contribution from the community could play a vital role to increase financial viability of the hydro project. Based on the study result, Option 2 (a) and (b) seem technically feasible; but it is not financially viable due to high investment cost. Therefore Electricity from micro hydro would be the best option to meet the heating demand of all households including holiday home.

5.5 Bunavoneadar Small-Hydro Project

5.5.1. Introduction

This study assesses two alternatives for a small hydro project at Bunavoneadar, considering technical and financial aspects. There are two proposed intake locations, the 1st option is at the old dam with 32 m available gross head, and the 2nd option is set at a higher point with 65 m available gross head. With a design flow of 400 l/s and overall efficiency of 60%, a small hydro scheme with the capacity of 75 kW (1st option) or 153 kW (2nd option) can be developed in Bunavoneadar. There was a hydro scheme installed at this site to supply electricity to the former whaling station, which was built in 1904 and closed in 1952. After closing the whaling station, this hydro station was also stopped. Some penstock pipe and old dam can still seen at the site. The proposed site is located at Bunavoneadar in the western part of North Harris and it lies at the costal area of Atlantic Sea. This site can be accessed at the secondary road (B 887). However, there is no road established yet to both selected intake locations.

5.5.2. Salient Features of the Project

Project	Bunavoneadar Small Hydro Project	
Location	Bunavoneadar (near to Whaling Station)	
Source name	Abhainn Eadarra river	
Measured Flow and Date	300 l/s, Aug 28, 2005	
Design flow (l/s)	400	
	1st option	**2nd option**
Annual Average Flow (l/s) (calculated from area rainfall method)	505	491
Intake location	NB 12954 BNG 04404	NB 13078 BNG 05120
Catchment area (km^2)	10.8	10.5
Gross head in (m)	32	65
Canal length (m)	0	625
Power house location	NB 13075 BNG 04221	
Installed capacity (kW)	75	153
Energy generated (kWh/year)	611,500	1,184,950
Overall efficiency %)	60, using Francis	60, using Cross flow
Penstock Pipe (m)	230 m mild steel, Ø 625 mm,	330 m mild steel, Ø 700 mm,
Turbine	Francis, 98.6 kW shaft power	Cross flow, 190 kW shaft power
Generator	115 kVA, 3-Phase Synchronous Generator,	230 kVA, 3-Phase Synchronous Generator,
Powerhouse	Stone masonry in cement mortar with slate roofing	
Tailrace canal	10 m, open canal discharged in sea	
Transmission	200 m length (Grid Connection Length)	
Total Project cost: (£)	320,081	592,618
Cost per kW (£)	4,253	3,876
End-Uses	Supply to the grid	
Grid connection	Possibilities of grid connection	
Ownership	North Harris Trust	

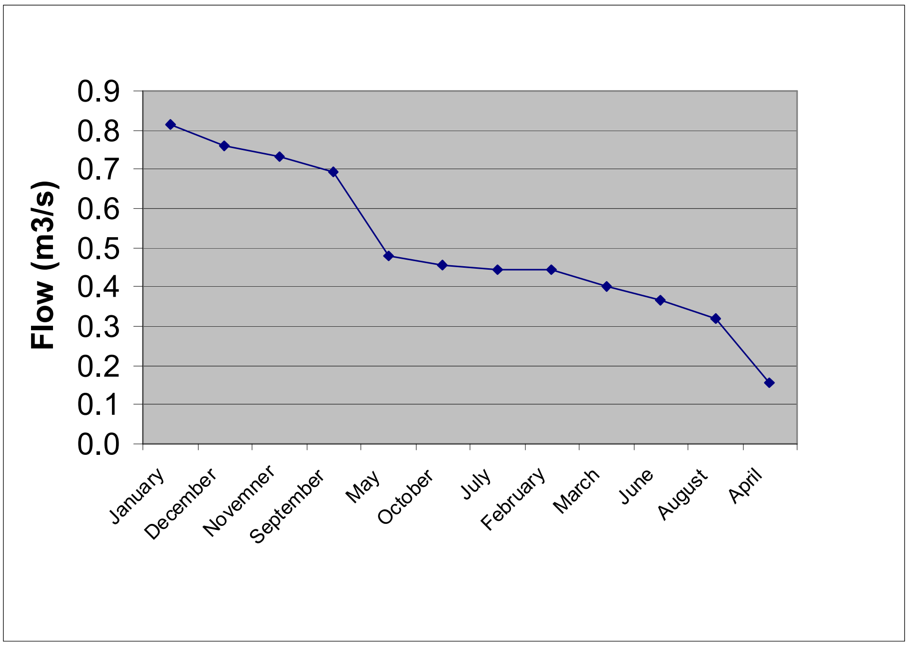
5.5.3. End Use of Generated Electricity

Electricity generated from the small hydro scheme at Bunavoneadar could be supplied to the grid, so that the North Harris Trust would be financially benefited by selling the electricity. 33KV capacity of local grid is also available within 200m from the proposed powerhouse.

5.5.4. Hydraulic Potential and Plant Capacity

Flow*:* The flow of Abhainn Eadarra river was measured at 300 l/s by using the weir method. Based on the rainfall data analysis, an approximated flow duration curve at the old dam site is shown in figure 5.11 below. In order to optimize the energy generation from the plant, the design flow is taken as 400 l/s which is available for 8 months with the consideration of 30 l/s for the fishery conservation purpose.

Figure 5.11: Flow Duration of Abhainn Eadarra River



Head: Measured head for the 1st option intake location is 32 m, while for the 2nd option is 65 m.

Site Selection: The first option of intake location has been selected at the existing dam and the distance from the road is relatively short. The second option of intake location is further up the hill. For this option, the capital investment is higher, due to longer penstock and additional components like canal construction. An access road of about 1 km should be provided to the intake. This option has some advantage as due to the high head of 65 m the generation capacity is doubled compared to the first option. The location of the power house is fixed at the lowest point nearby the stream discharge to the Atlantic sea. Locating of the power house at this point is cost-wise beneficial, as it minimizes the penstock length.

Figure 5.12 Flow measurement during the field study

Source: Photograph is taken by SESAM hydro group

Plant Capacity: The 1st option gives an installed capacity of 75 kW and would be able to generate up to 611,500 per year. The 2nd option provides double capacity of 153 kW and the electricity generated would be 1,184,950 kWh per year.

5.5.5. Project Financial Analysis

The total cost of the scheme is expected to be £ 320,081 (1st Option) and £ 592,618 (2nd option) respectively. The project could benefit through the sale of Renewable Obligation Certificates (ROCs) and Renewable Levy Exemption Certificates (LECs).

A detailed financial analysis has been worked out and concludes the financial viability with a positive NPV of £48,714 and 9.6 % Internal Rate of Return (IRR) for the first option and a NPV of £185,518 and 10% Internal Rate of Return (IRR) for the second option without grant. Pay back period of the investment would be 13 years (1st option) and 10 yrs (2nd option). Grant assistance of 40% capital cost would greatly increase the viability of the project increasing the predicted Internal Rate of Return from 3 % to 9.6 % (1st option) and 5.2 % to 12.7 % (2nd option) Details of financial analysis are presented in Appendix 5.5.1 up to 5.5.2.

5.5.6. Conclusion

The small-scale hydro power plant in Bunavoneadar would be an option to generate income for the North Harris Trust. The scheme seems to be technically feasible and financially viable with considering the grant; however a detailed survey and cost estimation is required to derive more precise capital investment. Both options seem to be possible to develop.

5.6 Airde Mor Wind Project

5.6.1. General Description and Conditions

A feasibility study done by the Western Coast Energy Ltd[1] identified three (3) possible sites with wind speeds of about 9m/s which were further studied by our team: Aide Mor (NGR 102750, 907750); Loch Leosail West (NGR 104970, 908640) and Loch Leosail South (NGR 106200, 907700). Our site investigations and further deliberations with North Harris Trust (NHT) revealed that the most feasible site is Aide Mor which lies 1.5km west of the Amhuinnsuidhe Castle. The reasons for selection are: (i) there are no eagles nesting in the area, (ii) the site is relatively near to the road and the 33kV transmission line and (iii) turbines can be installed at least 500 m away from settlements

Nevertheless the site is within the Special Protection Area and the National Scenic Area and therefore the consent with the SNH is required.

The site conditions are as given in Table 5.4

Table 5.4: Site Conditions for Airde Mor[2]

Average Wind Speed at 50m height above ground	8.88 m/s
Wind shear exponent[3]	0.16
Wind Speed at 10m height	6.9m/s
Average atmospheric Pressure	100 kpa
Annual average temperature	8.01 ^{o}C

As there is no long-term wind data available for the site, wind speeds and roses had to be taken from the European Wind atlas. This may result in inaccuracies in the energy yield and consequently in the economic calculations. These should be considered as estimations. For the calculations, two (2) Vestas V47 660kW with 50 m hub height have been selected. The technical and other data are shown in the Appendix 5.6. Energy yield, noise, flickering, the visual impact and the economic feasibility of the project have been simulated and calculated with WindPRO 2.4 software.

Two different sites have been analyzed, one that is as near as possible to the road to avoid excessive construction cost for an access road. This site, however, is technically not the optimum, as it is behind some small hills. The technically better site would be on top of Sidhean Mor, approximately 1.85km away from the main road.

[1] Final Report by Western Coast Energy Ltd for North Harris Trust , April 2004
[2] Source: http://eosweb.larc.nasa.gov/cgi-bin/sse/retscreen.cgi?html
[3] The wind shear exponent is the factor that takes into account of variation of wind speed with particular height

5.6.2. Option 1: Location below the Hill

5.6.2.1 *The Network and Accessibility*

The wind turbine site is situated about 1.85 km away from the B887 road. This distance is necessary to avoid the noise and flickering effect to nearby house and the road. This road is tarmac and can be used by a trailer for the transportation of the sections of the turbines and its other components. However, some narrow bends may make the transport of large turbine components difficult. Therefore the two 660 kW Vestas turbines have been selected for the site. Nevertheless the access has to be approved by the manufacturer. An access road linking the turbine site to the main road has to be constructed. However, there is a fairly flat opening that is proposed for a gravel road to support operations during construction. A 33 kV line runs approx 2.71 km away from the site, which up to now is only in single phase. The distance from the site to the nearest single phase grid connection is about 1.91km. This single phase transmission would have to be upgraded to three phase for about 0.8 km, where the three phase transmission is available.

5.6.2.2 *Energy Yield*

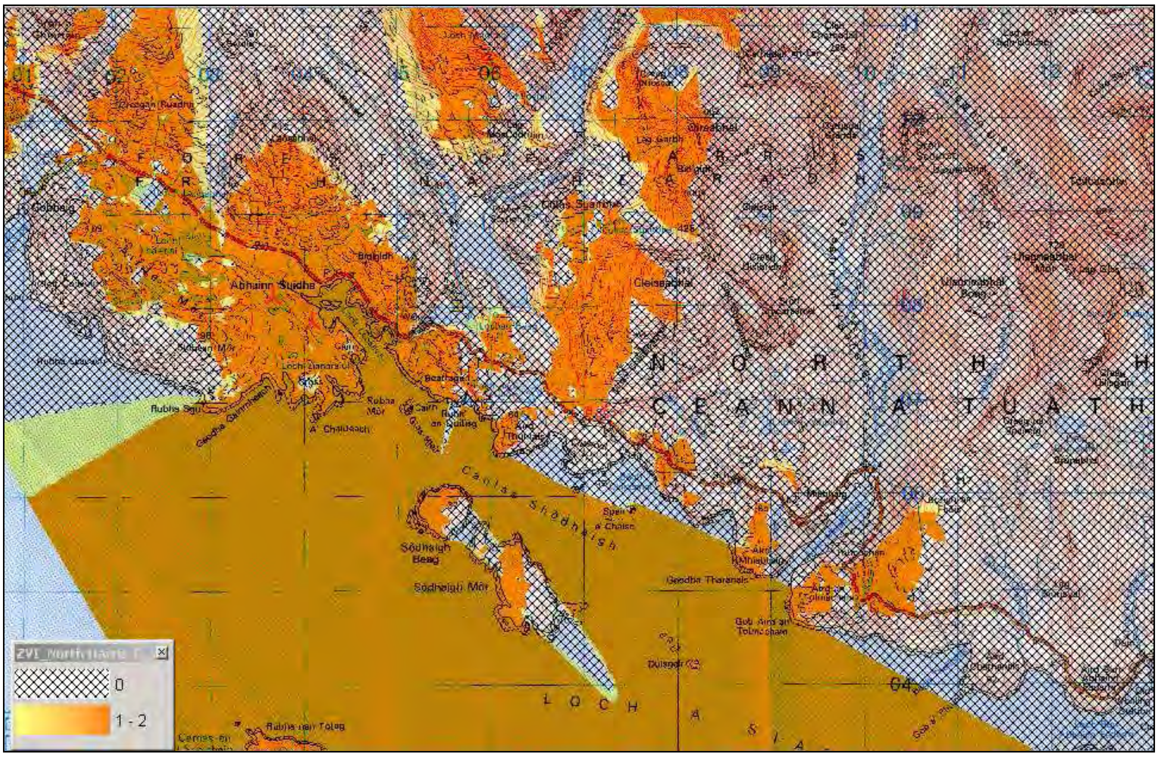
The calculations of energy yield gave an energy output of 5,008,000 kWh per year. As mentioned before this result might be inaccurate due to the unavailability of site-specific wind data. The total CO_2 savings out of this configuration is beset at **2,516** tons/year.

5.6.2.3 *Environmental Aspects: Visual Impacts*

Zones of Visual Influence

These are areas where anybody will be able to see the wind turbines. The map below shows the areas from which the turbines are visible.

Figure 5.13: Zones of Visual Impact (Option 1)



Source: SESAM by using WindPro software

The hatched (0) areas are places where no turbine can be seen, whilst in the others (1 – 2) only one or two turbines can be seen.

Photomontages have been produced with photographs from key points that were thought to be visually influenced by the presence of the turbines at the proposed site. These points are shown in Table 5.5:

Table 5.5: Points from where photographs have been taken

POINT	OSGB Reference Point	
	NB	**BNG**
300 m from Amhuinnsuidhe Castle on B887 Passing Place	104648	908115
Passing Place by first house after WTG site on B887	102800	909089
By Fishing Pier at Tarbert	112876	902356
South Harris Beach	106750	900100

The following photomontages show the visual appearance of the turbines from these points:

Figure 5.14: Wind Turbines as seen from a B887 Passing Place West of the Castle

Source: SESAM by using WindPro software

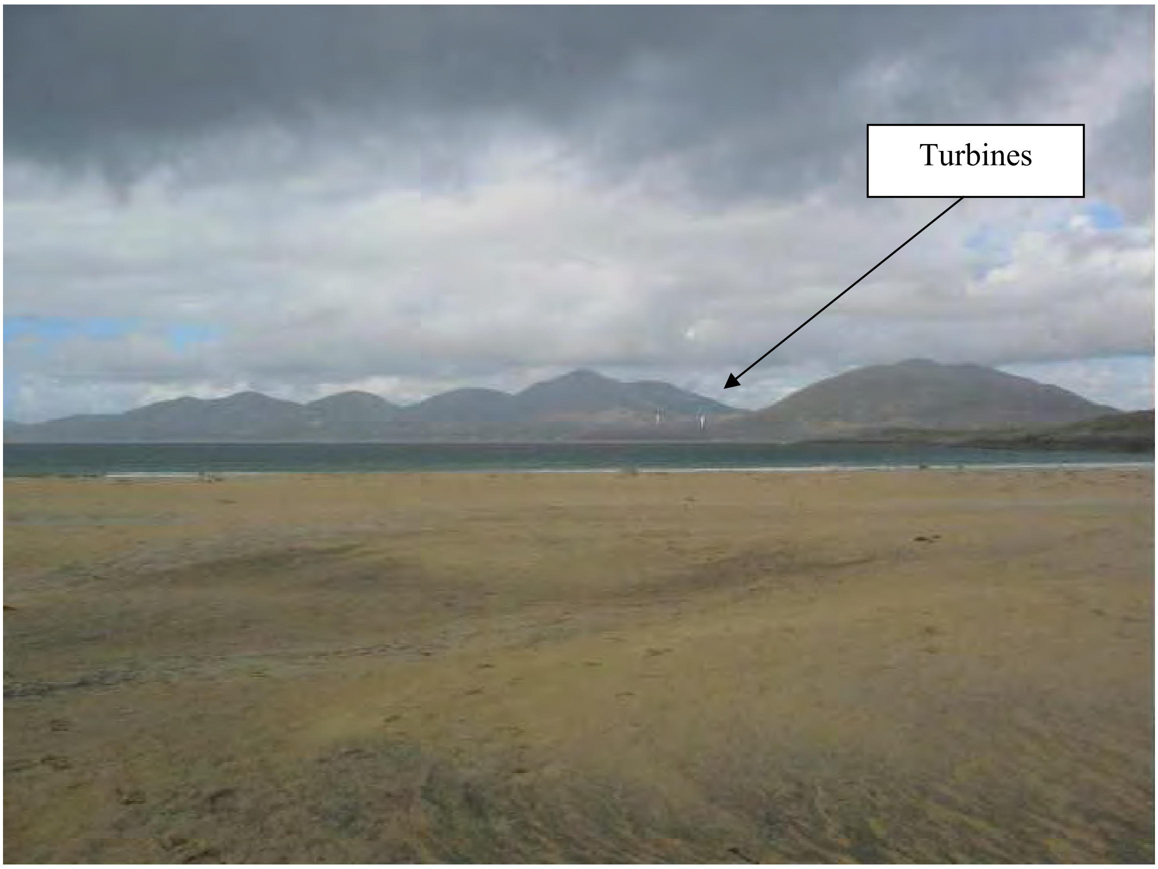
Figure 5.15: Photomontage by a house on B887 after turbine site

Source: SESAM by using WindPro software

Figure 5.16: Photomontage by Culnah-Aird close to A859 at Tarbert

Source: SESAM by using WindPro software

Figure 5.17: Photomontage from South Harris Beach

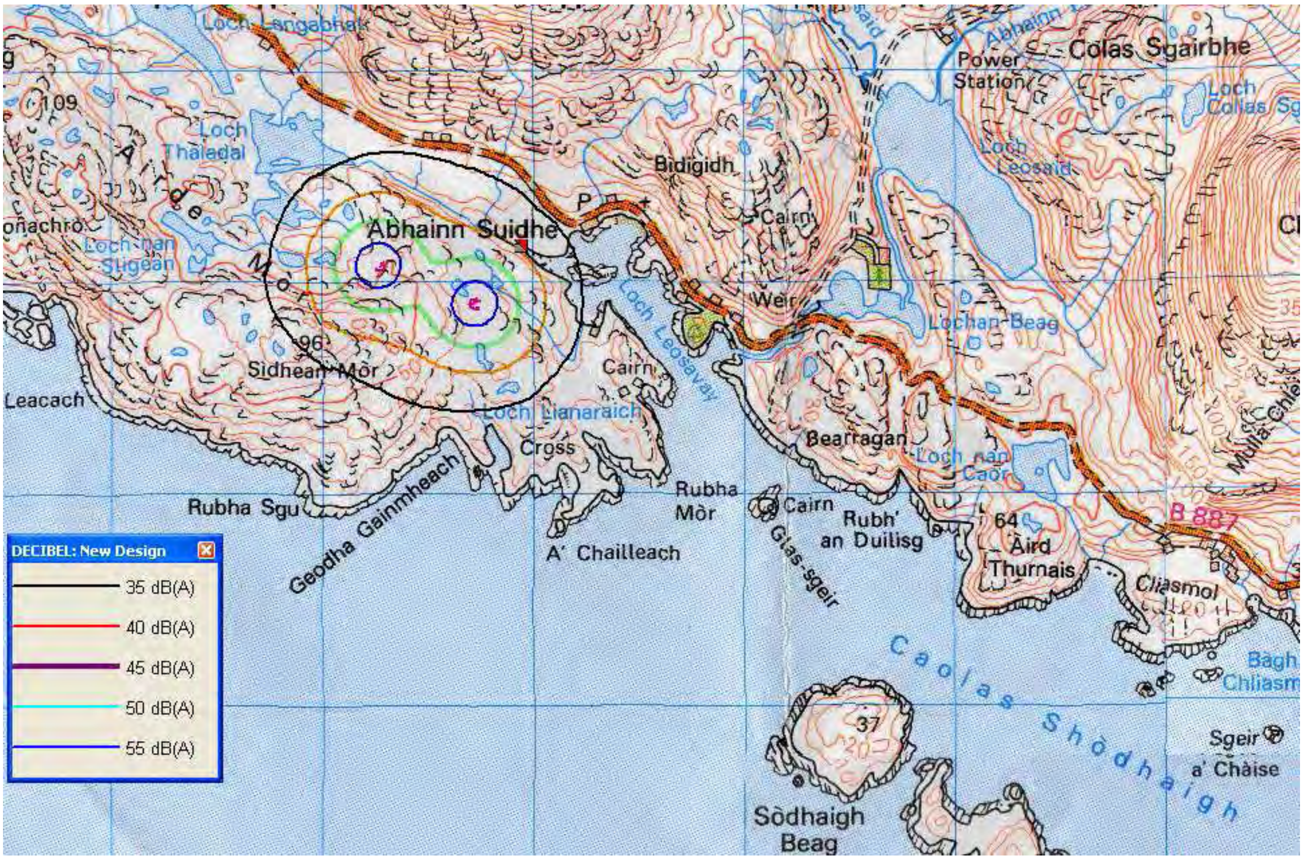


Source: SESAM by using WindPro software

5.6.2.4 *Environmental Aspects: Noise*

WindPRO simulation revealed that the nearest household is just beyond the allowable 35dB noise line. The noise zones are shown in the figure below.

Figure 5.18: Noise Sensitive Zones

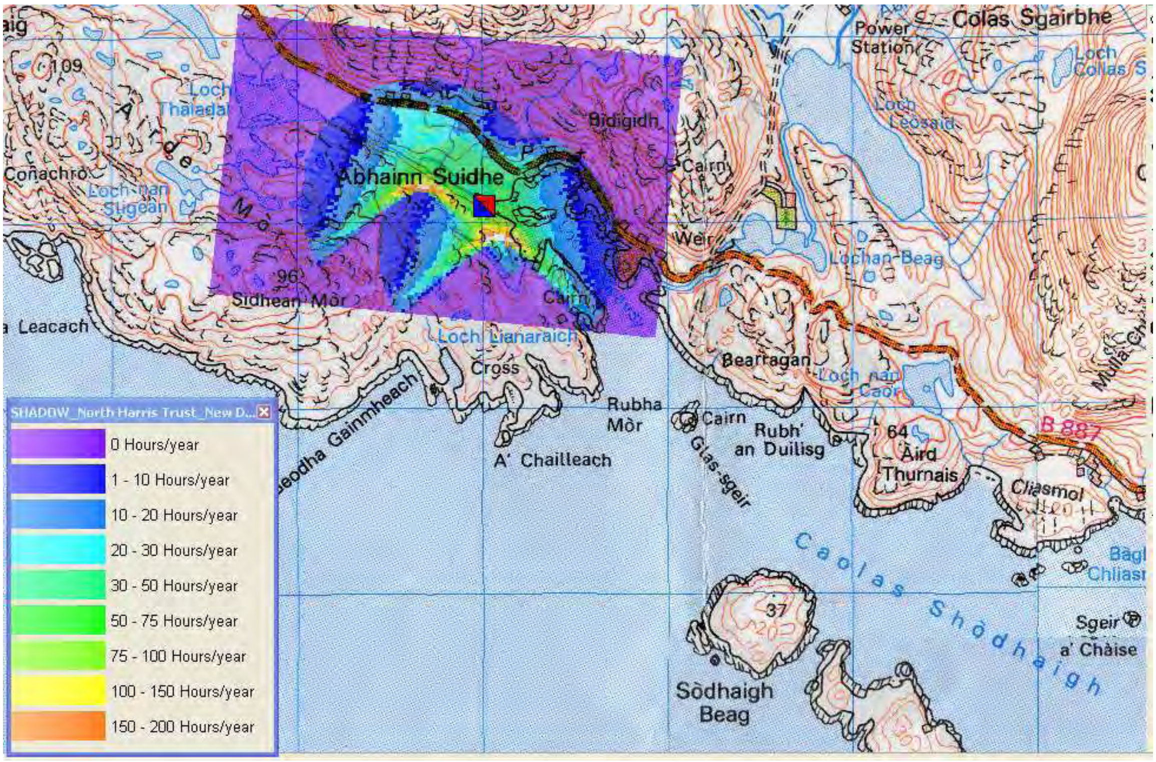


Source: SESAM by using WindPro software

5.6.2.5 *Environnemental Aspects: Flickering*

In the worst case (wind direction always moving with the sun, sun always shining) the nearest house will be affected by flickering less than 20 hours per year, practically this means, that there is no impact by flickering. The colour codes in Figure 5.19 give an insight as to the hours in a year that any house within the shaded area may experience flickering from the WTGs

Figure 5.19: Zones of Shadows (Flickering)



Source: SESAM by using WindPro software

5.6.3. <u>Wind turbine development at Airde Mor (Option 2)</u>

5.6.3.1 ***The Network and Accessibility***

The wind turbine site is situated at the top of the hill, with turbines 1 & 2 about 1.2 and 2.3km away from the B887 road. As discussed in Option 1 above, the turbines have to be connected to the nearest single phase grid point by underground cable about 3.56 km away from turbine 1. The rest of the cabling will be by overhead on to the 33KV three (3) phase line as mentioned in Option 1. Energy yield, noise, flickering, the visual impact and the economic feasibility of the project have also been simulated and calculated with the same software.

5.6.3.2 ***Energy Yield***

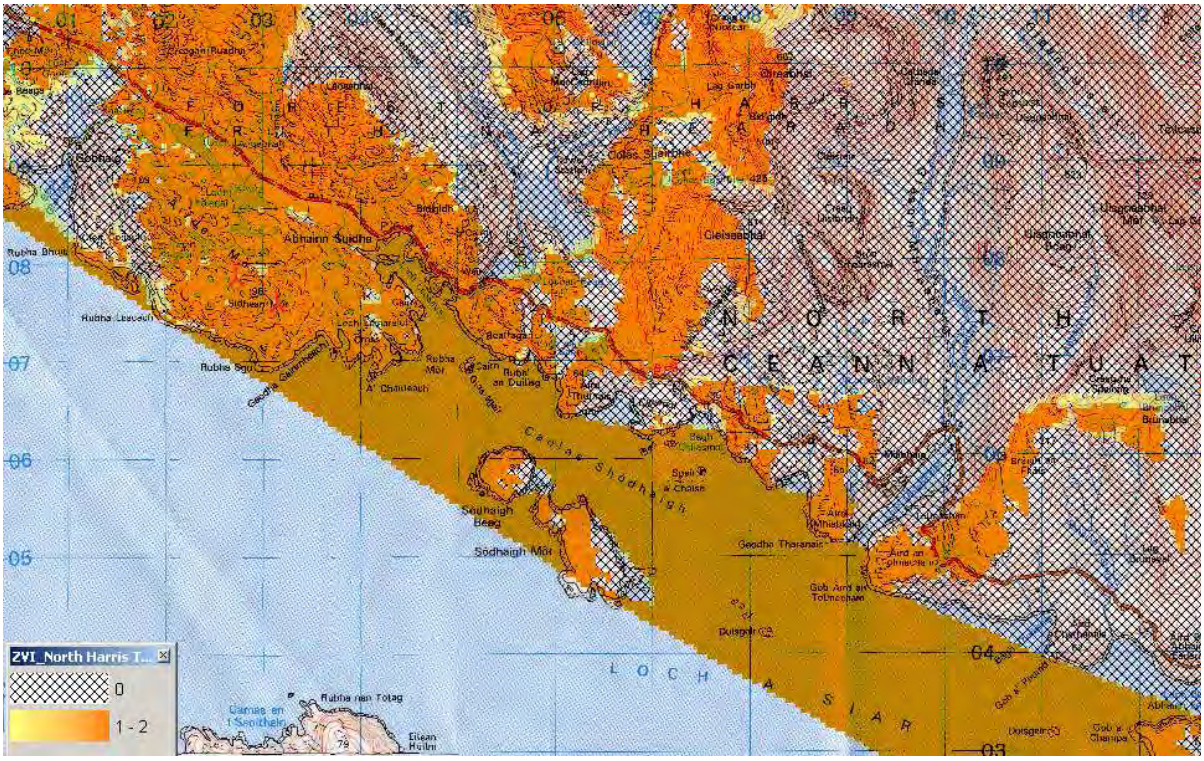
The calculations of energy yield gave an energy output of 5,263,000 kWh per year. As mentioned before this result might be inaccurate.

5.6.3.3 ***5.2.3.3 Environmental Aspects: Visual Impacts***

This was analysed from the points mentioned in Option 1 above that were thought to be visually influenced by the presence of the turbines at the proposed site.

Zones of Visual Impact

Figure 5.20: Zones of Visual Impact (Option 2)



Source: SESAM by using WindPro software

The following photomontages show the visual appearance of the turbines from these points:

Figure 5.21: Wind Turbines as seen from a B887 Passing Place West of the Castle

Source: SESAM by using WindPro software

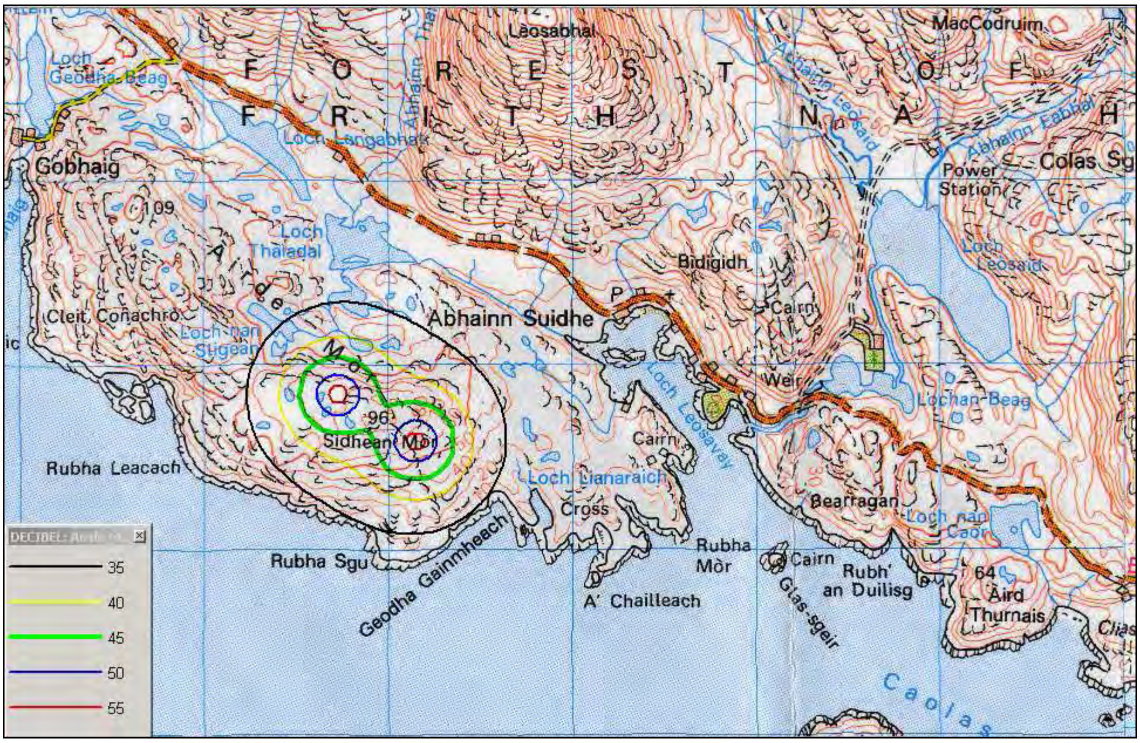
Figure 5.22: Photomontage by Culnah-Aird close to A859 at Tarbert

Source: SESAM by using WindPro software

5.6.3.4 ***Environmental Aspects: Noise***

WindPRO simulation revealed that there is no noise disturbance on any household at the immediate vicinity of the turbines since they are way beyond the allowable 35dB noise line. The noise zones are shown in the figure below.

Figure 5.23: Noise Sensitive Zones

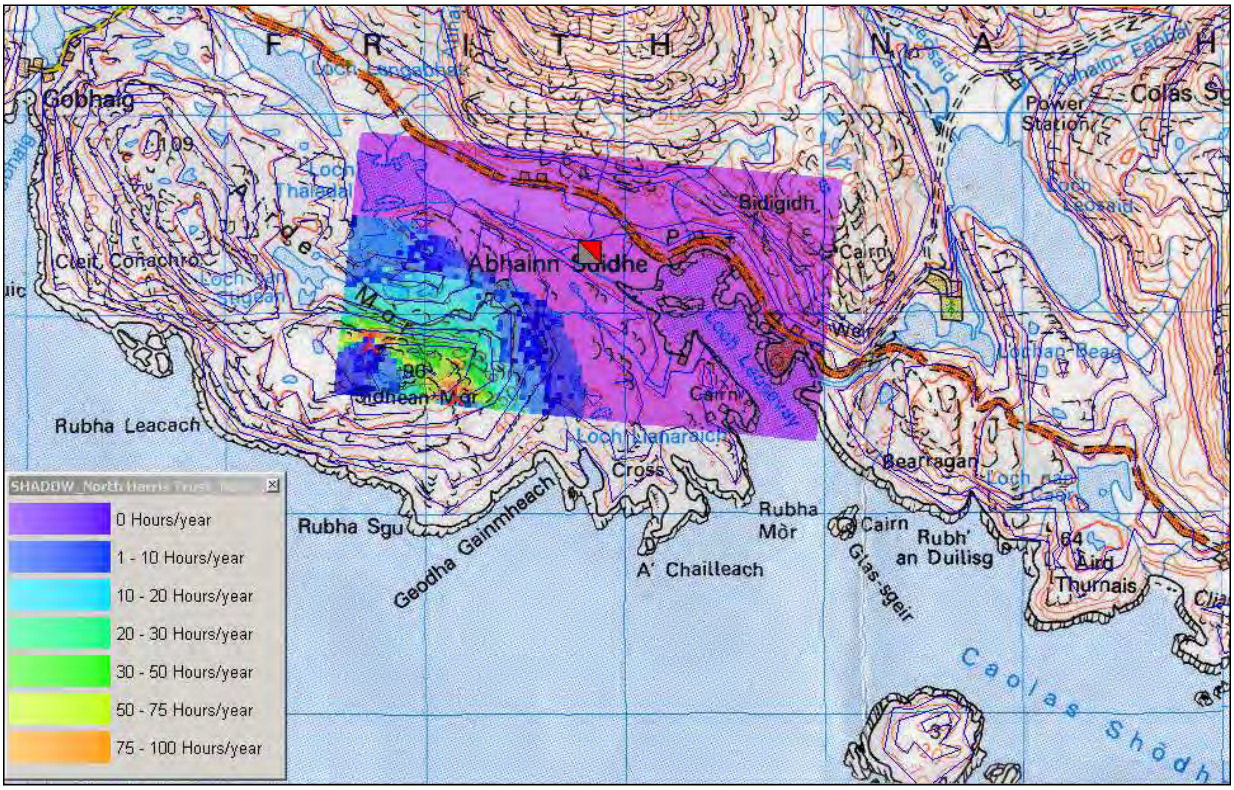


Source: SESAM by using WindPro software

5.6.3.5 ***Environmental Aspects: Flickering***

With all the assumptions mentioned in Option 1, no house be affected by flickering from any of the turbines at this particular site. The colour codes in Figure 5.24 give an insight as to the hours in a year that any house within the shaded area may experience flickering from the WTGs

Figure 5.24: Zones of Shadows (Flickering)



Source: SESAM by using WindPro software

5.6.4. <u>Economic Viability</u>

5.6.4.1 ***General Description***

In carrying out the financial analysis a number of facts and figures were assumed and this included: Tax: 0% tax allowances on community owned RE projects. The Interest_rate was taken as 6.4% and Inflation: 2%.The Incentives towards renewable energy_are:

- ROC potential value of 45£/MW and this value continue to decline down to 35 £/MW in year 20
- Climate Change Levy of 4.3£/MW and
- Market Price to Grid = 20 £//MW
- Grid Connection costs of £600 per meter length

- road construction is £250,000 per km. These high cost in construction are based on quotation for site specific conditions are subject to variation during the actual tendering.

5.6.4.2 ***Option 1: Turbines Below the Hill***

Turbines are to be located just down the hill, the distance for road construction to the tarmac road is 1.85km and the total cabling to the 3-phase substation is 2.71 km**.**

The annual energy output under the given site conditions for the two Vestas V47 660kw turbines is 5,008,000 kWh. The total investment for the project is **£**1,614,790.00 as detailed in Table 5.7. The financing composition is given in Table 5.8 where by different sources of funds have been put together based on Investment Policy by HICEC. Table 5.6 gives the summary of various grants and loans that can be extended by HICEC to NHT as per investment policy.

Table 5.6 Grants and Loans by HICEC[1]

Project Stage	Purpose of Assistance	Amount (£)
Start Up	Grant Assist with costs of setting up, information dissemination, etc	2,000
Feasibility	Grant to assist with cost of exploring technical and social feasibility study	15,000
Pre-Planning Consent	Grant converted to soft loan convertible to shares (interest rate 4%)	50,000
Post- Planning/Construction	Soft loan recovered in 10 years (interest rate 4%)	200,000

Thus the North Harris Trust has to acquire a loan of £ 1,347,790.00 from other sources (i.e. the Banks). Given the interest rate of 4% interest rate for loan extended by HICEC and 6.4 % rate for loan from other sources coupled with the inflation rate of 2% and various operation and maintenance costs, the calculated net profit before tax per year is at £159,100. The payback period of 6.7 years and the Net Present Value (NPV) is £2,141,402. The financial analysis also gives IRR as 15% which makes the project to be feasible. These cost and profit estimates are based on the average values obtained from different sources and are treated as

[1] Source: http://www.hie.co.uk/hicec-investment-policy.doc

best estimates for investment appraisal. The precise investment costs are to be obtained and evaluated by getting actual tendered/quotation prices.

5.6.4.3 ***OPTION 2: Turbine at the Top of the Hill***

Turbines are to be located at the top of the hill, the distance for road construction to the tarmac road is 2.3km and the total cabling to the 3-phase substation is 3.56 km. The annual energy output for same turbines is 5,263,000 kWh. The total investment for the project is **£**1,770,940.00 as detailed in Table 5.4. The financing composition is given in Table 5.5. Adopting the same financing structure as Option 1 then the North Trust Fund has to acquire a loan of £ 1,503,940.00 from other sources. The calculated net profit before tax per year is at £161,800 with a payback period of 7.1 years and NPV is 2,176,275. The financial analysis also gives IRR and ROI as 15% which also makes the project to be feasible.

5.6.4.4 ***Comparison of the two options and Conclusion***

Figure 5.25 and Figure 5.26 shows the annual liquidity for Option1 and Option2 respectively over the 20 years. Furthermore, Table 5.4 shows comparison of two options in terms of investment cost and Table 5.5 shows the financing structure for the two options

Figure 5.25: Annual Liquidity for Option 1

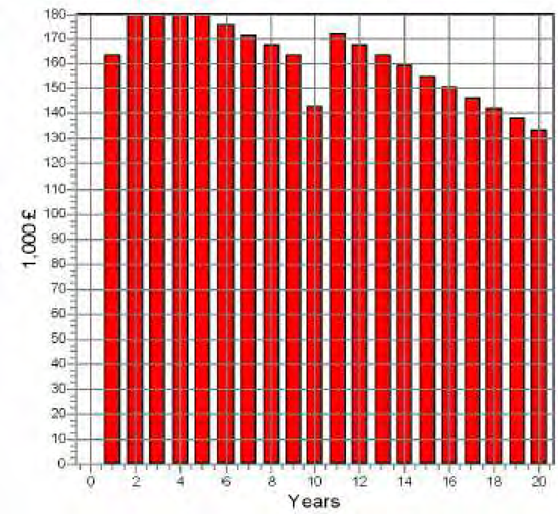


Figure 5.26: Annual Liquidity for Option 2

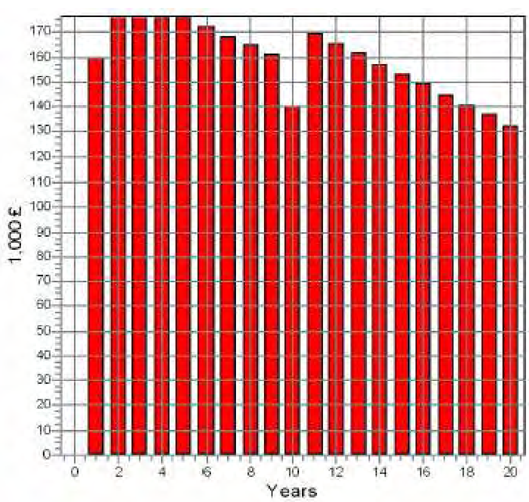


Table 5.7: Total Investment Costs

No.	Description	OPTION 1 Amount (£)	OPTION 1 Percentage of Total Investment	OPTION 2 Amount (£)	OPTION 2 Percentage of Total Investment
1	Turbine Components	726,000	45%	726,000	41%
2	Civil Works	145,200	9%	145,200	8%
3	Road Construction	462,000	29%	575,000	32%
4	Grid Electrical Costs	133,200	8%	165,600	9%
5	Project Management	14,520	1%	14,520	9%
6	Installation Costs	14,520	1%	14,520	1%
7	Power Line Upgrading	46,250	3%	57,500	1%
8	Legal/Development Costs	36,300	2%	36,300	3%
9	Bank Fees	14,520	1%	14,520	2%
10	Interest During Construction	21,780	1%	21,780	1%
Total Investment Costs		1,614,790	100	1,770,940	100

Table 5.8: Financing Structure

No.	Description	OPTION 1 Amount (£)	OPTION 1 Percentage of Total Investment	OPTION 2 Amount (£)	OPTION 2 Percentage of Total Investment	Interest Rate
1	Grant for Start up from HICEC	2,000	0.12%	2,000	0.11%	0
2	Grant for Feasibility Study from HICEC	15,000	0.93%	15,000	0.85%	0
3	Soft Loan from HICEC for Pre-Planning	50,000	3.10%	50,000	2.82%	4%
4	Soft Loan from HICEC for Post Planning Construction	200,000	12.39%	200,000	11.29%	4%
5	Loan from other Sources	1,347,790	83.47%	1,503,940.00	84.92%	6.4%
	Total Financing Required	1,614,790	100.00%	1,770,940	100.00%	

Table 5.9: Results of economic assessment

Comparison Item	Option 1	Option 2
Energy Output (MWh)	5,008	5,263
Investment (£)	1,614,790	1,770,940
NPV (£)	2,141,402	2,176,275
IRR	15%	15%
Payback Period (years)	6.7	7.1
Annual Profit before tax (£)	159,100	161,800

As shown in Table 5.6 there are only small differences between the two options as far as the profitability of the projects is concerned. These differences mainly depend on the cost of road construction and grid connection as well as the energy output of the turbines at the two different sites. As the assumed investment cost is still based on estimations and the energy yield could not be calculated with wind data that have been verified with on site measurements the results are not sufficient to decide for the one or the other site. It is therefore recommended that wind measurements are carried out on the site to allow a proper calculation of the energy yield.

[2] Soil Survey of Scotland 1982: Sheet 2, The Outer Hebrides

5.7 Domestic Solar Water Heating System

One household living in Govig is selected as the case study to show how solar thermal technology could be applied in North Harris area. This household has 5 residents, 2 adults and 3 children and an oil boiler is used for the central system to supply the hot water and space heating. This system annually consumes approximately 2500 liters of oil with an estimated cost of £733.

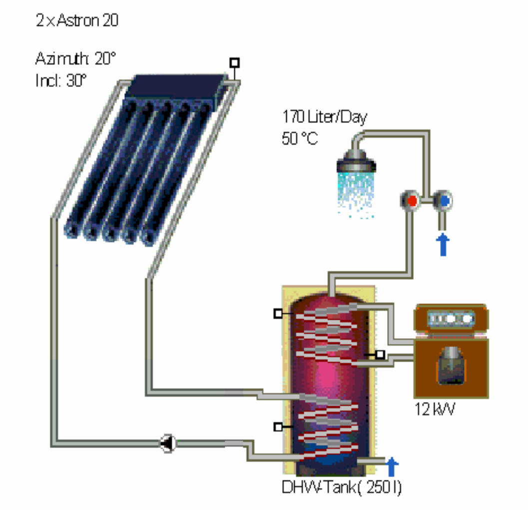
1) Hot water consumption	
Number of Persons:	5 persons (2 adults, 3 children)
Water consumption at 50°(Appendix 5.7.1):	per adult 40 l/d per child 30l
Household consumption:	170 l/d
Duration:	whole year
2) Building feature	
Available mounting surface:	38.4 m^2 Length 8m* Width 4.8m
Inclination:	30°
Azimuth angleβ:	South west 20°, no shadow
Roof type:	Slopping roof

5.7.1. Installation

The present oil central system supplies hot water and space heating, for this reason active system with double coil tank is recommended (see Figure 5.27).

This system installation incorporates a double coil hot water storage tank. The energy input for the bottom coil is from SWH system, the liquid in the collector loop is a special high temperature anti freezing/ anti corrosion liquid. The top coil gets energy from the central oil heating system which compensates for the cloud or rainfall weather when the solar collector can not operate at its full potential.

Figure 5.27: Solar Water Heating system



Source: SESAM by TSol software

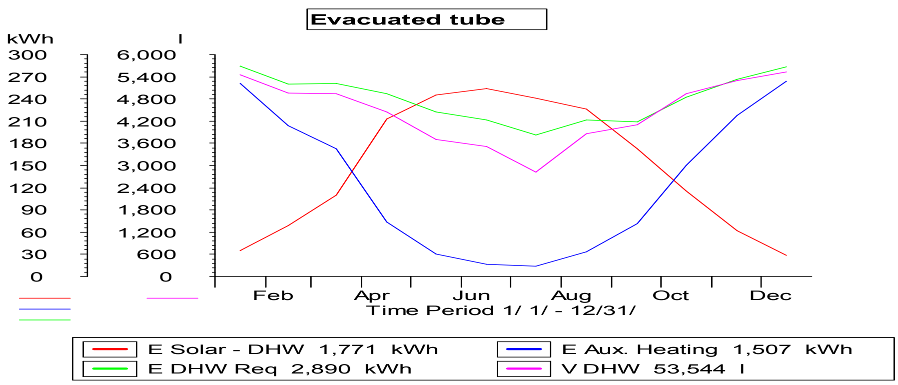
A heat pipe vacuum collector (THERMOMAX-system) was selected in this case study. The heat pipe vacuum collectors were selected for this SWH system due to its high performance in cold and cloudy weather. The area of the collector is 4 m^2, which is based on the combination of local radiation data, the collector inclination and the azimuth angle (Calculation from Tsol software).The collector can be mounted on the south west roof of the building.

Pump system is necessary in such systems where the collector position is higher than tank; it is used to circulate water from the collector to the tank.

It is recommended to install the tank in the loft; the volume of the tank is 250L

5.7.2. Predicted system performance

Figure 5.28: Energy balance



Source: SESAM by TSol software

TSol software was used to predict the SWH system performance under the local weather conditions. The total energy consumption for hot water, including heat losses of the tank, is 3,278kWh/year, the usable hot water energy is 2,890kWh, out of which 1,771kWh/year comes from SWH and 1,507kWh/year from the central oil system. 388kWh/year is heat losses of the tank. The SWH system can cover 54.0% of the annual energy consumption for the hot water supply, especially in the summer from May to September it covers 100% of hot water demand, even in the winter SWH still can provide 10%~30% of the hot water demand. Annual collector surface area irradiation is 1080.05kWh/m^2, energy produced by SWH system is 411.84kWh/m^2, and so total system efficiency is 38.1%.

5.7.3. Economic Analysis

Table 5.10 SWH Price List

Component	No	Price(£)
2m^2 collector	2	1916
Controller	2	660
MS20 Manifold for 20 Tubes	1	330
pump station	1	80
Power supplies	1	25
Tank 250	1	300
Pipe	1	36
Total equipment		3347
Installation		1340
		4700

The investment cost for domestic SWH system is relatively high because of several reasons. Firstly, the collectors suitable for this area is the heat pipe vacuum collectors, its cost is higher than flat-panel collector; Secondly the solar system in UK is higher than other European countries, the same system in Germany cost approximately 2500£; The third reason is the high installation cost, for North Harris area the cost even will be higher due to long-distance pre-investigation cost and transportation.

Table 5.11 Economic Efficiency Parameters

SWH system Life time:	20 year
Investment :	4700£
Grants(30% investment):	1410£
Capital Interest:	6.4%
Energy use Price Increase Rate:	3.0%
Energy supply by SWH:	1771 kWh/year
Oil saving (75% efficiency):	222.6 L/year
Local oil price	0.32£/ L
Oil cost	71£/year
Running cost	10£/year

Considering SWH system 20 years life time and 50% of investment grants, NPV (Net Present Value) of this system is -2400£, unit cost of Solar energy is 0.17£/ kWh (calculation in Appendix 5.7.4)

5.7.4. Conclusion

This case study shows that SWH system can operate well in North Harris area, it covers 100% of hot water demand in the summer from May to September, even in the winter SWH still can provide 10%~30% of the hot water demand. SWH saves 222L oil and saves 600kg CO_2 emission per year. But presently the economical analysis of SWH system is unfeasible. The main reason is its high investment. The potential method to reduce the cost in North Harris area is to get more grants from different agencies. Motivating the local installers is also a useful method to reduce the installation cost. Setting up a demonstration of domestic solar water heating system is also very necessary. It not only shows that SWH system could operate well in this area, but also trains and encourages the potential local installer that they could exploit the market.

Chapter 6: Conclusion and Recommendation

6.1 Conclusion

- From the household survey, more than 80% are of the opinion that more investments should be made in RE projects. And nearly half of the sample population is willing to pay more for energy produced from renewable sources
- High head and rainfall rate supports the presence of hydro potentials in the area.
- Despite the common opinion the weather conditions are still favorable to install Solar Water Heating (SWH) systems in the NHT area.
- Sea water or ground source heat pumps (bore hole type) could be a suitable solution for North Harris Trust houses, a planned holiday home in Govig and the Marine Harvest hatchery.
- Presently biomass could be available from Aline forest for ten years and there is a potential of biomass production in the study area.
- The Micro and small scale hydro schemes in Govig and Bunavoneadar seem technically feasible and financially viable when considering the grant and income from ROCs as well as the climate change levy exemption certificate. It carries all potentialities for further implementation. Bunavoneadar small scale hydro project would be the best option to generate income for NHT by selling the electricity to the grid.
- Biomass can be used to meet a considerable part of the heat energy demand in the area. From the Aline forest, at least 14 GWh/year wood energy, could be obtained for a ten year period. About 325 ha could be planted with the species Willow Hookers (*Salix hookeriana*), Willow ogier (*Salix viminalis*) and Crack Willow (*Salix fragilis*), which could produce about 2,000 oven dry ton wood fuel every year in this type of soil condition.
- There is feasible site to install two medium size wind power turbines in the Airde Mor. For economic evaluations there are small differences between the two options proposed, which this is mainly due to the fact that the cost of road construction and grid connection as well as the energy output of the turbines at the two different sites were based on approximations within reasonable limits.

- The heating demand of the hatchery could be met by using wood fuel. The required wood could be supplied by the Aline forest if the restructuring plan of existing forest would be executed. The energy demand could be minimized by retrieving heat from waste water.
- To make a 'show-case' of the use of renewable energies, the North Harris Trust house can be used to convert the existing space heating and hot water system by using wood chip boiler if supply of wood is conformed. The second option could be the combination of a heat pump and solar water heater. A heat pump is financially viable with a 60%-80% grant. A SWH system could contribute 50~ 60% of the hot water demand.
- Heat pump and solar water heating are technically feasible in this area. The financial feasibility of these technologies depends on the percentage of grant for the initial investment.

6.2 Recommendation

- Limited time has restricted the study team to conduct a more detailed survey and cost analysis of the various projects. Therefore, it is recommended that a more detailed survey and cost estimation should be carried out before the initiation of the proposed projects.
- As wood chips are one of the most promising and feasible potential for heating, a project for sustainable biomass plantation and harvesting should be strategically launched and implemented to ensure the continuous supply of wood fuel.
- As the wind data from European Wind Atlas gave only an approximation for the project at Airde Mor it is recommended, to carry out proper wind measurements at the proposed site to allow proper calculation of the energy yield and other economical data.
- The existing oil boiler of fish hatchery should be replaced by a wood chip boiler. For sustainable supply of wood fuel for the hatchery, North Harris Trust can initiate a program for plantation of short rotation coppice.
- In her own houses the North Harris Trust should set up a demonstration of solar water heating systems and biomass space heating system, showing its installation and operation to end users and potential installers. The unit could also serve for training of installers on the island

Summary of the proposed projects feasible for implementation

Project option	Capacity MWh/ Month	CO2 savings Tons/yr	Cost (£)	IRR %	Time scale	Remarks
Hydro power: - Govig	55	26	45,565	6.5	Immediately	Need detail survey
Bunavoneadar (1st option)	611	263	320,081	9.6	Medium	Need to upgrade the existing grid
Bunavonedar (2nd option)	1,184	510	592,618	12.7	Medium	Need to upgrade the existing grid
Wind power : - Airde Mor (1st Option)	5,008	2,516	1,614,790	15	Medium	Need to upgrade the existing grid
Airde Mor (2nd Option	5,263	2,645	1,770,940	15	Medium	Need to upgrade the existing grid
Biomass: - Hatchery	1,045	334	85,000	25	Medium	Biomass plantation and harvesting programme should be implemented to ensure the continuous supply of wood fuel.
Biomass - NHT	32	14	7,500	12	Immediately	

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Appendices

List of Appendices:

Appendix 1.1: Questionnaire Survey on RE for North Harris Community

Questionnaire Survey on Renewable Energy for North Harris Community – Scotland

We are students coming from University of Flensburg, Germany and pursing a master's programme in Energy Management. Our assignment is to find out if the renewable resources available in this community could be used to generate electricity to primarily meet the demand of the community and the castle. We will be staying in this community for about a month and would be administering this questionnaire to homes to enable us gather primary information for our assignment. We want to assure you that all personal data would only be used for analytical data and would not be shared with a third party. This personal data would be deleted after our assignment is completed.

0. General Information

0.1 Code: 2005______ (Please insert questionnaire number in the space provided)

0.2 Address

____

____

0.3 Interviewer: ________________ 0.4 Date: _____________________

1. Personal Information:

1.1 Sex:

Male ☐

Female ☐

1.2 To which age group do you belong?

Below 16 ☐

16 – 30 ☐

31 - 50 ☐

51- 65 ☐

Above 65 ☐

1.3 How many people live in the house?

__________persons

1.4 What is your position in this household?

Head of the family ☐

Family Member ☐

Other (Please Specify):____

1.5 Is this house owned by your family?

Yes ☐

No ☐

2. Information about the House

2.1 In which year was your house built?

Year of construction: ________

Don't know ☐

No answer ☐

2.2 What is the total floor area of your house?

Floor area: ________m^2 /ft^2 (please underline the unit)

2.3 Does your house have double glazed windows?

Yes ☐

No ☐

Don't know ☐

No answer ☐

2.4 Have your windows been changed since the house was built?

Year of installation: ____________

Don't know ☐

No answer ☐

2.5 Does your house have roof insulation?

Yes ☐

No ☐

Don't know ☐

No answer ☐

2.6 If the answer was yes, what is the thickness of the roof insulation?

Thickness of insulation: _________inch/cm (please underline the unit)

Don't know ☐

No answer ☐

2.7 Does the building have wall insulation?

Yes□
No□
Don't know□
No answer□

2.8 If the answer was yes, that is the thickness of the wall?
Thickness: ____________inch/cm (please underline the unit)
Don't know□
No answer□

3. Knowledge on Renewable Energy

How familiar are you with the following Renewable Energy Sources?

Renewable Energy Source	**Very Much**	**Much**	**Little**	**Not at All**
3.1 Biomass/Biogas				
3.2 Hydropower				
3.3 Wind Energy				
3.4 Geothermal (including Heat Pump)				
3.5 Tidal Energy				
3.6 Solar Thermal				
3.7 Solar Photovoltaic				
3.8 Wave Energy				

4. General Views on Renewable Energy Sources

In overall context, how much do you agree with the following statements about Renewable Energy Sources? Please tick the degree of your agreement with the following statements on the scale provided.

No	Statements	Strongly Agree	Agree	Disagree	Strongly Disagree	Don't Know	No Answer
4.1	Renewable Energy is a solution to problems related to climatic changes						
4.2	Renewable Energy can contribute to sustainable development						
4.3	Generally speaking, I fully support development of Renewable Energy Projects on the islands						
4.4	Solar thermal energy can contribute considerably to water heating requirements for the island						
4.5	Biomass Energy can contribute considerably to water and space heating requirements for the island						
4.6	Heat Pumps using sea water as source of energy can contribute considerably to heating requirements for the island						
4.7	Hydropower should be more exploited to meet the electricity requirements of the island						
4.8	Wind Energy should be more exploited to export electricity to the mainland						
4.9	I am willing to pay extra for energy generated from renewable energy sources in order to serve the environment						

5. Electricity Consumption

5.1 What is your average electricity consumption?

Electricity consumption: ____________ kWh./Year, £/year, kWh/Month,£/Month
(please underline the unit)

5.2 Do you have any high energy consumption equipment, e.g., workshop equipment apart from normal household appliances?

Yes ☐

No ☐

No answer ☐

5.3 If yes, please list the additional appliances

Electrical Equipment	Quantity	Power (kW)	Average use hours in week day	Average use hours in weekend day

6. Hot water and space heating

6.1 Do you use the same system for hot water and space heating?

- Yes ☐
- No ☐
- Don't know ☐
- No answer ☐

If your answer was "no", please go to question 6.4
If your answer was "don't know" or "no answer" please go to question 6.8

6.2 Which type of system do you use for hot water and space heating?

- Central ☐
- Independent ☐
- Open fire ☐
- Others (please indicate):____

6.3 How old is your water and space heating system?________________years

Go to question 6.8

6.4 Which type of system do you use for space heating?

Central ☐

Individual ☐

Open fire ☐

Others (please indicate)____

6.5 How old is your space heating system?

_______________years

6.6 Which type of system do you use for water heating?

Central ☐

Individual ☐

Open fire ☐

Others (please indicate)____

6.7 How old is your water heating system?

_________________years

6.8 Please indicate the quantity of fuels that you usually consume per year for water and space heating

	Please, use these columns if the same system is used for water and space heating		Please, use these columns if different systems are used for water and space heating			
	Water and space heating		Water heating		Space heating	
	Quantity	Unit	Quantity	Unit	Quantity	Unit
6.8.1 Electricity						
6.8.2 Oil						
6.8.3 Wood						
6.8.4 Coal						
6.8.5 Solar						
6.8.6 Gas						
6.8.7 Others						

6.9 Hot water consumption

6.9.1 How often per week is the hot water shower used in your home?

_____________times/week

Don't know ☐

No answer ☐

6.9.2 How often per week is the dish washing machine used in your home?

_____________times/week

Don't know ☐

No answer ☐

6.9.3 How often per week is the Cloth washing machine used in your home?

_____________times/week

Don't know ☐

No answer ☐

6.9.4 Do you consume larger quantities of hot water for any other purposes?

If yes, please indicate

Other purposes:____

7. Interest in new water and space heating systems

7.1 Are you interested in using solar energy as a supplement energy source to supply hot water?

Yes ☐

No ☐

Don't know ☐

No answer ☐

If your answer is "no", "no answer" or "don't know" please go to question 7.3.

7.2 What would be the reasons for you to change to a new hot water system?

____

____

7.3 Are you interested in changing your current space heating system?

Yes ☐

No ☐

Don't know ☐

No answer ☐

If your answer is "no", "no answer" or "don't know" please go to question 8.

7.4 What would be the reasons for you to change to a new space heating system?

8. If you want to add any other comments, please feel free to do so:

____

____

____

____

____

Thanks for your opinion and your assistance in partaking in this survey.

Observation by Interviewer

9. Details of the building

9.1 Type of house:

Detached ☐

Semi-detached ☐

Terraced ☐

Others (please indicate):____

9.2 Type of the roof:

Flat ☐

Gabled roof ☐

Pent roof ☐

Others (please indicate):____

9.3 Orientation of the roof, suitability for solar collectors:

South ☐

East or west ☐

South east/southwest ☐

No suitable orientation ☐

9.4 Roof covering

Tiles ☐

Stone tiles ☐

Slates ☐

Other (please indicate):____

9.5 Is there any tree or building or any other object that makes shadow on the roof?

Yes ☐

No ☐

9.6 Are there any obstacles for installing the solar water system?

Yes ☐

No ☐

If yes, please indicate details (e.g. attics, skylight windows etc.):__________________

____

____

9.7 Is the space left enough for a solar system (approximately 4-6 m^2)?

Yes ☐

No ☐

Appendix 4.4.1: Green Densities for the Conifer Species

Species	Volume/Weight Ratio (m^3/tonne)
Sitka Spruce	1.08
Lodgepole Pine	1.05
Average Volume/Weight Ratio	**1.065**

(Source: Baksh et al. 2002, p.22*)*

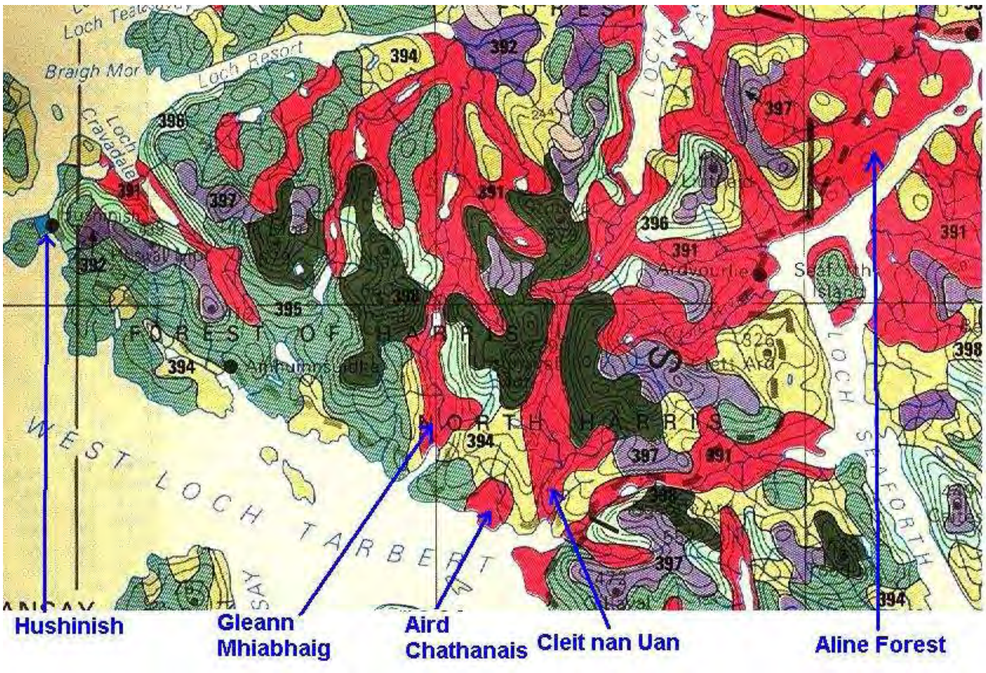
Appendix 4.4.2: Calorific value of wood at different moisture content

Type of Wood	Moisture Content (% Dry Wt)	Heating Value (kWh/kg)
Oven dried	0	5.4
Kiln Dried	10	4.7
Air dried	30	3.4
Fresh timber	50	2.1

Appendix 4.4.3: Timber harvest volume from 300 ha forest which is not suitable for forest

Type of tree	Area, ha	Average Timber volume, m^3/ha	Timber yield, m^3	Timber yield, ton	Energy content, kWh
Lodgepole Pine	180	26	17160	16112	54,780,000
Sitka Spruce	120	143	4680	4394	14,940,000
Total	300		21840	20506	69,720,000

Appendix 4.4.4. Map showing the selected site for plantation2



Appendix 4.4.5. Estimated crop establishment cost of for proposed plantation sites

Name of the place	Area, ha	Fencing length, m	Establishment cost		Fencing cost @ £8/m	Total initial cost, £	
			Manua	Machine		Manual	Machine
Aird Chathanais	50	3000	250000	350000	24000	274000	374000
Gleann mhiabhaig	130	8000	650000	910000	64000	714000	974000
Cleif nar Van	125	7000	625000	875000	56000	681000	931000
Hushinish	20	2250	100000	140000	18000	118000	158000
Total	**325**	20250	1625000	2275000	162000	1787000	2437000

[1]Assumption: Soil preparation : Hand preparation- 30 pence/tree.
Machine preparation- 10 pence /tree

Cost of seedlings – 30-40 pence / seedling

Planting and fertilizer – 10 pence / seedling

Fencing cost- 8 pounds / meter length
Total seedlings- 10000/ha

[1] Personal discussion with Mr. Steven Liddle, Western Isles Woodland Project Officer on 5 September 2005

Appendix 5.2.2.1: Fuel consumption and wood chip boiler selection for hatchery

Energy consumption of Fish hatchery	
Fuel oil consumption per week, litre	6000
Total duration during winte season, week	21
Total fuel oil consumption per year, litre	126000
Heating value of fuel oil, kWh/litre	10.36
Efficiency of boiler (assumed)	80%
Total heat energy requirement per year kWh	1044288
Total operating hour @24 h/day	3528
Average Boiler Capacity, kW	296
Selected wood chip boiler	PYROT 400 Nomial output 320 – 400 kW
Wood fuel requirement in hatchery	
Calorific value of wood at 30% moisture, kWh/kg	3.4
Efficiency of wood fired boiler	90%
Total wood energy requirement, kWh/year	1160320
Wood requirement per year, air dry ton	342
SRC woodland plantation required for supplying the fuel to hatchery	
Production willow, adt/ha/year[1]	8
Land required for willow plantation, ha	43

[1] Wood fuel production rate is calculated Cairns 2004, p.8

Appendix 5.2.2.2: Financial analysis of biomass option only

		Sensitivity Analysis	
Boiler price including feeding system, GBP[1]	65000	65000	65000
Cost of Woodchip store and shed, GBP	40000	40000	40000
Investment cost, GBP	105000	105000	105000
Interest rate	6.4%	6.4%	6.4%
Life time of boiler, year	25	25	25
Maintenance cost @4% of investment, GBP/year	4200	4200	4200
Total wood fuel need, air dry ton (adt)/year	342	342	342
Unit price of wood fuel, GBP/adt	**45**[2]	**50**	**60**
Total wood fuel cost, GBP/year	**15390**	**17064**	**20476**
Depreciation year	10	10	10
Fuel savings, Litre/year	126000	126000	126000
Revenue from Fuel savings @ 0.32 pence/litre, GBP	40320	40320	40320
Net Present Value (NPV)	**74785**	**53778**	**11761**
IRR	**11.8%**	**10.3%**	**7.3%**
Payback Period, year	**13**	**15**	**21**

[1] Contact by Telephone with Ms Shera, 3GEnergi, 3 The knows, Kelso TD5 Tel: 08000835949 on 08/09/05
[2] SDC Scotland 2005, p.26

Appendix 5.2.2.3. Specification of Boiler Model KOB PYROT

- "Flue gas recirculation which improves combustion efficiency and eliminates clinker formation for most fuel types.
- Flue gas cyclone deduster to remove fine particle from the flue gases- used mainly when sawdust and shavings or other fine particle fuels are being burnt.
- Automatic de ashing to a separate wheelie bin container.
- Automatic boiler tube cleaning. this system uses compressed air to clean the boiler tubes to maintain the highest operating efficiency and remove the need for periodic shutdown and maintenance.
- Fuel Pre-dryer: For wet fuels a pre-dryer may be installed in the feed system to ensure only dry fuel is presented to the boiler ensuring optimum combustion efficiency and no "steam plume" as often associated with wet fuel boilers.
- Optional auxiliary oil or gas burner can be fitted to the rear of the Pyrot combustion chamber giving 80% of the MCR to provide back up in case of unreliable fuel supplies or for feed system maintenance.
- With these options fitted the Kob Pyrot is the most user friendly, economical and cleanest burning biomass boiler available in Europe.
- I have witnessed a Pyrot boiler with lower emissions than any other boiler I have seen. CO levels were non-existent, NOx was lower than 50ppm and excess air ran at around 7% with no dust or visible smoke. The overall efficiency was in excess of 92%"[1]

The KOB PYROT Model

Type of Burner	Nominal Output	Burner dimensions			Weight
	kW	H mm	D mm	W mm	empty kg
PYROT 100	80 – 100	1765	2194	1050	1895
PYROT 150	120 – 150	1765	2444	1050	2200
PYROT 220	180 – 220	2024	2444	1330	3080
PYROT 300	250 – 300	2024	2816	1330	3560
PYROT 400	**320 – 400**	**2262**	**2853**	**1570**	**4600**
PYROT 550	430 – 540	2262	3083	1570	5940

[1] http://www.3genergi.co.uk/Kob%20Pyrot.html date 07.09.05

Appendix 5.2.2.4: Financial analysis of biomass option and Heat Pump only

Boiler price including feeding system, GBP[1]	40000
Cost of Woodchip store and shed, GBP	40000
Cost for Heat pump, GBP	120000
Total Investment cost, GBP	200000
Interest	6.4%
Life time of boiler, year	25
Maintenance cost @4% of boiler investment and 120 GBP/yr for Heat pump, GBP/year	3320
Total wood fuel need, air dry ton (adt)/year	130
Electricity cost for heat pump @0.04GBP/kWh, GBP/year	8640
Unit price of wood fuel, GBP/adt	**45**[2]
Total wood fuel cost, GBP/year	**5827**
Depreciation year	10
Fuel savings, Litre/year	126000
Revenue from Fuel savings @ 0.32 pence/litre, GBP	40320
Net Present Value (NPV)	**-67045**
IRR	**3.7%**
Payback Period, year	**>25**

[1] Contact by Telephone with Ms Shera, 3GEnergi, 3 The knows, Kelso TD5 Tel: 08000835949 on 08/09/05
[2] SDC Scotland 2005, p.26

Appendix 5.2.2.5 Calculation of heat exchanger area for recovering the waste heat

T of waste water entering the tank, T_{1max}, C	12
T of waste water leaving the tank, T_{1min}, C	8
T of fresh water leaving heat exchanger, T_{2max}, C	10
T of fresh water entering heat exchanger, T_{2mix}, C	5
dT_{max}	2
dT_{min}	3
dT_{max}/ dT_{min}	0.67
Ln (dT_{max}/ dT_{min})	-0.405
dT_{mean}	2.46
Temperature of water after heating, C	16
% of energy released to tank	63.6%
Energy for water heating from oil, kWh	1044288
Heat flow from waste water °Q, kW	188
Efficiency	0.8
Heat recovery rate, kW	150
Heat permeability coefficient k, kJ/m²hK	2500
Area of Heat exchanger, °Q/(dT_{mean} * k)	110
Diameter of pipe, m	0.05
Circumference, m	0.157
Length of the pipe, m	700
Total operating hour	3528
Total energy supplied from heat exchanger, kWh	531638
Heat to be supplied by boiler, kWh	512650
Capacity of the boiler, kW	145
Motor capacity, kW	4
Electricity consumption, kWh/year	14112
Selected wood chip boiler[1]	Kob PYRTEC 200 Nomial output 150 – 200 kW

[1] http://www.3genergi.co.uk/Kob%20Pyrtec.html date 7.09.05

Appendix 5.2.2.6: Financial analysis of Option 3 - biomass fired boiler and waste heat recovery

		Sensitivity Analysis	
Boiler price including feeding system, GBP[1]	40000	40000	40000
Cost of Woodchip store and shed, GBP	40000	40000	40000
Cost of heat exchanger with pump, insulated pipe to waste water basin, cover of waste water basin	5000	5000	5000
Total investment cost, GBP	85000	85000	85000
Interest rate	6.4%	6.4%	6.4%
Life time of boiler, year	25	25	25
Maintenance cost @4% of investment, GBP/year	3400	3400	3400
Total wood fuel need, air dry ton (adt)/year	168	168	168
Unit price of wood fuel, GBP/adt	**45[2]**	**100**	**140**
Total wood fuel cost, GBP/year	**7538**	**16753**	**23454**
Electricity cost for pump, GBP/year	564	564	564
Depreciation year	10	10	10
Fuel savings, Litre/year	126000	126000	126000
Revenue from Fuel savings @ 0.32 pence/litre, GBP	40320	40320	40320
Net Present Value (NPV)	**208385**	**94942**	**12438**
IRR	**25%**	**15%**	**8%**
Payback Period, year	**5**	**10**	**20**

[1] Contact by Telephone with Ms Shera, 3GEnergi, 3 The knows, Kelso TD5 Tel: 08000835949 on 08/09/05
[2] SDC Scotland 2005, p.26

Appendix 5.2.2.7. Specification of Boiler Model KOB PYRTEC

"The Pyrtec is a traditional underfed stoker design of boiler. Kob have enhanced this with their usual high build quality and excellent control system including Lambda control , and BMS options. An integral flue cyclone deduster and automatic ignition are fitted as standard to all models. As with the Pyrot there are options for de-ashing to wheelie bins of 240 litre or 800 litre size and compressed air boiler tube cleaning. Extra primary air fans are available for very wet fuel. Many Pyrtecs are installed in multi-boiler configuration for large municipal district heating systems[1]."

Pyrtec size range.

Type of burner	Nominal output	Burner dimensions			Weight
	kW	H mm	D mm	W mm	empty kg
Pyrtec 140	100 - 150	1640	1693	950	2135
Pyrtec 200	***150 - 220***	***1640***	***2139***	***950***	***2755***
Pyrtec 350	250 - 360	1980	2389	1110	4175
Pyrtec 500	380 - 530	2200	2539	1210	5590
Pyrtec 650	480 - 680	2398	2789	1210	6680
Pyrtec 1000	720 - 1000	2760	3406	1610	10695

[1] http://www.3genergi.co.uk/Kob%20Pyrtec.html date 7.09.05

Appendix 5.2.3.1 Calculation of heat pump for hatchery project

Oil consumption for hatchery for 5 months	126000	Liters (6000 l/ week)
Energy from the oil	1305360.00	KWh
		1l oil=10. 36 KWh energy
Temperature of cool water in winter season, T1	2	°C
Temperature of hot water, T2	16	°C
Temperature of discharge water, T3	14	°C
Proposed loop length for 225 m2 discharge tank	4500	meters
(Considering 30 meters loop length each and 0.3m apart from each other and 3 loops in one line)		
Heat recovery from discharge water	180	KW
(Considering 1KW power recovery from 25 meter loop length)		
Energy gain from 4500 meter loop	4320	Kwh/day
Energy gain from 4500 meter loop for 5 months	648000	KWh/5 months
Energy required for 1 liter cold water to be heated up from		
T1 to T2 °C = m*s*(T2-T1), Specific heat of water, s=1.16 Wh/Kg.k		
Energy required for 1 liter cool water to be heated up from 2°C to 16 °C	16.24	Wh
Possible amount of water heating per day from discharge water 266009.85		Liters
Required heat pump capacity for hot water	180	KW
(Considering water heating for 24 hours)		
Cost of heat pump system and installation:		
Cost of heat pump system	90000	(@500 pounds/KW)
Water source collector (horizontal loop) and installation	27000	(@100 pounds/KW heat extraction
(Source of cost: www.est.org.uk/uploads/documents/housebuildings/CE.pdf, page12)		
Buffer tank	2000	pounds
Physical contingency	1000	pounds
Total investment cost	**120000**	**Pounds**

Appendix 5.2.4.1 Financial Analysis of Hatchery Hydropower Project (Hatchery Ownership)

SN	Description	Units	Without Grant	With Grant
1	Interest	%	6.4	6.40
2	Inflation, Tax	%	0	0
3	Grant	%	0	50[1]
4	Market price of electricity[2]	£/kWh	0.02	0.02
5	Oil price[3]	£/lit	0.32	0.32
6	Premium			
	ROCs[4]	£/kWh	0.045~0.035	0.045~0.035
	LECs[5]	£/kWh	0.0043	0.0043
7	Total Investment	£	74,088	74,088
8	Grant Amount	£	0	37,044
9	O & M Cost	£/yr	2,222.6	2,222.6
10	Revenue	£/yr	5,497	5,497
11	CO_2 Saving[6]	Ton/yr	18.9	18.9
12	Net Present Value (NPV)	£	-36,298	745.97
13	Internal Rate of Return (IRR)	%	-0.67	6.65
14	Payback Period	Year	none	20

Appendix 5.2.4.2 Financial Analysis of Hatchery Hydropower Project (NHT Ownership)

SN	Description	Units	Without Grant	With Grant
1	Interest	%	6.4	6.40
2	Inflation, Tax	%	0	0
3	Grant	%	0	40
4	Market price of electricity	£/kWh	0.02	0.02
5	Premium			
	ROCs	£/kWh	0.045~0.035	0.045~0.035
	LECs	£/kWh	0.0043	0.0043
6	Total Investment	£	74,088	74,088
7	Grant Amount	£	0	29,635
8	O & M Cost	£/yr	2,223	2,223
9	Revenue	£/yr	7,644	7,644
10	CO_2 Saving	Ton/yr	47.4	47.4
11	Net Present Value (NPV)	£	-18,704.5	10,930.7
12	Internal Rate of Return (IRR)	%	2.9	9.5
13	Payback Period	Year	none	14

[1] For business purpose there is not any grants (information from Henk Munneke), however it is just assumed.
[2] Electricity price with grid connection has been adapted from BHA, 2005, P.17
[3] Oil price will increase by 2 % per year (assumed from OECD, 2005, p.1-3)
[4] ROCs value will be decreased from 0.045 £/kWh to 0.035 £/kWh during 20 years period (the values are adapted from: BHA, 2005, P.17)
[5] LECs will remain constant as 0.0043 £/kWh during 20 years period (the value is adapted from: BHA, 2005, P.17)
[6] CO_2 Saving from grid connection 0.43 kg/kWh (adapted from "*Environmental Reporting –1999, p27"*

Appendix 5.3.2: Space heating and hot water system with combination of solar and wood fuel boiler system

Energy from Solar system, kWh/yr	8120
Energy from wood fired system, kWh/yr	24280
Total energy	32400
Cost of energy saved, GBP, @ 0.0516 GBP/Kwh	1671.84
Efficiency of boiler	80%
No of collector (3 $m^{2)}$	6
Investment cost for solar system, GBP (Mainfolder 30 tubes, Controller, pump station, power supply,tank-400 l, pipe)	19000
Investment cost for wood boiler system, GBP	3900
no of Radiator	8
cost of radiator, GBP	100
installation cost, GBP	80
total cost of radiator, GBP	880
Cost of buffer tank, GBP	2000
Cost of heating network	250
Total investment cost for the system, GBP	26030
maintenance cost for wood fired system, 3% of investment, GBP/yr	210.9
maintenance cost for solar system, GBP/yr	10
Life time, yr	20
interest rate	6.40%
Cost of wood GBP/ton adt	50
Total wood cost GBP/yr	446.32
Grant 50%	
NPV (net present value)	**- 9084**
IRR	**-5%**
Pay back period	**>20**
Unit energy cost , GBP/KWh	**0.077**
Grant 80%	
NPV (net present value)	**4104**
IRR	**15%**
Pay back period	**8**
Unit energy cost , GBP/KWh	**0.0415**

Appendix 5.3.3: Calculation for combination of heat pump and solar for the trust house

Energy from solar, KWh/yr	2800
Energy from heat pump, KWh/yr	29600
Electricity cost for heat pump, GBP/yr	509.12
Investment cost for solar system, GBP	6510
Investment cost for heat pump, GBP	15150
Total investment, GBP	21660
maintenance cost for heat pump, GBP/yr	25
maintenance cost for solar, GBP/yr	10
Interest rate	6.40%
Life time, year	20
Depreciation, yr	20
Grant : 50%	
NPV	-2242
IRR	-1%
Payback period, year	> 20
Unit cost, GBP/KWh	0.069
Grant : 80%	
NPV	7165
IRR	24%
Payback period, year	4
Unit cost, GBP/KWh	0.023

Appendix 5.3.4: Financial calculation using only biomass for space heating and hot water system in the Trust house

Total floor area, m^2	200
Hot water demand, Kwh/yr	4080
total space energy required, Kwh/yr	28280
Operation hour, hr	4320
Total energy demand, kwh/yr	32360
Tariff, GBP/Kwh	0.0516
Cost of energy saved GBP, @ 0.0516 GBP/Kwh	1669.78
Boiler efficiency	80%
Total energy required from wood, Kwh/yr	40450
Wood requirement, ton adt/yr	11.90
cost of wood, GBP/ton adt	50
total fuel wood cost, GBP	594.85
boiler capacity, KW	15
Investment cost, incl installation GBP	5460
Cost of tank-400 l, GBP	800
Cost for the piping system, GBP	250
Cost of circulating pump, GBP	400
no of Radiator	6
cost of radiator, GBP	100
total cost of radiator, GBP	600
Total investment cost, GBP	7510
maintenance cost, 3% of investment, GBP/yr	225.3
Life time, yr	20
interest rate	6.40%
Grant : 50%	
NPV (net present value)	1573
IRR (Internal rate of return)	12%
Payback period	10.00
Unit cost of energy GBP/KWh	0.0465
Grant : 80%	
NPV (net present value)	5453
IRR (Internal rate of return)	47%
Payback period	2
Unit cost of energy GBP/KWh	0.034

Appendix 5.3.5: Heating with heat pump

Hot Water:		
Hot water required for 6 persons (Cosidering 40 litres/person consumption)	240	litres/day
Hot water required for 6 persons	87600	litres/yr
Temperature of cool water in summer season, T1	12	°C
Temperature of cool water in winter season, T2	8	°C
Temperature of hot water, T3	50	°C
Energy required for 1 litre cool water (in summer) to be hot, Q= ms(T3-T1)	44.08	Wh
Where s is the specific heat of water = 1.16 Wh/kg.k		
Total energy required for cool water(in summer)to be hot	1904.256	KWh
Energy required for 1 litre cool water (in winter) to be hot, Q= ms(T3-T2)	48.72	Wh
Total energy required for cool water(in winter)to be hot	2104.704	Kwh
(Considering water heating for 4 hours)		
Energy required for 87600 litres of cool water to be hot	4080.96	Kwh/year
Hot water and space heating:		
Required heat pump capacity for space heating and hot water	15	KW
Total energy required for hot water and space heating	32362	KWh/year
Cost of heat pump system and installation:		
Investment Cost of heat pump system (Source:(www.est.org.uk/uploads/documents/housebuildings/CE.pdf, page12)	19300	Pounds
Economic Viability of the project:		
Yearly electricity cost for 21080.96 KWh energy	1669.88	Pounds
Initial investment for heat pump, Io	19300	Pounds
Yearly electricity cost for driving heat pump	556.62	Pounds
Heat pump life time	20	Years
Interest rate	6.4%	
Maintenance cost for heat pump for 15 years (Considering 10 years warranty period no maintenance cost)	500	Pounds
Yearly maintenance cost for heat pump for life time	25	Pounds
Grant : 50%		
NPV	-2922	Pound
IRR	2%	
Pay back period	>20	Year
Unit cost of energy , GBP/KWh	0.0635	
Grant : 80%		
NPV	6083	
IRR	23%	
Pay back period	5	
Unit cost of energy , GBP/KWh	0.0262	

Appendix 5.3.6: Trust house with only SWH System

	Price(£)
3 m2 collector*2	2874
Manifold for 30 Tubes*2	802
Controller*1	533
pump station*1	80
power supplies*1	25
Tank 300*1	400
Pipe*1	36
Total equipment	4750
Installation	1350
Total investment cost	6100

	Trust house	Trust house
Investment	-6100£	-6100£
Grants	3050£ (50% investment)	4080£(80% investment)
Saving	2605£	2605£
Running cost	-111£	-111£
NPV calculation	-556£	1274£
Unit cost	0.10	0.04

Appendix 5.4.1 Financial Analysis of Govig Hydropower Project

SN	Description	Units	Without Grant	With Grant
1	Interest	%	6.4	6.40
2	Inflation, Tax	%	0	0
3	Grant	%	0	30
4	Market price of electricity[5]	£/kWh	0.02	0.02
5	Premium			
	ROCs[6]	£/kWh	0.045~0.035	0.045~0.035
	LECs[7]	£/kWh	0.0043	0.0043
6	Total Investment	£	45.565	310,081
7	Grant Amount	£	0	13,670
8	O & M Cost	£/yr	3,004	3,004
9	Revenue	£/yr	5,623	5,623
10	CO_2 Saving[8]	Ton/yr	26.36	26.36
11	Net Present Value (NPV)	£	-13,523.7	145.9
12	Internal Rate of Return (IRR)	%	2.5	6.45

[5] Electricity price with grid connection has been adapted from BHA, 2005, P.17
[6] Renewable Obligation Certificates (ROCs) value will be decreased from 0.045 £/kWh to 0.035 £/kWh during 20 years period (the value is adapted from: BHA, 2005, P.17)
[7] Climate Change Levi Exemption Certificates (LECs) will remain constant as 0.0043 £/kWh during 20 years period (the value is adapted from: BHA, 2005, P.17)
[8] CO_2 Saving from grid connection 0.43 kg/kWh (adapted from "*Environmental Reporting , 1999, p27"*

13	Payback Period	Year	none	20

Appendix 5.4.2 Financial Analysis of Govig Hydropower Project (excluding local contribution)

SN	Description	Units	Without Grant	With Grant
1	Interest	%	6.4	6.40
2	Inflation, Tax	%	0	0
3	Grant	%	0	30
4	Market price of electricity	£/kWh	0.02	0.02
5	Premium			
	ROCs	£/kWh	0.045~0.035	0.045~0.035
	LECs	£/kWh	0.0043	0.0043
6	Total Investment	£	45.565	310,081
7	Grant Amount	£	0	11,637
8	Local Contribution	£	6,775	6,775
9	O & M Cost	£/yr	3,004	3,004
10	Revenue	£/yr	5,623	5,623
11	CO_2 Saving	Ton/yr	26.36	26.36
12	Net Present Value (NPV)	£	-6,748.6	4,88.5
13	Internal Rate of Return (IRR)	%	4.2	8.5
14	Payback Period	Year	none	16

Appendix 5.4.3 Detail Cost Estimation of Govig Micro Hydro Project

Description of items		Unit	Quantity	Unit Cost	Amount	Relative Costs
Feasibility Study						
	Site investigation	p-d	2	£400.00	£800.00	1.76%
	Hydrologic assessment	p-d	2	£400.00	£800.00	1.76%
	Environmental assessment	p-d	0	£400.00	£0.00	0.00%
	Preliminary design	p-d	0	£400.00	£0.00	0.00%
	Detailed cost estimate	p-d	2	£400.00	£800.00	1.76%
	Report preparation	p-d	3	£400.00	£1,200.00	2.63%
	Travel and accommodation	p-trip	1	£600.00	£600.00	1.32%
	Subtotal:				**£4,200.00**	**9.22%**
Development						
	PPA negotiation	p-d	0	£400.00	£0.00	0.00%
	Permits and approvals	p-d	2	£319.20	£638.40	1.40%
	Land survey	p-d	0	£22,800.00	£0.00	0.00%
	Project financing	p-d	0	£684.00	£0.00	0.00%
	Legal and accounting	p-d	2	£500.00	£1,000.00	2.19%
	Travel and accommodation	p-trip	1	£600.00	£600.00	1.32%
	Subtotal:				**£2,238.40**	**4.91%**
Engineering						
	Design and tender documents	p-yr	1.0	£912.00	£912	2.00%
	Contracting	p-d	2	£400.00	£800	1.76%
	Construction supervision	p-yr	1.0	£3,500.00	£3,500	7.68%
	Subtotal:				**£5,212.00**	**11.44%**
Renewable Energy (RE) Equipment						
	Turbines/generators, controls	kW	8	£700.00	£5,618.34	12.33%
	Equipment installation	%	10%	£5,618.34	£561.83	1.23%
	Transportation	%	5%	£5,618.34	£280.92	0.62%
	Subtotal:				**£6,461.09**	**14.18%**
Balance of Plant						
	Access road	km	0.0	£22,800.00	£0.00	0.00%
	Earth excavation	m³	10.0	£4.56	£45.60	0.10%
	Rock excavation	m³	2.0	£27.36	£54.72	0.12%
	Concrete dam	m³	0	£456.00	£0.00	0.00%
	Canal	m³	0	£22.80	£0.00	0.00%
	Intake	m³	2	£547.20	£1,094.40	2.40%
	Pipeline/penstock	kg	2,832	£3.19	£9,039.74	19.84%
	Powerhouse civil	m³	24	£456.00	£10,944.00	24.02%
	Transmission line	km	0.4	£3,648.00	£1,459.20	3.20%
	Transportation	%	5%	£22,637.66	£1,131.88	2.48%
	Subtotal:				**£23,769.55**	**52.17%**
Miscellaneous						
	Contractor's overhead	%	10%	£23,769.55	£2,376.95	5.22%
	Contingencies	%	5%	£26,146.50	£1,307.33	2.87%
	Subtotal:				**£3,684.28**	**8.09%**
	Total cost				**£45,565.32**	**100%**
	Per kW cost				**£5,677.07**	
Local contribution					**£6,775.00**	
Total cost (excluding local contribution)					**£38,790.32**	

O&M Cost

	Unit	Quantity	Unit Cost	Amount	Relative Costs
Land lease	project	1	£0	£0	0.0%
Property taxes	%	0	£45,565	£0	0.0%
Water rental	kW	8	£0	£0	0.0%
Insurance premiums	%	0.40%	£45,565	£182	6.1%
Transmission line maintenance	%	5.00%	£1,459	£73	2.4%
Spare parts	%	0.50%	£45,565	£228	7.6%
O&M labour	p-yr	1	£1,000	£1,000	33.3%
Travel and accommodation	p-trip	1	£1,000	£1,000	33.3%
General and administrative	%	10%	£2,483	£248	8.3%
Contingencies	%	10%	£2,731	£273	9.1%
Total				£3,004	100%

Appendix 5.4.4 Detail Cost Estimation of Govig Micro Hydro Project (With Local Contribution)

Description of items		Unit	Quantity	Unit Cost	Amount	Relative Costs
Feasibility Study						
	Site investigation	p-d	2	£400.00	£800.00	1.76%
	Hydrologic assessment	p-d	2	£400.00	£800.00	1.76%
	Environmental assessment	p-d	0	£400.00	£0.00	0.00%
	Preliminary design	p-d	0	£400.00	£0.00	0.00%
	Detailed cost estimate	p-d	2	£400.00	£800.00	1.76%
	Report preparation	p-d	3	£400.00	£1,200.00	2.63%
	Travel and accommodation	p-trip	1	£600.00	£600.00	1.32%
	Subtotal:				**£4,200.00**	**9.22%**
Development						
	PPA negotiation	p-d	0	£400.00	£0.00	0.00%
	Permits and approvals	p-d	2	£319.20	£638.40	1.40%
	Land survey	p-d	0	£22,800.00	£0.00	0.00%
	Project financing	p-d	0	£684.00	£0.00	0.00%
	Legal and accounting	p-d	2	£500.00	£1,000.00	2.19%
	Travel and accommodation	p-trip	1	£600.00	£600.00	1.32%
	Subtotal:				**£2,238.40**	**4.91%**
Engineering						
	Design and tender documents	p-yr	1.0	£912.00	£912	2.00%
	Contracting	p-d	2	£400.00	£800	1.76%
	Construction supervision	p-yr	1.0	£3,500.00	£3,500	7.68%
	Subtotal:				**£5,212.00**	**11.44%**
Renewable Energy (RE) Equipment						
	Turbines/generators, controls	kW	8	£700.00	£5,618.34	12.33%
	Equipment installation	%	10%	£5,618.34	£561.83	1.23%
	Transportation	%	5%	£5,618.34	£280.92	0.62%
	Subtotal:				**£6,461.09**	**14.18%**
Balance of Plant						
	Access road	km	0.0	£22,800.00	£0.00	0.00%
	Earth excavation	m³	10.0	£4.56	£45.60	0.10%
	Rock excavation	m³	2.0	£27.36	£54.72	0.12%
	Concrete dam	m³	0	£456.00	£0.00	0.00%
	Canal	m³	0	£22.80	£0.00	0.00%
	Intake	m³	2	£547.20	£1,094.40	2.40%
	Pipeline/penstock	kg	2,832	£3.19	£9,039.74	19.84%
	Powerhouse civil	m³	24	£456.00	£10,944.00	24.02%
	Transmission line	km	0.4	£3,648.00	£1,459.20	3.20%
	Transportation	%	5%	£22,637.66	£1,131.88	2.48%
	Subtotal:				**£23,769.55**	**52.17%**
Miscellaneous						
	Contractor's overhead	%	10%	£23,769.55	£2,376.95	5.22%
	Contingencies	%	5%	£26,146.50	£1,307.33	2.87%
	Subtotal:				**£3,684.28**	**8.09%**
	Total cost				**£45,565.32**	**100%**
	Per kW cost				**£5,677.07**	
	Total cost excluding local cost				**£38,790.20**	

O&M Cost

	Unit	Quantity	Unit Cost	Amount	Relative Costs
Land lease	project	1	£0	£0	0.0%
Property taxes	%	0	£45,565	£0	0.0%
Water rental	kW	8	£0	£0	0.0%
Insurance premiums	%	0.40%	£45,565	£182	6.1%
Transmission line maintenance	%	5.00%	£1,459	£73	2.4%
Spare parts	%	0.50%	£45,565	£228	7.6%
O&M labour	p-yr	1	£1,000	£1,000	33.3%
Travel and accommodation	p-trip	1	£1,000	£1,000	33.3%
General and administrative	%	10%	£2,483	£248	8.3%
Contingencies	%	10%	£2,731	£273	9.1%
Total				**£3,004**	**100%**

Appendix 5.4.5 SWH Price List

Components	No	Price(£)
3 m2 collector	1	1437
Manifold for 30 Tubes	1	401
controller	1	533
pump station	1	80
power supplies	1	25
Tank 250	1	300
pipe	1	36
Total equipment		2812
Installation(30% of equipment)		1124.8
Total investment		3936.8

Appendix 5.4.6 Heat pump at Govig Holiday Home

Area of one holiday home at Gobhaig	54.00	m2
Hot water required for 4 persons, for 6 months, Mar-Oct (Considering 40 liters/person consumption)	28800.00	liters/yr
Temperature of cool water in summer season, T1	12.00	°C
Temperature of hot water, T2	50.00	°C
Energy required for 1litre cool water in summer to be hot, Q=ms(T2-T1)	44.08	Wh
Required heat pump capacity for hot water(Considering water heating for 4 years)	1.76	KW
Energy required for 28800 liters cool water to be hot	1269.50	KWh/year
Space Heating:		
Required heat pump capacity for space heating (for new house)	40.00	W/m2
Required heat pump capacity for space heating	2.16	KW
Yearly energy required for space heating (Considering heat loss due to heat transfer to out side of house)	50.00	KWh/m2
Yearly energy required for space heating	2700.00	KWh/yr
Hot water and space heating:		
Required heat pump capacity for space heating and hot water	4	KW
Total energy required for hot water and space heating	3969.50	KWh/year
Electricity needed for driving heat pump (Considering performance factor, COP of heat pump is 3)	1.31	KW
Cost of heat pump system and installation:		
Cost of heat pump system (@800 pounds/KW)	3138.56	Pounds
Ground source heat collector (bore hole) and installation (@500 pounds/KW heat extraction)	5200.00	Pounds
Buffer tank	450	Pounds
Physical contingency	500	Pounds
Total investment cost	9288.56	Pounds
Economic Viability of the project:		
Yearly electricity tariff for 3970 KWh electricity consumption	237.38	Pounds
Initial investment for heat pump, Io (Considering 30% grant)	6501.99	Pounds
Yearly electricity cost for driving heat pump	79.13	Pounds
Heat pump life time	20.00	Years
Interest rate	6.4%	
Maintenance cost of heat pump for 10 years (@ 50 pounds/year) (Considering 10 years warranty period no maintenance cost)	500.00	Pounds
Yearly maintenance cost for heat pump for life time	25.00	Pounds
Depreciation	325.10	Pounds
Pay back period	Over life time	

Appendix 5.5.1 Financial Analysis of Bunavoneadar (1st Option) Hydropower Project

SN	Description	Units	Without Grant	With Grant
1	Interest	%	6.4	6.40
2	Inflation	%	0	0
3	Tax	%	0	0
4	Grant	%	0	40
5	Market price of electricity[1]	£/kWh	0.02	0.02
6	Premium			
	ROCs[2]	£/kWh	0.045~0.035	0.045~0.035
	LECs[3]	£/kWh	0.0043	0.0043
7	Total Investment	£	320,081	320,081
8	Grant Amount	£	0	128,032
9	O & M Cost	£/yr	18,109	18,109
10	Revenue	£/yr	42,077	42,077
11	CO_2 Saving[4]	Ton/yr	263	263
12	Net Present Value (NPV)	£	-79,318	48,714
13	Internal Rate of Return (IRR)	%	2.92	9.6
14	Payback Period	Year	>20	13

Appendix 5.5.2 Financial Analysis of Bunavoneadar (2nd Option) Hydropower Project

SN	Description	Units	Without Grant	With Grant
1	Interest	%	6.4	6.40
2	Inflation	%	0	0
3	Tax	%	0	0
4	Grant	%	0	40
5	Market price of electricity	£/kWh	0.02	0.02
6	Premium			
	ROCs	£/kWh	0.045~0.035	0.045~0.035
	LECs	£/kWh	0.0043	0.0043
7	Total Investment	£	592,618	592,618
8	Grant Amount	£	0	227,047
9	O & M Cost	£/yr	28,372	28,372
10	Revenue	£/yr	81,526	81,526
11	CO_2 Saving	Ton/yr	509.5	509.5
12	Net Present Value (NPV)	£	-51,529	185,518
13	Internal Rate of Return (IRR)	%	5.24	12.7
14	Payback Period	Year	none	10

[1] Electricity price with grid connection has been adapted from BHA, 2005, P.17
[2] Renewable Obligation Certificates (ROCs) value will be decreased from 0.045 £/kWh to 0.035 £/kWh during 20 years period (the value is adapted from: BHA, 2005, P.17)
[3] Climate Change Levi Exemption Certificates (LECs) will remain constant as 0.0043 £/kWh during 20 years period (the value is adapted from: BHA, 2005, P.17)
[4] CO_2 Saving from grid connection 0.43 kg/kWh (adapted from "*Environmental Reporting – Guidelines for Company Reporting on Greenhouse Gas Emissions, 1999, p27" http://www.defra.gov.uk, printed on 09.08.05*

Appendix 5.5.3 Detail Cost Estimation of Bunavonedar (Old Dam Site) Micro Hydro Project

Initial Costs (Credits)		Unit	Quantity	Unit Cost	Amount	Relative Costs
Feasibility Study						
	Site investigation	p-d	5	£400.00	£2,000.00	0.62%
	Hydrologic assessment	p-d	5	£400.00	£2,000.00	0.62%
	Environmental assessment	p-d	5	£400.00	£2,000.00	0.62%
	Detailed cost estimate	p-d	5	£400.00	£2,000.00	0.62%
	Report preparation	p-d	5	£400.00	£2,000.00	0.62%
	Travel and accommodation	p-trip	2	£1,140.00	£2,280.00	0.71%
	Subtotal:				**£12,280.00**	**3.84%**
Development						
	PPA negotiation	p-d	5	£400.00	£2,000.00	0.62%
	Permits and approvals	p-d	5	£400.00	£2,000.00	0.62%
	Project financing	p-d	5	£400.00	£2,000.00	0.62%
	Legal and accounting	p-d	10	£400.00	£4,000.00	1.25%
	Project management	p-yr	1.0	£30,000.00	£30,000.00	9.37%
	Travel and accommodation	p-trip	2	£1,140.00	£2,280.00	0.71%
	Subtotal:				**£42,280.00**	**13.21%**
Engineering						
	Design and tender documents	p-yr	1.0	£10,000.00	£10,000.00	3.12%
	Contracting	p-d	5	£400.00	£2,000.00	0.62%
	Construction supervision	p-yr	1.0	£20,000.00	£20,000.00	6.25%
	Subtotal:				**£32,000.00**	**10.00%**
Renewable Energy (RE) Equipment						
	Turbines/generators, controls	kW	75	£300.00	£22,579.20	7.05%
	Equipment installation	%	10%	£22,579.20	£2,257.92	0.71%
	Transportation	%	10%	£22,579.20	£2,257.92	0.71%
	Subtotal:				**£27,095.04**	**8.47%**
Balance of Plant						
	Access road	km	0.3	£13,680.00	£4,104.00	1.28%
	Earth excavation	m³	60.0	£4.56	£273.60	0.09%
	Rock excavation	m³	50.0	£27.36	£1,368.00	0.43%
	Concrete dam	m³	60	£456.00	£27,360.00	8.55%
	Dewatering	%	2%	£27,360.00	£547.20	0.17%
	Spillway	m³	16	£456.00	£7,296.00	2.28%
	Canal	m³	0	£22.80	£0.00	0.00%
	Intake	m³	7	£547.20	£3,830.40	1.20%
	Pipeline/penstock	kg	24,921	£3.19	£79,547.83	24.85%
	Powerhouse civil	m³	29	£547.20	£15,759.36	4.92%
	Fishway	m lift	20.0	£228.00	£4,560.00	1.42%
	Transmission line and substation	km	0.2	£11,400.00	£1,710.00	0.53%
	Transportation	%	5%	£146,356.39	£7,317.82	2.29%
	Subtotal:				**£153,674.21**	**48.01%**
Miscellaneous						
	Contractor's overhead	%	15%	£153,674.21	£23,051.13	7.20%
	Training	p-d	10	£319.20	£3,192.00	1.00%
	Contingencies	%	15%	£176,725.34	£26,508.80	8.28%
	Subtotal:				**£52,751.93**	**16.48%**
	Total Cost				**£320,081.18**	**100%**
	Per kW Cost				**£4,252.78**	

O&M Cost

	Unit	Quantity	Unit Cost	Amount	Relative Costs
Land lease	project	1	£0	£0	0.0%
Property taxes	%	0	£320,081	£0	0.0%
Water rental	kW	75	£0	£0	0.0%
Insurance premiums	%	0.40%	£320,081	£1,280	7.1%
Transmission line maintenance	%	5.00%	£1,710	£86	0.5%
Spare parts	%	0.50%	£320,081	£1,600	8.8%
O&M labour	p-yr	2	£5,000	£10,000	55.2%
Travel and accommodation	p-trip	2	£1,000	£2,000	11.0%
General and administrative	%	10%	£14,966	£1,497	8.3%
Contingencies	%	10%	£16,463	£1,646	9.1%
Total				**£18,109**	**100%**

CO_2 Saving		Unit	Quantity	CO_2 Factor	CO_2 Saving(Ton/yr)
Old Dam Site	Electricity to grid connection	kWh	611577.76	0.430	263.0

Appendix 5.5.4 Detail Cost Estimation of Bunavonedar (New Intake Site) Micro Hydro Project

Items		Unit	Quantity	Unit Cost	Amount	Relative Costs
Feasibility Study						
	Site investigation	p-d	7	£400.00	£2,800.00	0.47%
	Hydrologic assessment	p-d	5	£400.00	£2,000.00	0.34%
	Environmental assessment	p-d	5	£400.00	£2,000.00	0.34%
	Detailed cost estimate	p-d	5	£400.00	£2,000.00	0.34%
	Report preparation	p-d	7	£400.00	£2,800.00	0.47%
	Travel and accommodation	p-trip	2	£1,140.00	£2,280.00	0.38%
	Subtotal:				**£13,880.00**	**2.34%**
Development						
	PPA negotiation	p-d	10	£400.00	£4,000.00	0.67%
	Permits and approvals	p-d	10	£400.00	£4,000.00	0.67%
	Project financing	p-d	10	£400.00	£4,000.00	0.67%
	Legal and accounting	p-d	10	£400.00	£4,000.00	0.67%
	Project management	p-yr	1	£59,280.00	£59,280.00	10.00%
	Travel and accommodation	p-trip	4	£1,140.00	£4,560.00	0.77%
	Subtotal:				**£79,840.00**	**13.47%**
Engineering						
	Design and tender documents	p-yr	1	£20,000.00	£20,000.00	3.37%
	Contracting	p-d	10	£400.00	£4,000.00	0.67%
	Construction supervision	p-yr	1	£40,000.00	£40,000.00	6.75%
	Subtotal:				**£64,000.00**	**10.80%**
Renewable Energy (RE) Equipment						
	Turbines/generators, controls	kW	153	£300.00	£45,864.00	7.74%
	Equipment installation	%	10%	£45,864.00	£4,586.40	0.77%
	Transportation	%	10%	£45,864.00	£4,586.40	0.77%
	Subtotal:				**£55,036.80**	**9.29%**
Balance of Plant						
	Access road	km	1.2	£22,800.00	£27,360.00	4.62%
	Earth excavation	m³	303	£4.56	£1,379.86	0.23%
	Rock excavation	m³	100	£27.36	£2,736.00	0.46%
	Concrete dam	m³	60	£456.00	£27,360.00	4.62%
	Dewatering	%	2%	£27,360.00	£547.20	0.09%
	Spillway	m³	16	£456.00	£7,296.00	1.23%
	Canal	m³	421	£22.80	£9,598.80	1.62%
	Intake	m³	10	£547.20	£5,472.00	0.92%
	Pipeline/penstock	kg	51,574	£3.19	£164,624	27.78%
	Powerhouse civil	m³	29	£547.20	£15,759.36	2.66%
	Fishway	m lift	30	£228.00	£6,840.00	1.15%
	Transmission line and substation	km	0.2	£11,400.00	£2,280.00	0.38%
	Transportation	%	5%	£271,253.42	£13,562.67	2.29%
	Subtotal:				**£284,816.10**	**48.06%**
Miscellaneous						
	Contractor's overhead	%	15%	£284,816.10	£42,722.41	7.21%
	Training	p-d	10	£319.20	£3,192.00	0.54%
	Contingencies	%	15%	£327,538.51	£49,130.78	8.29%
	Subtotal:				**£95,045.19**	**16.04%**
	Total				**£592,618.09**	**100.00%**
	Per kW Cost				**£3,876.36**	

O&M Cost

		Unit	Quantity	Unit Cost	Amount	Relative Costs
	Land lease	project	1	£0	£0	0.0%
	Property taxes	%	0	£592,618	£0	0.0%
	Water rental	kW	153	£0	£0	0.0%
	Insurance premiums	%	0.40%	£592,618	£2,370	8.4%
	Transmission line maintenance	%	5.00%	£2,280	£114	0.4%
	Spare parts	%	0.50%	£592,618	£2,963	10.4%
	O&M labour	p-yr	3	£5,000	£15,000	52.9%
	Travel and accommodation	p-trip	3	£1,000	£3,000	10.6%
	General and administrative	%	10%	£23,448	£2,345	8.3%
	Contingencies	%	10%	£25,792	£2,579	9.1%
	Total				**£28,372**	**100%**

CO_2 Saving		Unit	Quantity	CO_2 Factor	CO_2 Saving(Ton/yr)
New Intake	Electricity to grid connection	kWh	1,184,975.7	0.430	509.5

Appendix: 5.6.1 Option 1-Detailed Listing of Economic Figures

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WINDBANK (WTG economics) - Detailed listing of economic figures

Calculation: New Design

Assumptions

Amount in 1,000 £ (excl. VAT) when nothing is specified. All expenditures are marked with (-).

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Operation											
INCOME											
Sale of electricity, 5,008 MWh/Year (Note 1)	0	347	347	347	347	347	344	340	337	334	331
EXPENDITURES	**0**	**-96**	**-96**	**-96**	**-96**	**-97**	**-97**	**-97**	**-98**	**-98**	**-116**
Operation and maintenance (Note 2)	0	-15	-15	-15	-16	-16	-16	-17	-17	-17	-35
Depreciation (Straight-line over 20 years)	0	-81	-81	-81	-81	-81	-81	-81	-81	-81	-81
WORKING PROFITS, ORDINARY	**0**	**251**	**251**	**251**	**251**	**250**	**248**	**243**	**239**	**236**	**214**
FINANCING	**0**	**-101**	**-98**	**-94**	**-90**	**-86**	**-82**	**-77**	**-73**	**-67**	**-62**
Interests, loans (Note 3)	0	-101	-98	-94	-90	-86	-82	-77	-73	-67	-62
Working profits	**0**	**150**	**154**	**157**	**160**	**164**	**164**	**166**	**167**	**168**	**152**
BALANCE											
ASSETS	**1,616**	**1,694**	**1,790**	**1,886**	**1,981**	**2,076**	**2,167**	**2,256**	**2,339**	**2,419**	**2,478**
Installation	1,615	1,534	1,453	1,373	1,292	1,211	1,130	1,050	969	888	807
Cash balance	0	160	337	513	689	865	1,037	1,205	1,370	1,531	1,671
LIABILITIES	**1,616**	**1,694**	**1,790**	**1,886**	**1,981**	**2,076**	**2,167**	**2,256**	**2,339**	**2,419**	**2,478**
Net worth	0	150	304	461	621	785	949	1,115	1,281	1,449	1,602
Debt (Note 3)	1,615	1,544	1,486	1,425	1,360	1,291	1,218	1,140	1,058	970	876
Liquidity of the year (This year's cash balance growth minus transferences) (after tax)	0	160	177	176	176	176	172	168	165	161	140

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Operation										
INCOME										
Sale of electricity, 5,008 MWh/Year (Note 1)	327	324	321	317	313	310	307	303	300	297
EXPENDITURES	**-117**	**-118**	**-118**	**-119**	**-120**	**-121**	**-121**	**-122**	**-123**	**-124**
Operation and maintenance (Note 2)	-36	-37	-38	-38	-39	-40	-41	-41	-42	-43
Depreciation (Straight-line over 20 years)	-81	-81	-81	-81	-81	-81	-81	-81	-81	-81
WORKING PROFITS, ORDINARY	**210**	**206**	**202**	**198**	**194**	**190**	**186**	**181**	**177**	**173**
FINANCING	**-56**	**-52**	**-47**	**-43**	**-38**	**-32**	**-27**	**-21**	**-14**	**-7**
Interests, loans (Note 3)	-56	-52	-47	-43	-38	-32	-27	-21	-14	-7
Working profits	**154**	**154**	**155**	**155**	**156**	**158**	**159**	**161**	**163**	**166**
BALANCE										
ASSETS	**2,567**	**2,652**	**2,733**	**2,809**	**2,882**	**2,950**	**3,014**	**3,074**	**3,130**	**3,182**
Installation	727	646	565	484	404	323	242	161	81	0
Cash balance	1,841	2,006	2,167	2,325	2,478	2,627	2,772	2,913	3,050	3,182
LIABILITIES	**2,567**	**2,652**	**2,733**	**2,809**	**2,882**	**2,950**	**3,014**	**3,074**	**3,130**	**3,182**
Net worth	1,756	1,910	2,065	2,220	2,376	2,533	2,692	2,853	3,016	3,182
Debt (Note 3)	811	742	668	589	506	417	322	221	114	0
Liquidity of the year (This year's cash balance growth minus transferences) (after tax)	170	165	162	157	153	149	145	141	137	132

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Appendix: 5.6.2 Option 1-Budget for Liquidity and Profit/Loss

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WINDBANK (WTG economics) - Budgets for liquidity and profit/loss

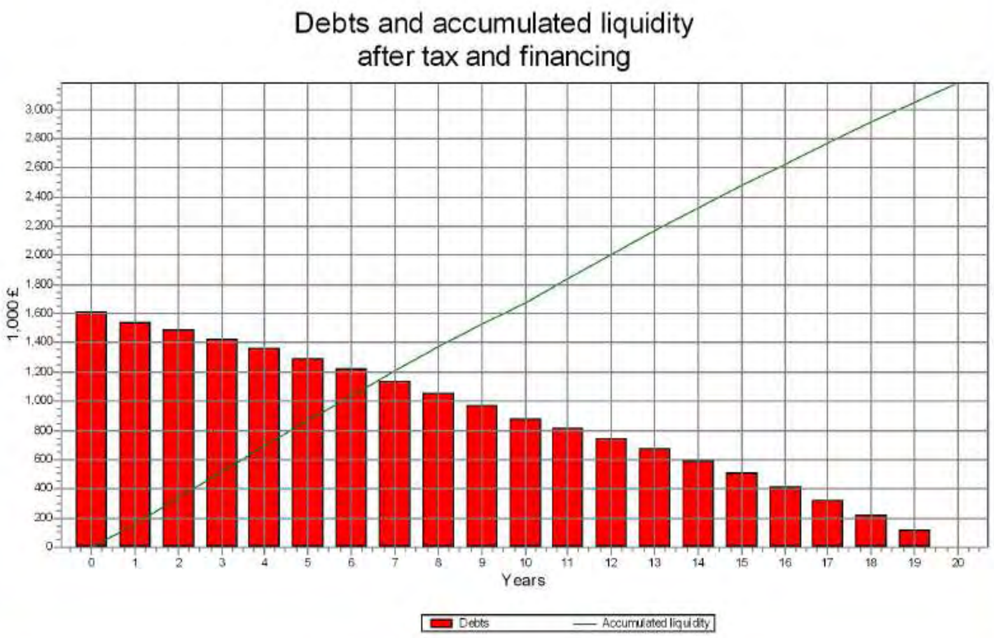
Calculation: New Design

CASH FLOW - amount in 1,000 £

Calendar year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2025
Age	0	1	2	3	4	5	6	7	8	9	10	11	20
INCOME	0	347	347	347	347	347	344	340	337	334	331	327	297
Sale of electricity	0	347	347	347	347	347	344	340	337	334	331	327	297
EXPENDITURES	0	187	170	171	171	171	172	172	172	173	191	157	165
Operating Costs	0	15	15	15	16	16	16	17	17	17	35	36	43
Repayment on loans	0	71	58	61	65	69	73	78	83	88	93	65	114
Interests on loans	0	101	98	94	90	86	82	77	73	67	62	56	7
PROFITS	0	160	177	176	176	176	172	168	165	161	140	170	132
Cash balance	0	160	337	513	689	865	1,037	1,205	1,370	1,531	1,671	1,841	3,182
Debts	1,615	1,544	1,486	1,425	1,360	1,291	1,218	1,140	1,058	970	876	811	0

Profit and loss account - amount in 1,000 £

Calendar year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2025
Age	0	1	2	3	4	5	6	7	8	9	10	11	20
INCOME, Energyprod.	0	347	347	347	347	347	344	340	337	334	331	327	297
EXPENDITURES before interests and depreciations	0	15	15	15	16	16	16	17	17	17	35	36	43
Operation & Maintenance	0	15	15	15	16	16	16	17	17	17	35	36	43
WORKING PROFITS	0	332	332	332	331	331	327	323	320	316	295	291	254
SIMPLE RETURN ON INVESTMENT (%)	0	21	21	21	21	20	20	20	20	20	18	18	16



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Appendix: 5.6.3 Option 1-Economic Assumptions and Ratios

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WINDBANK (WTG economics) - Assumptions and ratios

Calculation: New Design

WTG PARK

WTG type	2 units VESTAS V47 660-200 47.0 !O!
Inst.Power Unit/Total	660 kW / 1,320 kW
Hub height	50.0 m

ENERGY CALCULATION

Calculated Energyprod. - 0 %	5,008 MWh/Years

VALUE OF ENERGY PRODUCTION

Years	£/kWh	Years	£/kWh	Years	£/kWh
2005	0.0693	2012	0.0679	2019	0.0633
2006	0.0693	2013	0.0673	2020	0.0626
2007	0.0693	2014	0.0666	2021	0.0620
2008	0.0693	2015	0.0660	2022	0.0613
2009	0.0693	2016	0.0653	2023	0.0606
2010	0.0693	2017	0.0646	2024	0.0600
2011	0.0686	2018	0.0640	2025	0.0593

TURN-KEY BUDGET (Amount in £ excl. VAT)

I	Turbine Components	726,000
	Civil Works	145,200
D1I	Road Construction	462,500
D1I	Grid Electrical Cost	133,200
	Project Management	14,520
I	Installation	14,520
D1	Power Line upgrading	46,250
	Legal/Development Cost	36,300
	Bank Fees	14,520
	Interest During Construction	21,780
	Net installation price	**1,614,790**
	Cost per 1,000 kWh	**322**
	Total entitled depreciation amount	641,950
	Total O/M expenditure	972,840

D) Entry is included in the depreciation amount
I) Entry is included in the calculation of the insurance premium
O) Entry is divided linearly over the period in question

MISCELLANEOUS

Expected month of installation	12/2005
Expected life span	20 Years
Inflation	2.0 %
First regulation of inflation	1. January 2006

INFORMATION ON PURCHASER

Private/Company owned, personly taxation	
Tax on operation and depreciation	0.0 %
Tax on interests	0.0 %
Depreciation: Maximum annual depreciation	0.0 %

FINANCING

Type of loan	Amount [£]	Term [years]	Interest rate [%]
Annuity	1,347,790	20	6.4
Annuity	200,000	10	6.4
Cash credit	17,000		0.0
Annuity	50,000	10	4.0

Interests on negative cash balance	0.0 %
Interests on positive cash balance	0.0 %

OPERATION AND TRANSFERENCES

Annual O/M expenditures	
Operation & Maintenance:	2.0 % of WTG price From year 0 to 10
	4.0 % of WTG price From year 10

RATIOS

		/kW	/m2	/MWh
Preliminary expenses	£	1,223	465	322
O/M costs	average £/years	17	6	4
Energy production	kWh/Years	3,794	1,443	-

Minimum life span for redemption of loan	6.7 Years
Simple pay back time	5.2 Years
Net present value for share	2,141,402 £
Net present value in % of investment	132.6 %
Production price at calculation interest 8.5%	0.05 £/kWh

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Appendix: 5.6.4 Option 1-Turn-Key Budget

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WINDBANK (WTG economics) - Main Result

Calculation: New Design

TURN-KEY BUDGET **(Amount in £ excl. VAT)**

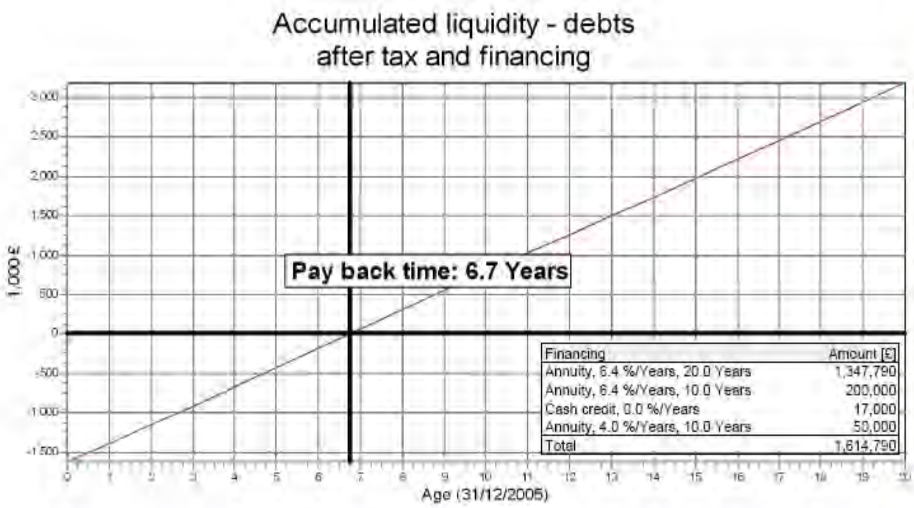
2 units VESTAS V47 660-200 47.0 !O!

	Fixed assets	Operating Costs
Road Construction	462,500	-
Grid Electrical Cost	133,200	-
Project Management	14,520	-
Installation	14,520	-
Power Line upgrading	46,250	-
Legal/Development Cost	36,300	-
Bank Fees	14,520	-
Interest During Construction	21,780	-
Total	**743,590**	**0**

Total Turn-Key Price: **1,614,790** **Cost per 1,000 kWh** **322**

Profit and loss account(before financing)

Income (electricity)				Years: 1		Years 6		Mean of 20 years
Description	Adjustement	MWh/Years	£/kWh	£ total	£/kWh	£ total	£/kWh	£ total
Market Price to Grid	No inflation	5,008	0.0200	100,158	0.0200	100,158	0.0164	81,886
Climate Change Levy	No inflation	5,008	0.0043	21,534	0.0043	21,534	0.0035	17,606
ROC	Annual values	5,008	0.0450	225,356	0.0443	221,850	0.0338	169,397
Total, electricity			0.0693	347,047	0.0686	343,542	0.0537	268,889
-O/M and transferences:			0.0029	14,520	0.0029	14,520	0.0045	22,506
Annual profit before tax and financing			0.0664	332,527	0.0657	329,022	0.0492	246,383
Profit in % of investment				21 %		20 %		15 %



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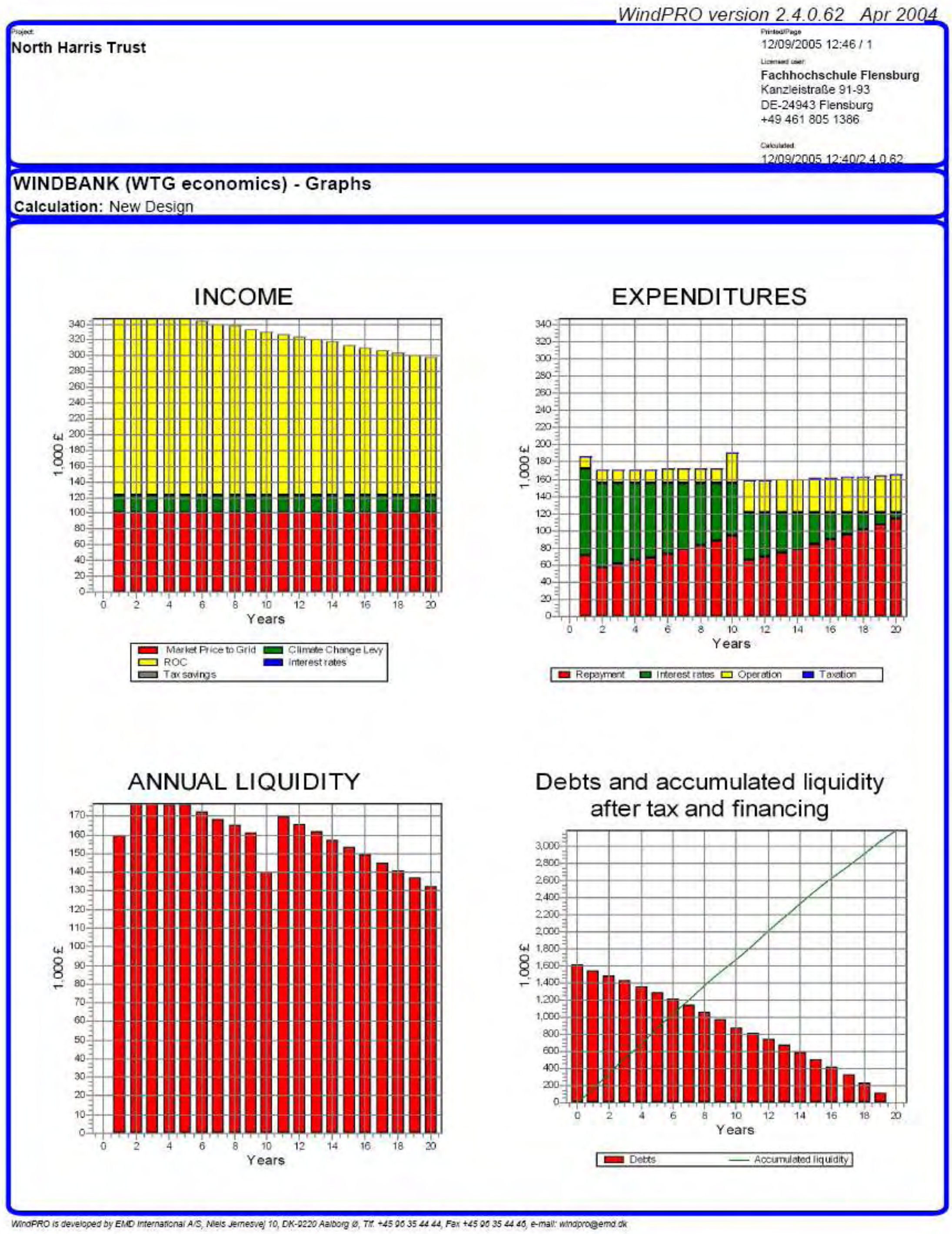
Appendix: 5.6.5 Option 1-Economic Graphs



Appendix: 5.6.6 Option 2-Detailed Listing of Economic Figures

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WINDBANK (WTG economics) - Detailed listing of economic figures

Calculation: New Design

Assumptions

Amount in 1,000 £ (excl. VAT) when nothing is specified. All expenditures are marked with (-).

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Operation																					
INCOME																					
Sale of electricity, 5,263 MWh/Year (Note 1)	0	365	365	365	365	365	361	357	354	351	347	344	340	337	333	329	326	323	319	316	312
EXPENDITURES	**0**	**-103**	**-104**	**-104**	**-104**	**-106**	**-106**	**-106**	**-108**	**-108**	**-124**	**-125**	**-126**	**-128**	**-127**	**-128**	**-128**	**-129**	**-130**	**-131**	**-132**
Operation and maintenance (Note 2)	0	-15	-15	-15	-16	-16	-16	-17	-17	-17	-35	-36	-37	-38	-38	-39	-40	-41	-41	-42	-43
Depreciation (Straight-line over 20 years)	0	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89	-89
WORKING PROFITS, ORDINARY	**0**	**261**	**261**	**261**	**260**	**260**	**256**	**252**	**249**	**245**	**223**	**219**	**216**	**211**	**206**	**202**	**198**	**193**	**189**	**185**	**180**
FINANCING	**0**	**-111**	**-107**	**-104**	**-99**	**-95**	**-90**	**-86**	**-80**	**-75**	**-69**	**-63**	**-58**	**-53**	**-48**	**-42**	**-36**	**-30**	**-23**	**-16**	**-8**
Interests, loans (Note 3)	0	-111	-107	-104	-99	-95	-90	-86	-80	-75	-69	-63	-58	-53	-48	-42	-36	-30	-23	-16	-8
Working profits	**0**	**150**	**154**	**157**	**161**	**165**	**166**	**167**	**168**	**170**	**155**	**156**	**157**	**158**	**158**	**160**	**162**	**164**	**166**	**169**	**172**
BALANCE																					
ASSETS	**1,771**	**1,846**	**1,938**	**2,029**	**2,121**	**2,211**	**2,298**	**2,381**	**2,460**	**2,538**	**2,590**	**2,674**	**2,753**	**2,828**	**2,899**	**2,966**	**3,028**	**3,086**	**3,139**	**3,189**	**3,234**
Installation	1,771	1,682	1,594	1,505	1,417	1,328	1,240	1,151	1,063	974	885	797	708	620	531	443	354	266	177	89	0
Cash balance	0	164	344	524	704	883	1,059	1,230	1,398	1,562	1,705	1,877	2,044	2,208	2,368	2,523	2,674	2,820	2,962	3,100	3,234
LIABILITIES	**1,771**	**1,846**	**1,938**	**2,029**	**2,121**	**2,211**	**2,298**	**2,381**	**2,460**	**2,538**	**2,590**	**2,674**	**2,753**	**2,828**	**2,899**	**2,966**	**3,028**	**3,086**	**3,139**	**3,189**	**3,234**
Net worth	0	150	304	461	622	787	953	1,119	1,288	1,457	1,612	1,768	1,925	2,083	2,241	2,401	2,563	2,727	2,892	3,062	3,234
Debt (Note 3)	1,771	1,696	1,634	1,568	1,499	1,424	1,345	1,262	1,173	1,079	978	906	828	745	658	564	465	359	247	127	0
Liquidity of the year (This year's cash balance growth minus transferences) (after tax)	0	164	180	180	180	179	175	171	168	164	143	172	168	164	159	155	151	147	142	138	134

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Appendix: 5.6.7 Option 2-Budget for Liquidity and Profit/Loss

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WINDBANK (WTG economics) - Budgets for liquidity and profit/loss

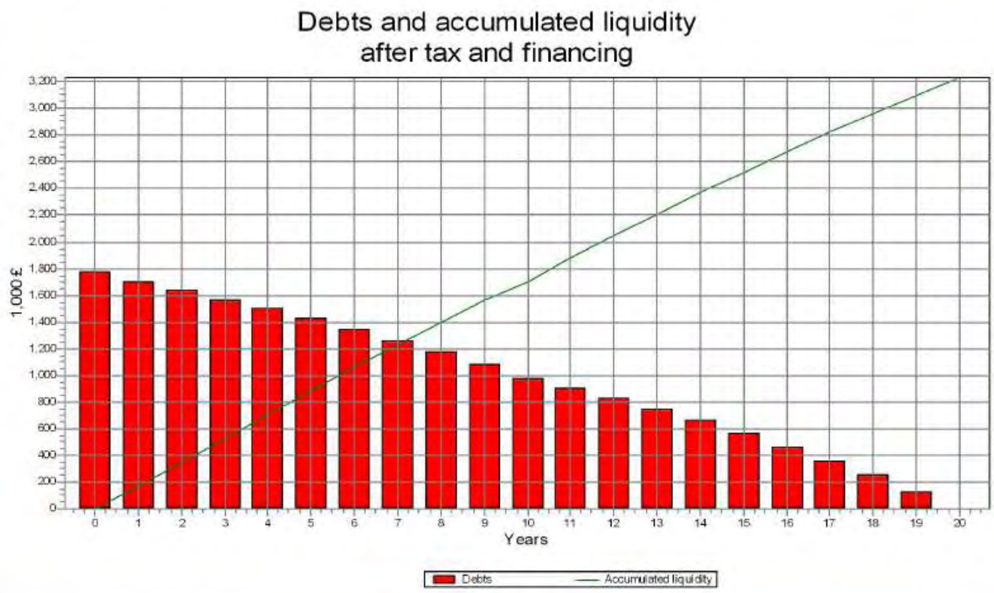
Calculation: New Design

CASH FLOW - amount in 1,000 £

Calendar year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2025
Age	0	1	2	3	4	5	6	7	8	9	10	11	20
INCOME	0	365	365	365	365	365	361	357	354	351	347	344	312
Sale of electricity	0	365	365	365	365	365	361	357	354	351	347	344	312
EXPENDITURES	0	201	184	185	185	185	186	186	186	187	205	172	179
Operating Costs	0	15	15	15	16	16	16	17	17	17	35	36	43
Repayment on loans	0	75	62	66	70	74	79	84	89	94	100	73	127
Interests on loans	0	111	107	104	99	95	90	86	80	75	69	63	8
PROFITS	0	164	180	180	180	179	175	171	168	164	143	172	134
Cash balance	0	164	344	524	704	883	1,059	1,230	1,398	1,562	1,705	1,877	3,234
Debts	1,771	1,696	1,634	1,568	1,498	1,424	1,345	1,262	1,173	1,078	978	905	0

Profit and loss account - amount in 1,000 £

Calendar year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2025
Age	0	1	2	3	4	5	6	7	8	9	10	11	20
INCOME, Energyprod.	0	365	365	365	365	365	361	357	354	351	347	344	312
EXPENDITURES before interests and depreciations	0	15	15	15	16	16	16	17	17	17	35	36	43
Operation & Maintenance	0	15	15	15	16	16	16	17	17	17	35	36	43
WORKING PROFITS	0	350	350	349	349	349	345	341	337	333	312	308	269
SIMPLE RETURN ON INVESTMENT (%)	0	20	20	20	20	20	19	19	19	19	18	17	15



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Appendix: 5.6.8 Option 2-Economic Assumptions and Ratios

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WINDBANK (WTG economics) - Assumptions and ratios

Calculation: New Design

WTG PARK

WTG type	2 units VESTAS V47 660-200 47.0 !O!
Inst.Power Unit/Total	660 kW / 1,320 kW
Hub height	50.0 m

ENERGY CALCULATION

Calculated Energyprod. - 0 %	5,263 MWh/Years

VALUE OF ENERGY PRODUCTION

Years	£/kWh	Years	£/kWh	Years	£/kWh
2005	0.0693	2012	0.0679	2019	0.0633
2006	0.0693	2013	0.0673	2020	0.0626
2007	0.0693	2014	0.0666	2021	0.0620
2008	0.0693	2015	0.0660	2022	0.0613
2009	0.0693	2016	0.0653	2023	0.0606
2010	0.0693	2017	0.0646	2024	0.0600
2011	0.0686	2018	0.0640	2025	0.0593

TURN-KEY BUDGET (Amount in £ excl. VAT)

D1I	Turbine Components	726,000
	Civil Works	145,200
D1I	Road Construction	575,000
D1I	Grid Electrical Cost	165,600
	Project Management	14,520
I	Installation	14,520
D1	Power Line upgrading	57,500
	Legal/Development Cost	36,300
	Bank Fees	14,520
	Interest During Construction	21,780
	Net installation price	**1,770,940**
	Cost per 1,000 kWh	**336**
	Total entitled depreciation amount	1,524,100
	Total O/M expenditure	246,840

D) Entry is included in the depreciation amount
I) Entry is included in the calculation of the insurance premium
O) Entry is divided linearly over the period in question

MISCELLANEOUS

Expected month of installation	12/2005
Expected life span	20 Years
Inflation	2.0 %
First regulation of inflation	1. January 2006

INFORMATION ON PURCHASER

Private/Company owned, personly taxation	
Tax on operation and depreciation	0.0 %
Tax on interests	0.0 %
Depreciation: Maximum annual depreciation	0.0 %

FINANCING

Type of loan	Amount [£]	Term [years]	Interest rate [%]
Annuity	1,503,940	20	6.4
Annuity	200,000	10	6.4
Cash credit	16,999		0.0
Annuity	50,000	10	4.0

Opening cash balance (yields interest)	-1 £
Interests on negative cash balance	0.0 %
Interests on positive cash balance	0.0 %

OPERATION AND TRANSFERENCES

Annual O/M expenditures	
Operation & Maintenance:	2.0 % of WTG price From year 0 to 10
	4.0 % of WTG price From year 10

RATIOS

		/kW	/m2	/MWh
Preliminary expenses	£	1,342	510	336
O/M costs	average £/years	17	6	4
Energy production	kWh/Years	3,987	1,517	-

Minimum life span for redemption of loan	7.1 Years
Simple pay back time	5.4 Years
Net present value for share	2,176,275 £
Net present value in % of investment	122.9 %
Production price at calculation interest 8.5%	0.05 £/kWh

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Appendix: 5.6.9 Option 2-Turn-Key Budget

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WINDBANK (WTG economics) - Main Result

Calculation: New Design

TURN-KEY BUDGET **(Amount in £ excl. VAT)**

2 units VESTAS V47 660-200 47.0 !O!

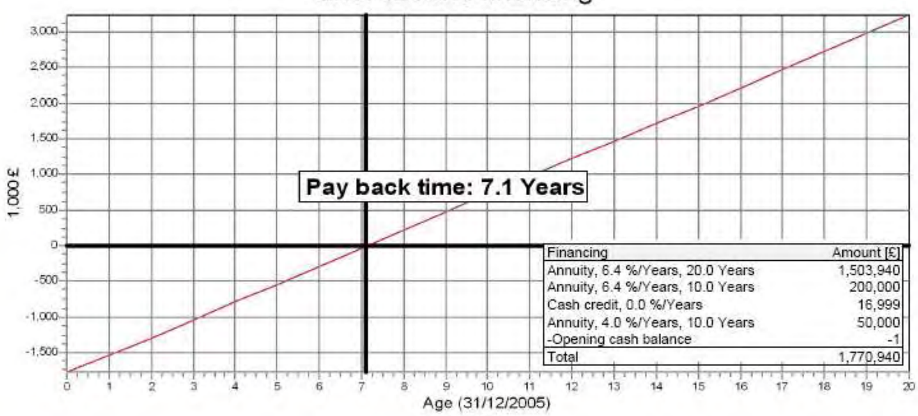
		Fixed assets	Operating Costs
Road Construction	:	575,000	-
Grid Electrical Cost	:	165,600	-
Project Management	:	14,520	-
Installation	:	14,520	-
Power Line upgrading	:	57,500	-
Legal/Development Cost	:	36,300	-
Bank Fees	:	14,520	-
Interest During Construction	:	21,780	-
Total	:	**899,740**	**0**

Total Turn-Key Price: **1,770,940** **Cost per 1,000 kWh** **336**

Profit and loss account(before financing)

Income (electricity)			Years: 1		Years 6		Mean of 20 years	
Description	Adjustement	MWh/Years	£/kWh	£ total	£/kWh	£ total	£/kWh	£ total
Market Price to Grid	No inflation	5,263	0.0200	105,258	0.0200	105,258	0.0164	86,056
Climate Change Levy	No inflation	5,263	0.0043	22,630	0.0043	22,630	0.0035	18,502
ROC	Annual values	5,263	0.0450	236,831	0.0443	233,146	0.0338	178,023
Total, electricity			0.0693	364,719	0.0686	361,035	0.0537	282,581
-O/M and transferences:			0.0028	14,520	0.0028	14,520	0.0043	22,506
Annual profit before tax and financing			0.0665	350,199	0.0658	346,515	0.0494	260,075
Profit in % of investment				20 %		20 %		15 %

Accumulated liquidity - debts
after tax and financing



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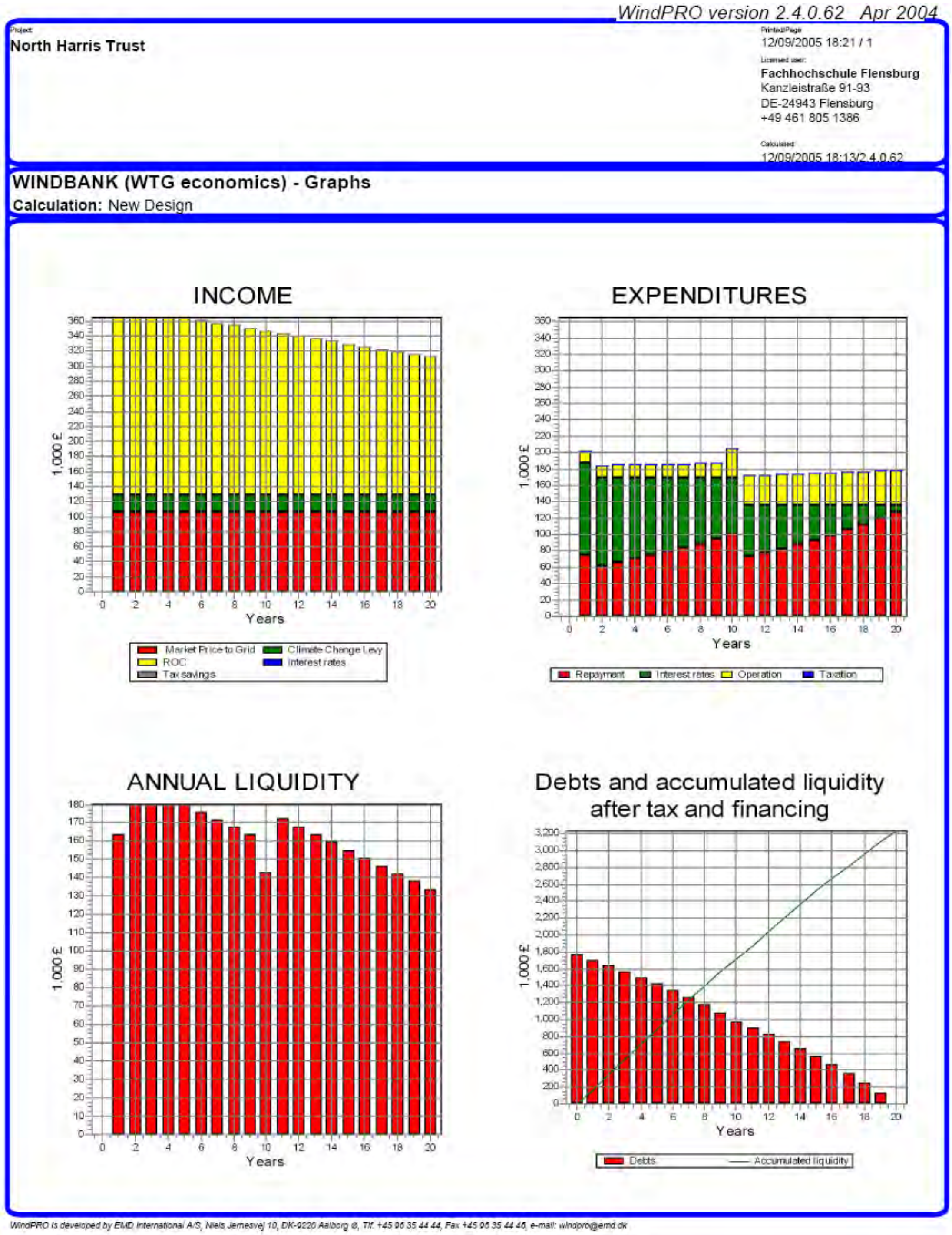
Appendix: 5.6.10 Option 2-Economic Graphs



Appendix 5.7.1 Average domestic hot water utilization

Application	Water temp. (℃)	Consumption(L/day)
Sink	55	40
Wash basin	35	10
Bath	40	30-50
Shower	40	50
Bidet	40	25
Washing machine(cold)	30-40	60-70
Washing machine(hot)	50-60	60-70
Dishwashing machine	50-65	
Total		
Low	60	10-20
Average	60	20-40
High	60	40-80

Source: Combined from Thermomax ,P35and interview questionnaire

Appendix 5.7.2 System sizing

No. of person	No. of tubes	Approximate storage tank size (l)
1-2	20	100-150
2-3	30	200-250
5-6	40	300-350
7-8	50	400-450

Source: Thermomax,P37

Appendix 5.7.3 Economic Efficiency Parameter

	Govig 6	Govig holiday house
SWH system Life time	20 year	20 year
Investment	4700£	4000£
Grants(30% of investment)	1410£(30% of investment)	1200£(30% of investment)
Capital Interest	6.4%	6.4%
Energy use Price Increase Rate	3.0%	3.0%
Annual Energy supply by SWH	1771 kWh	1465 kWh
Fuel saving:	222.6 L/year (75% efficiency):	1627 kWh/year (90% efficiency)
Local Fuel price	0.32£/ L	0.0599£/ kWh
Annual Fuel cost	71£/year	63£/year
Annual Running cost	10£	10£

Appendix 5.7.4 NPV calculation

	Govig household	Govig holiday house
Investment	-4700£	-4000£
Grants	1410£(30% investment)	1200£(30% investment)
Saving	1184£	13722£
Running cost	-281£	-111
NPV calculation	-2387£	-1539£

Appendix 5.7.5 Components Price List of the Solar Water Heating System in UK

Collector	
2m2 collector(1960 x 1420 mm, 45kg)	958£
3m2 collector(1960 x 2120 mm, 68 Kg)	1437£
Manifolds	
MS20 Manifold for 20 Tubes	284£
MS30 Manifold for 30 Tubes	401£
Controllers	
Pump Control Unit for 2m2 collector	£330
Pump Control Unit for 3m2 collector	£533
Power Supplies	
21V mains adapter for 1 or 2 collector systems	£25
24V mains adapter for 3 or 4 collector systems	£49
Pumps	
Pump: Replacement for 1 collector with filter	£81
Pump: Replacement for 2 collector with filter & 24 VDC adaptor	£127
Pump: Replacement for 3-4 collector with 24VDC adaptor	£139
Tank Twin Coil	
Vented 120 litre 1050x400 TWIN coil cylinder	£260
Vented 153 litre 1800x350 TWIN coil cylinder	£332
Vented 184 litre 1300x450 TWIN coil cylinder	£284
Vented 210 litre 1800x400 TWIN coil cylinder	£325
pipe(15m)	£36