Towards a Greener Applecross

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Disclaimer

Although the contents were reviewed several times before being part of this report, the accuracy of the results cannot be guaranteed. The University of Flensburg as well as the authors of the present document have no legal responsibility in case of any errors, omissions or misleading statements. Therefore, we recommend that expert opinion of the relevant topics should be sought after before using any data presented in this report.

ORGANIZATION OF THE REPORT

From the 17thof February till the 22nd of March 2014 a group of twelve master of engineering students and three professors from theEnergy and Environmental Management department of the University of Flensburg undertook a field study in the community of Applecross. The purpose of thestudy consisted on giving suggestions for improvement in the areas of energy efficiency, small renewables, biomass and transportation. The findings and suggestions are adressed in five chapters. Chapter 1 of this report illustrates the context of Applecross, the energy trends, main fuel used by households through different periods. It also recapitulates the main objective and purpose of the present study. Consequently, explains the methodology and constraints found during the development of the present research.

Chapter 2 of this report shows the current situation of dwellings in the community of Applecross. The most common types of dwellings surveyed were detached and semi-detached houses. Some terraced houses and flats were also surveyed. This chapter also describes the most common fuels used for space and water heating, some common characteristics of the dwellings and attitudes and behaviours of the householders. Additionally, a definition of Hard-to-Treat houses adapted to the current conditions of Applecross is presented. Towards the end of this chapter, a description of the alternatives that HtT houses have to improve their energy efficiency is provided.

Chapter 3 explains the potential of Applecross to produce energy from solar, wind and hydro resources which in conjunction with Chapter 2 and Chapter 4 convey in Chapter 5 in two case studies. In the first case study, three representatives HtT houses in Applecross and their assessment regarding energy usage and efficiency is done; describing some options for improving their current energy situation. These improvements include insulation, replacement of existing main heating system for a wood-fuelled heating system and implementation of domestic renewables such as solar PV, solar thermal and micro wind turbines. Then, in order to facilitate the process of decision making and to evaluate the feasibility of proposed alternatives for each Hard to Treat houses, a bubble diagram was created. In the second case study was considered the development of a District Heating system for a Biomass Stand-alone system, Hydro Stand-alone system and a combined Hydro and Biomass System. A case study of the location of these systems was done in Camusterrach Place and Burnside areas. The results from the financial analysis of the three systems shows that in each case they are all feasible however having a combined Hydro and Biomass district system would be most financially attractive. This is because of the flexibility of the system and ability to offer a more secure solution.

Chapter 4 focused on evaluating different scenarios of demand and supply of wood fuel to see if they match. Currently the biomass consumption is being met mainly from dead or felled trees and until recently (from December 2013) from living trees as part of the forestry management. In this study three scenarios for the Biomass demand have been analysed which include the BAU scenario, 100% Biomass Bases Heating Systems future scenario and 100% Biomass Based Heating system with Energy Efficiency scenarios. In all the three it was seen that to meet the annual demand (estimated as 863.5m3 from the survey) huge amounts of wood will have to be taken out from the existing forest when mixed together with the replantation plan from Forestry Management practices. Suggestions have thus been made to make use of the Croft and Common Grazing land to plant more trees.

Chapter 6 The current transport situation in the community was assessed based on data collected from interviews and field surveys with emphasis on private road transport. The analysis shows that 90% of respondents have access to at least one vehicle. The annual average vehicle mileage per household is 9,479 miles. Correspondingly an annual average of 1,688 litres of fuel is expended per household leading to annual CO_2 emission of 1,760kg per household. The estimated expenditure on private road transportation per household is £2,421. The introduction of electric vehicles may lead to annual potential savings of £528 with a corresponding annual electricity demand of 1,788kWh per household. The study concludes that commuting to work is the most frequent purpose for travel within the community. This is followed by shopping, school and leisure in that order. The usual work place destinations are within the Peninsula and the usual destinations for shopping outside the community are Inverness and Lochcarron. To reduce the total CO_2 emission for shopping trips to Inverness, car sharing and shopping delivery services may be adopted as solutions. The establishment of electric vehicle and electric bike-sharing schemes could be options for eco-friendly transportation within the community.

Finally, the findings and suggestions convey in a conclusion chapter called “An Energy Vision for Applecross 2020”; where the concept of self-sufficiency is described as the ability to use local in resources in a sustainable way to produce the energy required for self-need and to generate income This vision has been described through a visual example of how Applecross would look like in the future if the five components identified work in a synergetic manner to meet Energy efficiency by 2020.

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1. INTRODUCTION

1.1. BACKGROUND

The Applecross peninsula is located on the west coast of Wester Ross, United Kingdom and is considered as one of the most remote areas of Scotland. It is a community with a population of approximately197 people according to the 2011 Highland Council census profile. Before the 20th century Applecross was only accessible by boat.Currently it can be accessed by two roads: Bealach nam Bo and the road along the coastfrom Shieldag. This condition of remoteness has shaped Applecross energy profile over the years.

The households in Applecross are mostly resident-owned; having between 1 and 2 full-time residents with 1 or 2 cars. Most of the population is economically active in the sectors of agriculture, forestry, fishing, accommodation and food services activities, human health and social work activities (Highland Council 2011).

The area surrounding Applecross is believed to be one of the earliest settlements in Scotland (Goldthrope 2014). It is believed that this settlement was founded by Saint Maelrubha, an Irish monk, in the year 673(G. Cameron 2014).

Currently, 26,700 hectares of land in the peninsula are owned by the Applecross Trust. The Trust is a conservation charity seeking to “ensure that the special character of the peninsula is preserved in a responsible and progressive manner whilst acknowledging its wilderness heritage and its importance as an area of outstanding natural beauty” (The Applecross Trust 2011).

Information available indicates that peat was the main energy resourcein the mid-nineteenth century according to the Statistical Account(Cameron, Fuel sources in Old Applecross 2014). Up until the early 20th century, external fuel supplywas limited to coal via boats. With the completion of the Bealach nam Bo road, opportunities for alternative energy resourceswidened. In 1955, the community was connected to the national electricity grid (Cameron, Fuel sources in Old Applecross 2014). Currently, the community is exploring the potential of its hydro energy resources.

The community has launched several initiatives and programmes to enhance the living conditions of the population. Among them, one can find the Applecross Community Company “focusing on community development and renewable energies” (Applecross Community Company n.d.), and the Applecross Energy Efficiency providing information to the community regarding “energy efficiency measures, domestic renewable technologies and available assistance to reduce the energy needed to live life in comfort” (Applecross Energy Efficiency n.d.).

This report seeks to contribute to the information gathering process regarding energy use in the Applecross peninsula and provide alternatives to fulfil the community’s objective of stable energy supply, reduction of carbon emissions and the implementation of cost-effective technologies.

1.2. OBJECTIVE

The purpose of this study is to assess the current energy situation of the Applecross Community in order to suggest greener alternatives for housing, small and medium enterprises and transport sectors.

Specifically the field work was based on the following objectives:

1. Suggest and prioritize energy efficiency alternatives for household buildings according to the following parameters: cost, ease of implementation and environmental impact.
2. Assess the feasibility of using biomass as fuel source for heating at household level.
3. Assess and recommend options for energy supply from renewable sources at household level.
4. Study the feasibility of a biomass-hydro district heating scheme
5. Suggest measures for an environmentally friendly transport system

1.3. METHODOLOGY

A series of various methodologies were used to perform the different tasks. In order to assess the current energy use and energy situation of the households and businesses of Applecross, a detailed questionnaire was prepared and a survey was conducted in 65 occupied households out of a total number of 114. An energy profile of the households in the community was created based onaverage electricity consumption, typical heating systems and fuels, and behavioursof residents regarding energy efficiency. Three representative houses were then selected for a detailed energy audit. The aim was to identify possible upgrades regarding space and water heatingfor each house and using these results as reference for similar dwellings in the community.

The potential of domestic renewable energy for dwellings in Applecross was conducted in three phases. Firstly, the Meteonorm7 software was used to assess the distribution of the global horizontal radiation and wind speed in Applecross. For the wind assessment, the wind speed of the South Eastern part along the coast of Applecross at a height of 15 meters was considered. Then during the survey, specific site assessments were conducted in the properties that were interested in installing these type of technologies. Later, the results from the previous phases were used to assess the total potential for solar PV, and solar thermal using the TSOL Pro 4.4 and RETScreen softwares. Also,the Homersoftware was used to assess the potential production of energy from the micro-wind turbines. Consequently, this assessment was performed for the whole Applecross community and for the individual case studies.

The main purpose of the hydro feasibility study in this report covers only the heat demand of certain households.The hydro potential was based on previous hydro feasibility studies of rivers near certain townships. This was supplemented by hydrological modelling using geographical information systems (GIS). Then, calculations of monthly energy supply were done. The flow data at hand for one of the rivers (Allt nan Corp) was used to validatethe existing desk studies. Based on that, two potential sites for hydro-to-heat schemes were identified which were the townships of Estate and Camusterrach. The heat demand of the existing dwellings was estimated using the data from the survey. The results in conjunction with the Scottish Heat Atlas was used to analyse the feasibility of constructing hydro schemes for these two townships.

The study of the use of biomass for heating in Applecross was carried out in three phases. Firstly, data from the household survey were used for estimating the space and water heating demand. Secondly, key informant interviews and field visits were performed to understand and estimate the forest/woodland status of Applecross. Thirdly, future scenarios were created and sensitivity analyses were carried out for the scenarios. Also, the feasibility of a combined hydro-district heating scheme in Camusterrach was studied.

For the transport section of this report, primary and secondary data from field surveys were used to perform a quantitative and qualitative analysis of the status of the transport sector in Applecross. Interviews were also undertaken with community stakeholders and staff of the Applecross community company. Furthermore, interviews were conducted with the coordinator of the Wester Ross community car scheme. Quantitative data were analysed using statistical tools, then additional cost calculations were done based on the results of the statistical analysis. Qualitative data were analysed based on the content and relevance to the objectives of the study. The amount of CO_2 emissions from road transportation in the study area was calculated based on annual estimated fuel consumption of households.

1.4. SCOPE

This study looks to contribute to the current work done by the Applecross Community Company and Applecross Energy Efficiency to improve the living conditions and current energy situation of the households in Applecross. Therefore, it analyses the current situation and proposes alternatives for improvement in four different areas: energy efficiency for households, small domestic renewables for the production of electricity and heat, biomass for heating and transportation.

1.5. CONSTRAINTS

While assessing energy efficiency, the lack of information regarding records of electricity and water consumption in the households represented a challenge. Further assumptions regarding energy use had to be made in order to estimate average energy consumption for the community. Additionally, lack of information regarding the construction (composition) of walls, floors and roofs in the dwellings was an obstacle when estimating heat losses.

Absence of a proper database on the forest resource was the biggest constraint for assessing the wood resource in Applecross. Also, real wood demand was difficult to estimate for Applecross due to the presence of an informal supply chain of wood, different wood consumption of each of the houses depending on their use of this resource as primary or secondary heating fuel. Additionally, it was difficult to estimate, due to the lack of information, the increase of the total consumption of wood due to occupants of the holiday houses during summer.

The solar energy potential, for both thermal and electricity, of Applecross was estimated only as a function of the available roof-top area of 65 dwellings. Therefore, factors like different types of shading were estimated. Also, availability of data forhot water demand for solar thermal systems for the study area was limited. Hence the study was limited to theoretical assumptions and simulations.

The unavailability of site-specific wind speed data is the major constraint for the wind potential study.

Limited access to annual data related to road transportation in Applecross placed a constraint on the scope for the transport sector study. The absence of historical data thwarted efforts to simulate future scenarios of fossil fuel consumption attributed to road transportation. The study was conducted during the winter season and therefore data obtained on occupancy rates of buildings placed a limitation of estimates for the community as a whole. This placed a limitation on the data obtained to assess the transport behaviour of all the residents and in particular the tourists and part-time residents of the community.

2. BUILDINGS

2.1. CURRENT SITUATION

2.1.1. ENERGY CONSUMPTION

2.1.1.1. GENERAL OVERVIEW OF THE COMMUNITY OF APPLECROSS

With the aim of understanding the current energy situation of Applecross a survey was conducted by the students of the Master of Energy and Environmental Management Programme of the University of Flensburg. A sample of the questionnaire is presented in Annex A. From a total database of 267 properties in Applecross (including holiday houses and permanent residences), 65 households from 16 different townships were interviewed. It is important to note that out of the total properties in Applecross; approximately 50% are used as holiday houses and second homes and hence unoccupied for most of the part of the year, especially during the period when the survey was conducted. Therefore, our survey excluded the houses classified as holiday houses or holiday rentals,as well as public buildings such as schools and churches.

KEY ASPECTS:

HOUSEHOLDERS

The Scottish Government publication called *Demographic change in Scotland* (2010), identifies three main age categories of adults: working age from 16 to 60 years old, pensionable age from 60 to 64 age and retirees from 65 and older. According to our survey, 76% of the householders in Applecross are of working age and 13% are in pensionable age and11% are more than 65 years old.

STOCK OF BUILDINGS

According to the *Scottish Heat Atlas* (2013), the buildings in Scotland and therefore Applecross can be classified in 5 categories[1]. In Applecross, 35% of the households identified their buildings inside the category of buildings built pre 1919. These buildings are characterized by solid stone walls,high heat losses, solid floors and its value as heritage. Approximately 8% of the buildings in Applecross correspond to buildings built between the years 1919 and 1944. These buildings share almost the same characteristics as the previous ones. The third and fourth categories correspond to buildings built from 1945 to 1964 and from 1965 to 1983 respectively. Most of these buildings have the same architecture, due to an incentive given by the Department of Agriculture (Newman 2014) for housing in rural areas of Scotland. These buildings are characterized by having as well solid stone walls with no insulated cavity and ventilation schemes. Some energy efficiency measures can be easily implemented. Wall insulation is mostly recommended to be done on the exterior of the building due to reduced interior space (Sustainable Uist 2012). Finally, the fifth category consists of dwellings built post-1983. These houses are characterized for having in most cases built-in energy efficiency measures, like double-glazed windows, loft insulation and in a few cases renewable energy for space heating and electricity like solar PV and ground source heat pumps (air to heat systems), especially in those constructed after 1990.

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[1] Buildings built pre 1919, buildings built between 1920 and 1944, buildings built between 1945 and 1964, buildings built between1965 and 1983 and buildings built after 1983

ENERGY MEASURES IN BUILDINGS

According to the survey, the implementation of energy efficiency measures neither depends on the ownership of the dwelling nor on the type of dwelling. However, 55% of the buildings characterized as resident-owned detached houses have undergone energy efficiency retrofits whilst only 9% of the resident-owned semi-detached houses have undergone same.

Moreover, there is a strong correlation between the implementation of energy efficiency measures and the age of buildings:the newer the building the lower the demand of the dwelling for space heating (Scottish Government, 2013); possibly due to higher housing standards set by the UK Government (Newman 2014). As it will be explained in the next chapters, the demand for space heating also depends on the habits and attitudes towards fuel use. The current focus on implementation of energy measures, can be in part explained by recent support from the Scottish Government with programs such as Green Homes Back Scheme, Green Deal and Eco, Warm Homes Fund(See Table 2-1for policies to improve energy efficiency of housing). For example, policies like 2010 building standards look to reduce 30% of CO_2 emissions by dwellings compared to 2007 standards (Scottish Government, 2010).

TABLE 2-1: POLICIES AND PROGRAMMS TO IMPROVE ENERGY EFFICIENCY OF HOUSINGSUPPORT AND INCENTIVE PROGRAMMES ENCOURAGING OWNERS AND HOUSEHOLDERS TO TAKE ACTION

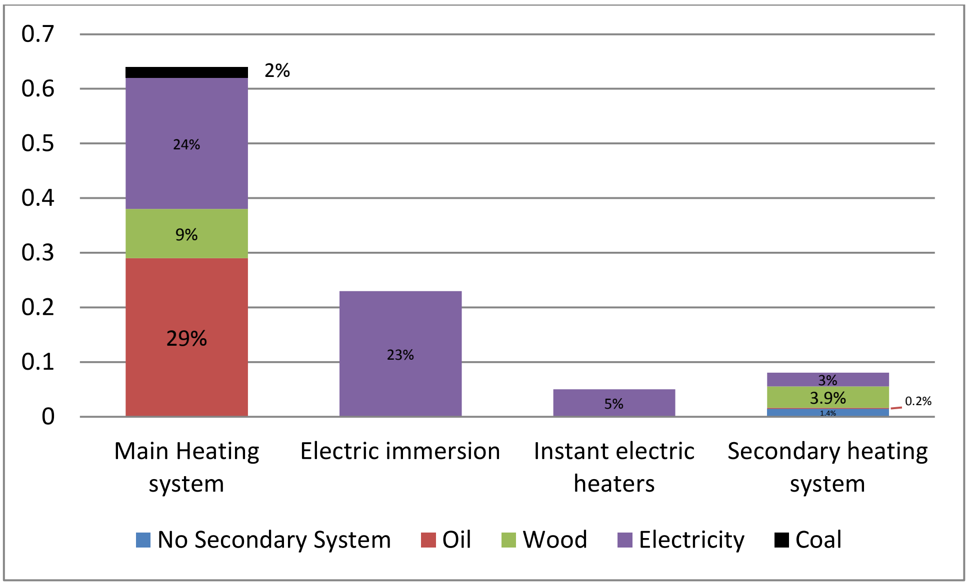
Scottish Government programmes		UK Government /Energy Supplier		Local Government / Landlord programmes	
Demand led	**Area Based**	**Demand led**	**Area Based**	**Demand led**	**Area Based**
Energy Assistance Package	Home Insulation Scheme	Carbon Emission Reduction Target (CERT)	Community Energy Saving Programme	Council tax discounts	Private: Landlord accreditation Scheme
Energy Saving Scotland • **Advice Centers** • **Home Renewables Grant** • **Boiler Scrappage** • **Home Loans Pilot**	Universal access Home Insulation	Feed in Tariff (FITs) Renewable Heat Incentive		Increase local uptake of Scottish and supplier schemes	Energy Saving Scotland Small Business Loan
Energy Efficiency Design Awards	Climate change fund	Green Deal / Company Obligation – under development			
Wider Scottish Government policies – Standards and Regulation					
Building standards for new homes and extension for equipment such as replacement of boilers and windows being updated in 2010 **Energy Performance Certificates** **Scottish Housing Quality Standards (SHQS)** **Powers to regulate all homes for energy efficiency** **Planning: permitted development rights; support for microgen and low carbon district heating in SPP and NPF2**					

SOURCE: THE SCOTTISCH GOVERNMENT, 2010(PAGE 38)

FUEL FOR ENERGY

83% of the households surveyed use electricity for cooking; the second most commonly used fuel for cooking is LPG. For space heating the figure varies, currently 39% of the households are using mainly wood for space heating whilst 25% use oil and 13% use electricity. Also 65% of the households heat their water by means of a central heating system. Out of this, 29% of the households use oil for space and water heating with an average consumption of 2,140 litres of oil and an average expenditure of £1,375[2] per year. Only 9% of the households use wood for bothspace and water heating, with an average consumption of wood per year of 2,600 kg and an average expenditure of £303[3]per year. 24% use electricity and the remaining 3% use coal (SeeFigure 2-1).

FIGURE 2-1ANSWERS TO THE QUESTION: HOW IS YOUR WATER HEATED?



SOURCE: AUTHORS

CO2 EMISSIONS

The amount of CO_2 emitted strongly depends on the type of fuel used for electricity, space and water heating, size of the dwelling and insulation of the building. From the data described above, a household that uses wood for water and space heating in average will emit about 65 kg of CO_2 per year. However, a household that uses oil for space and water heating in average will emit more than the previous household; approximately 5,670 kg of CO_2 per year.

FUEL POVERTY

Fuel poverty is defined as the condition of being unable to afford to keep one's home adequately heated. It is calculated according to the fuel prices of the year, income and energy efficiency at home. A household is considered to be in fuel poverty when more than 10% of its income is spent on energy bills (Wilson et. al., 2012). Our survey indicates that 49% of the

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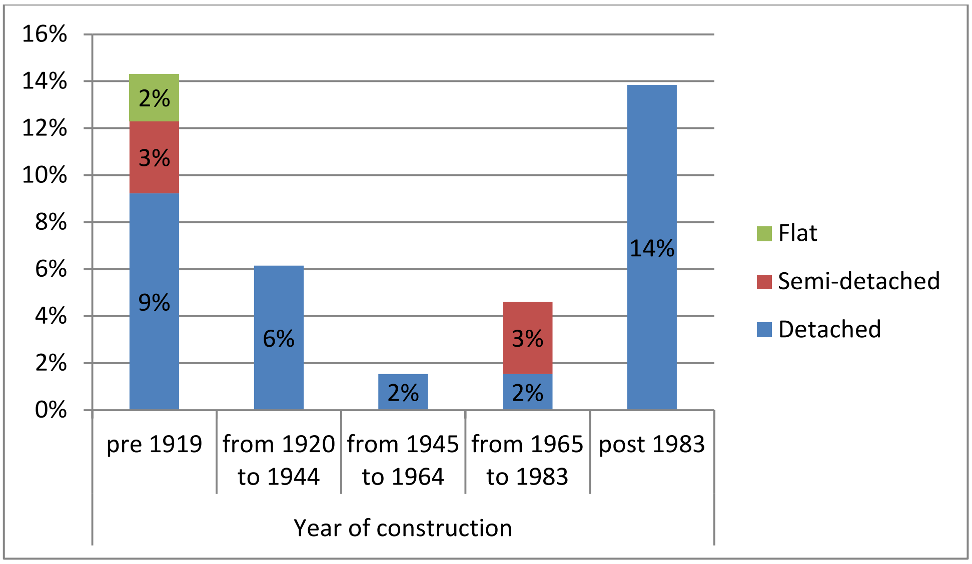
[2] Considering an average price per litre of Oil of 64.26 pence (http://www.boilerjuice.com/heatingOilPrices.php)

[3] Local price of 1m^3 (300 kg) of wood is £35

respondents are currently living in fuel poverty which is twice the Scottish average in 2011 (Wilson et. al., 2012). Consequently, as we can see in Figure 2-2, most of the households that indicated to have spent more than 10% of their income to pay their energy bills live in dwellings constructed before the year 1983.

FIGURE 2-2 FUEL POVERTY IN APPLECROSS ACCORDING TO TYPE OF DWELLING AND YEAR OF CONSTRUCTION



SOURCE: AUTHOR[4]

2.1.1.2. DEVELOPMENT OF TOWNSHIPS

The earliest information gathered about Applecross refers to mid-1700s when Clachan, Estate and Borrodale were the only townships that existed (Cameron, 2014). Houses during this period were built out of materials that were available at hand and reused materials from previous dwellings. Applecross was among the earliest communities in Scotland to use coal for heating. Most of the lands in these townships in Applecross were fertile and the main occupation of the people was farming. These people were settled along the valley that ends in Applecross bay.

Between 1840 and 1850, many agrarian communities struggled with the potato famine in the Highlands. Inhabitants of Northern Scotland were forced to emigrate, reduced to destitution or exposed to starvation when blight destroyed the potato (Devine 1995, p. 159). Particularly in Applecross, the landlords were experiencing a reduction in their incomes. The MacKenzie family, owners of Applecross at that moment, forced the inhabitants of the valley to move in order to maximize the land available for their economic activities. The people established themselves in dwellings in unfertile lands along the shore and became crofters. New

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[4] Based on 26 respondents (42% out of 65) that indicated to be in fuel poverty. The missing 7% corresponds to respondents that were not able to identify the year of construction of their dwelling in the survey.

townships such as Culduie were established at that time (Cameron, History of Urbanization in Applecross 2014).

In these new dwellings, drains and proper walls were introduced. The population began to increase because better health care was provided and therefore more children survived until adulthood. The Crofters Act 1886 gave the crofters security of tenure and provided ownership of land.

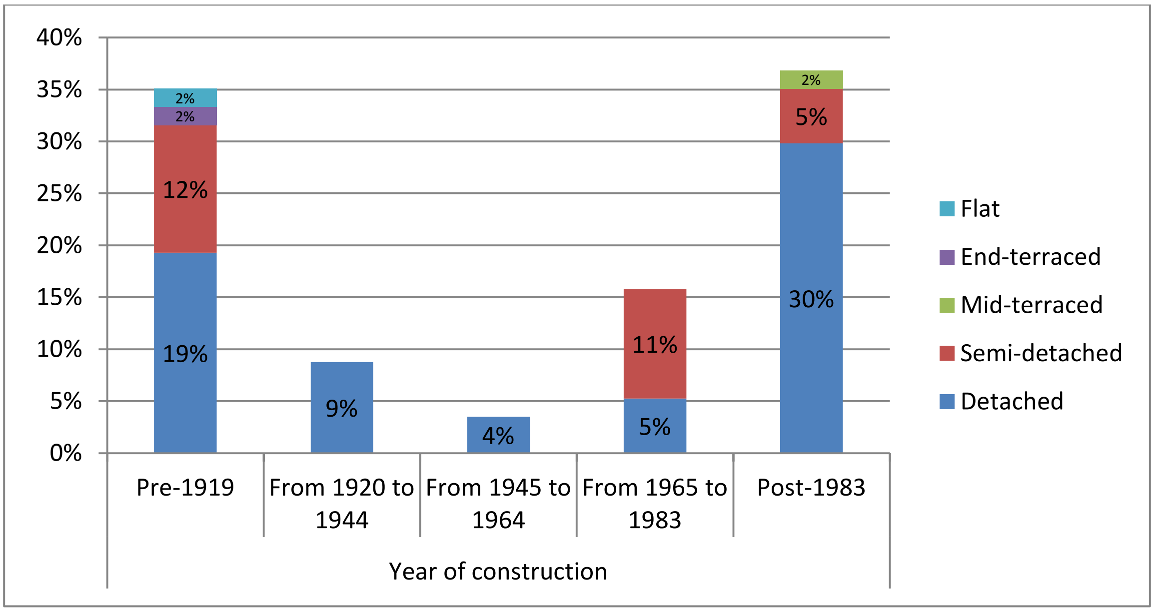
In the late 1900s, the opening of new roads paved way for new townships in the south (Cammusterrach, Camusteel, Toscaig, and Milltown) and in the north (Lonbain, Fearnmore, Arina and Kenmore) making Applecross what we see now (Cameron, History of Urbanization in Applecross 2014).

2.1.1.3. CHARACTERISTICS OF BUILDINGS

The most common types of dwellings recorded during the survey were detached, semi-detached, end-terraced houses and flats; the first two constituted 92% of the total households interviewed.

Most of the respondents are occupying houses built before 1919 or built after 1983 as shown inFigure 2-3.

FIGURE 2-3 TYPES OF DWELLINGS AND YEAR OF CONSTRUCTION OF THE HOUSEHOLD IN APPLECROSS



SOURCE: AUTHORS BASED ON 57 INTERVIEWS

The survey also showed that roofs in Applecross are not much different from one dwelling to the other. From Table 2-2it can be seen that 77% of the houses have an unused attic space and the rest use their loft space as room or storage room.Additionally, those houses with a loft space are insulated with less than 100 mm of insulating material.

TABLE 2-2 DESCRIPTION OF USE OF LOFT SPACES IN HOUSES IN APPLECROSS

House Type	Used Loft Space	Not used Loft Space
Detached	15%	43%
Semi-detached	8%	26%
Mid-Terrace	0%	2%
End-Terrace	0%	3%
Flat	0%	3%
Total	**23%**	**77%**

SOURCE: AUTHOR BASED ON 65 INTERVIEWS

Another significant characteristic is that 55% of the surveyed houses have coombed ceilings (see Table 2-3).

TABLE 2-3PRESENCE OF COOMBED CEILINGS IN THE HOUSES IN APPLECROSS

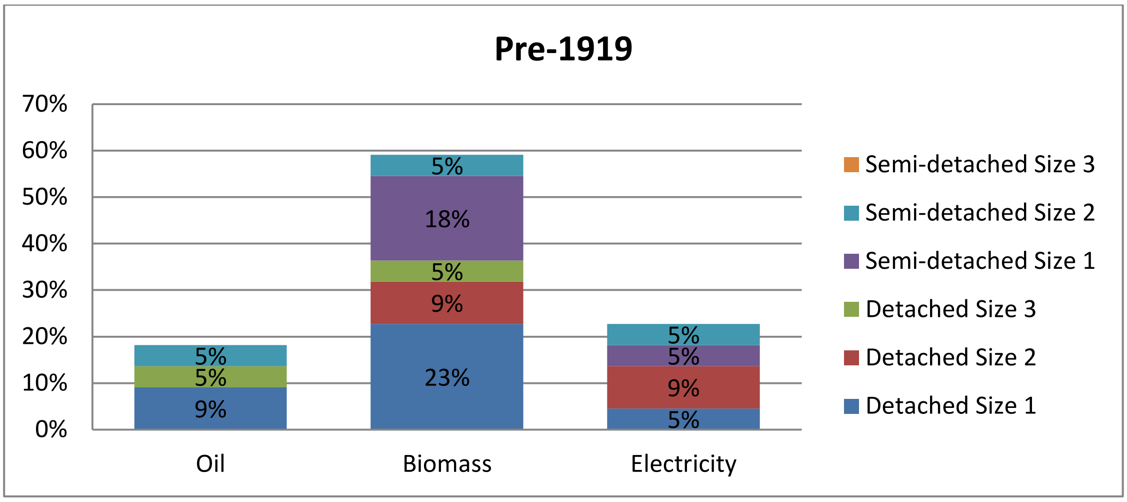
House Type	Coombed Ceilings	No Coombed Ceilings
Detached	29%	29%
Semi-detached	22%	12%
Mid-Terrace	0%	2%
End-Terrace	3%	0%
Flat	2%	2%
Total	**55%**	**45%**

SOURCE: AUTHOR BASED ON 65 INTERVIEWS

Regarding heating systems, the survey also showed a predominance of three fuels: biomass, heating oil and electricity. In the order of preference biomass is the most commonly used fuel in the community.

Houses built before 1919 represent a 35% of the surveys conducted. These houses showed a clear preference for using wood as primary fuel for their space heating system. Figure 2-4 shows and electricity; and small-sized detached houses prefer biomass and oil. On the other hand, larger and medium-sized semi-detached houses prefer biomass and electricity as their primary fuel for space heating. Percentages in Figure 2-4 add up more than 100% due to rounding.

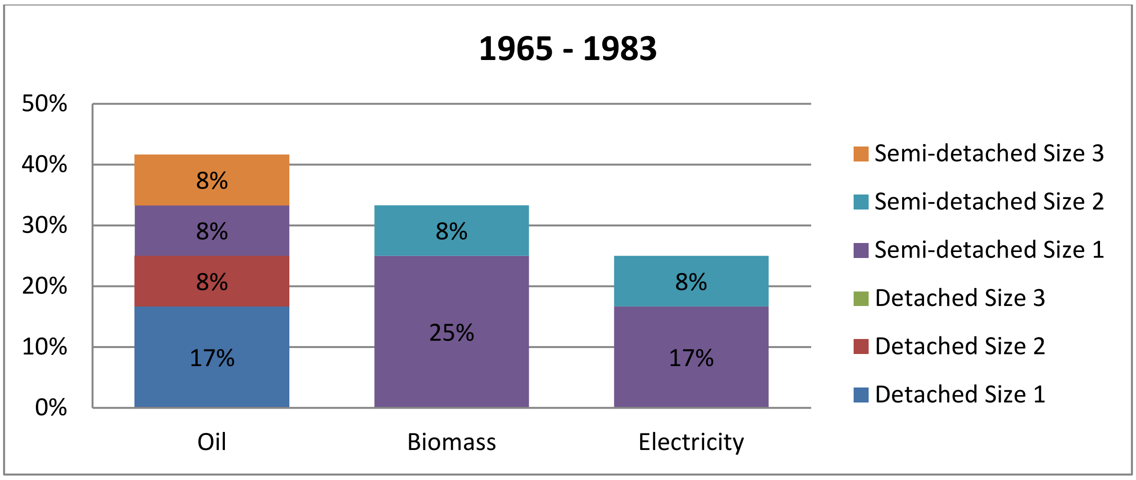
FIGURE 2-4 PERCENTAGE OF HOUSES BUILT PRE-1919 AND THEIR PRIMARY FUEL FOR SPACE HEATING (PER HOUSE SIZE)



SOURCE: AUTHOR BASED ON 22 INTERVIEWS OUT OF 65 TOTAL INTERVIEWS[5]

Houses built between 1965 and 1983 represent 19% of the conducted surveys. Figure 2-5 shows that most of these houses have a preference for oil-fired space heating systems. Large and medium-sized detached houses prefer to use oil. Large and medium-sized semi-detached houses prefer to use biomass and electricity; whilst small-sized semi-detached houses prefer to use oil.

FIGURE 2-5 PERCENTAGE OF HOUSES BUILT BETWEEN 1965 AND 1983 AND THEIR PRIMARY FUEL FOR SPACE HEATING (PER HOUSE SIZE)



SOURCE: AUTHOR BASED ON 12 INTERVIEWS OUT OF 65 TOTAL INTERVIEWS

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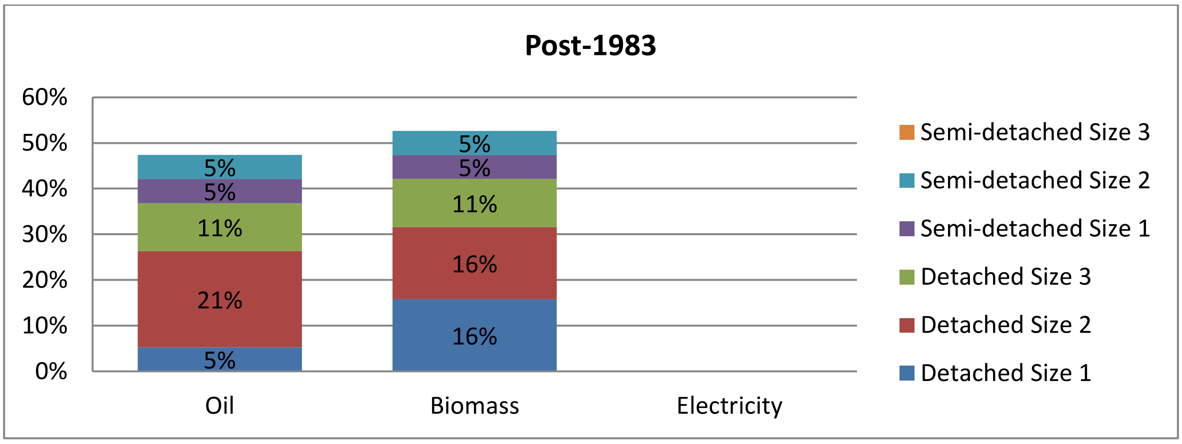
[5] Size 1 are houses with 6 to 8 rooms, size 2 are houses with 9 to 11 rooms and size 3 are houses with more than 12 rooms. This classification is applicable to Figure 2-7; Figure 2-8, Figure 2-9 and Figure 2-10. Rooms include kitchen, toilets, staircases, storerooms, living rooms, bedrooms.

Houses built after 1983 represent 31% of the conducted survey. Figure 2-6 shows that both detached and semi-detached houses built within this period of time prefer to use oil and biomass as fuel for their primary space heating system. Electricity is not used as primary space heating system.

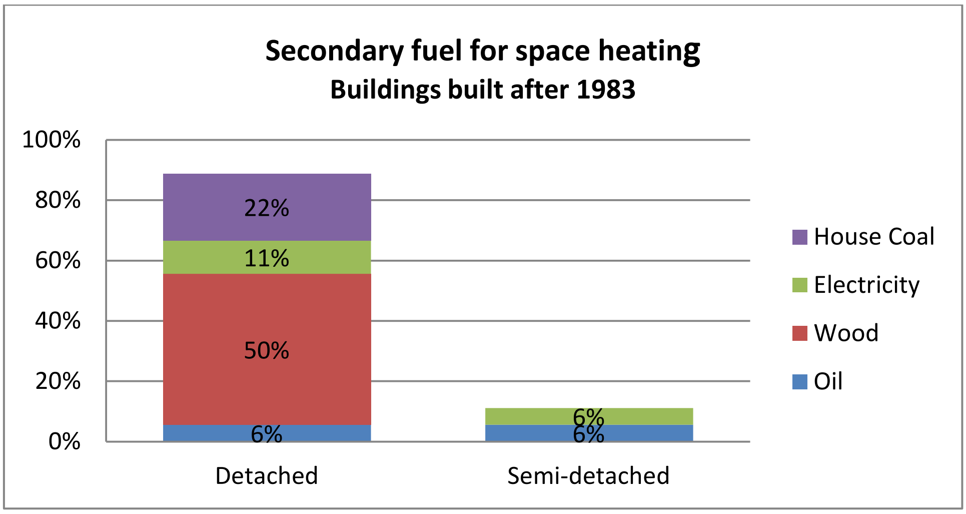
FIGURE 2-6 PERCENTAGE OF HOUSES BUILT POST-1983 AND THEIR PRIMARY FUEL FOR SPACE HEATING (PER HOUSE SIZE)



SOURCE: AUTHOR BASED ON 19 INTERVIEWS OUT OF 65 TOTAL INTERVIEWS

In those houses built after 1983 that are not using electricity as primary space heating system, there is a clear preference to use this fuel as secondary heating system, as can be seen in Figure 2-7.

FIGURE 2-7 PERCENTAGE OF HOUSES BUILT POST-1983 AND THE SECONDARY FUEL USED FOR SPACE HEATING



SOURCE: AUTHOR BASED ON THOSE HOUSES WHO DON'T USE ELECTRICITY AS PRIMARY FUEL FOR HEATING

The figures shown above reflect that in remote rural communities such as Applecross, availability and affordability of fuels play a major role when deciding the type of heating systems to be used in the households. Wood logs supplied locally have recently been made available and most households have opted for this fuel.

2.1.1.4. ATTITUDES AND BEHAVIOURS

The amount and type of fuel used and the number of rooms heated will strongly depend on the price of the fuel, whether the household suffers from fuel poverty, the level of occupancy, the inhabitants per dwelling and the year of construction of the house. As stated before in Section 2.1.1.1, more than 80% of the households in Applecross use electricity for cooking. When it comes to fuel used for space heating, the survey reflected that most householders use wood; followed by oil and electricity. However, approximately 48% of the households use two fuels for space heating which could be a mix of oil and wood or oil and electricity or wood and electricity.

Approximately 77% of the dwellings in Applecross fall into the category of Hard-to-treat houses, which means that they have stone walls, floor without insulation and poor or no loft insulation at all. It is difficult to improve theenergy performance of such buildings. Consequently, these dwellings need more energy than newer dwellings built after 1983 to reach the level of comfort temperature of 20°C in the whole house (Scottish Heat Map, 2013), and therefore in most of the houses surveyed the occupants tend to heat just the rooms where they are staying as a way to save on their energy bill, rather than improving the building. This condition is even more emphasized when we consider that 30% of the dwellings have just one occupant and that also more than 40% of the households indicated that they pay more than 10% of their income to cover their energy bill (See Fuel Poverty section of this report).

2.1.1.5. DEFINITION OF HARD-TO-TREAT HOUSES

Hard-to-Treat (HtT) buildings in the community of Applecross are identified as buildings “that cannot accommodate ‘staple’ or cost-effective fabric energy efficiency measures” (Sustainable Uist, 2012) usually supported by the Government such as cavity wall insulation or loft insulation.

For the purpose of identifying the HtT houses in Applecross, this study considers the following criteria[6]:

A. SOLID WALLS

According to BRE Housing (2008, p. 5), there are some wall types considered as solid walls, which include both traditional 9” masonry walls and non-traditional masonry walls, such as:

- Single leaf masonry;
- Above 9” thick stone walls;
- Concrete walls (either panel or in situ);
- Metal or timber panels; and

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[6] The criteria for selection is based on (BRE Housing 2008) and (Sustainable Uist 2012).

- Mixed walls (where the ground and first floor were constructed of different walls).

These types of walls are considered to be difficult to insulate; however applying some insulation to the solid walls in HtT houses can reduce heat losses by 35% (Newman, 2014).

B. BUILT PRE-1990

It was assumed that dwellings that were built after this date had already followed and applied the local or national building regulations; therefore those dwellings also have sufficient energy efficiency measures and are not to be considered HtT houses. According to Ted King's presentation (2007, p. 3-5), in 1990, the building standard requirements in United Kingdom were improved by implementing the floor insulation standard with U-value of 0.45 W/m^2K and updating the U-values of walls and roofs; these numbers are nowadays lower than the regulated values before 1990). The purpose of the improvement was to upgrade the energy efficiency in buildings in order to support United Kingdom's emission reductions target in Kyoto Protocol (King 2007).

C. NO STANDARD LOFTS (OR NO LOFT SPACE)

The dwellings that are built before 1990 have roof types such as mansard, flat or pitched roof. These roof types don't have too much loft space and are rarely insulated; therefore they are included among the HtT buildings. In addition, improper loft insulation, below 270 mm thickness for mineral wool insulation (Energy Saving Trust 2013), can also be categorized as HtT. Installing insulation on roofs could prevent HtT houses from losing 25% of their heat (Newman, 2014) as compared to houses without any insulation on the roof (See Figure 2-8)

A mansard roof has a very shallow loft space and is difficult to access. Pitched roof may have some loft space which could be insulated; however, the obstacle for installing insulation in narrow loft spaces in Applecross is the lack of local trained technicians. Flat roof has no loft space at all.

D. LISTED BUILDINGS

The presence of heritage and conserved buildings in the community of Applecross limits the improvement options due to planning restrictions on visual changes in the exterior of the building. Buildings that are listed and meet four other parameters herein described are considered HtT. As an example, the Applecross Estate Bramble House is a listed building where efficiency measures are hard to improve without making visual changes to the exterior of the building.

E. COOMBED CEILINGS

Coombed ceilings refer to a ceiling fitted to the underside of the joists in a pitched roof (Newman, 2014). They are usually a sign of the existence of rooms in the roof that were part of a renovation done to the original building. As it was observed during the survey, the coombed ceilings are indicated by the presence of dormer shapes on the roof of the houses in Applecross. This roof characteristic is important to identify as insulating coombed ceilings have been proven to effectively reduce the heat losses from the house. On the other hand, the insulation process in coombed ceilings is difficult and expensive, when it is compared to open loft spaces and usually implies the problem of installing internal solid walls insulation.

F. HEATING SYSTEM

The heating system in Applecross is off the national gas network. Across Scotland, storage heaters are the most common heating systems in properties off the gas network (BRE Housing 2008); however, in Applecross wood burning stoves, open fires and oil boilers are the most common heating systems. Looking into ways to improve the heating systems of the households in Applecross can lead to significant reductions on energy and fuel bills, as well as CO_2 emissions.

G. LIMITED FUEL OPTIONS

Most of the HtT buildings are using oil and electricity as fuels for heating. The prices of these fuels have increased in the last years and there seem to be a pre-disposition from residents of HtT houses to avoid the use of wood-burning stoves as primary heating systems since this implies chopping, loading and storing logs of wood. This is considerably understandable since the mean age of the residents of HtT houses is 56 years-old.

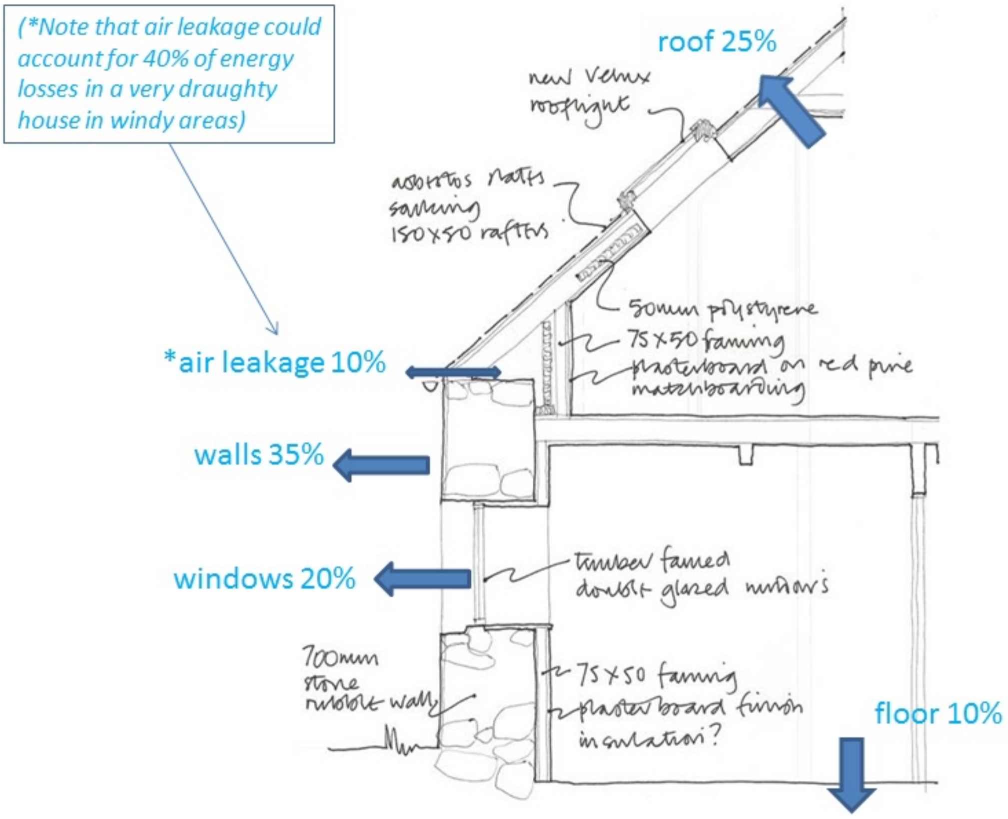
H. FLOOR INSULATION

HtT buildingsusually have no floor insulation, very less or poor insulation since that kind of technology was introduced around early 1990's. Insulating floors could prevent houses from losing 10% of their heat as compared to houses with no insulation on floors (Newman, 2014) (see Figure 2-8).

I. FUEL POVERTY

Increasing fuel prices and energy inefficient houses (which can be translated into high energy bills) lead to fuel poverty. Energy efficiency can help protect these households who are particularly vulnerable.

FIGURE 2-8 HEAT LOSSES IN A STANDARD BUILDING



SOURCE: (NEWMAN 2014)

2.1.1.6. FUEL SOURCES AND ENERGY SUPPLY

One of the most ancient sources of energy in the Peninsula of Applecross is peat, “a brown material consisting of partly decomposed vegetable matter forming a deposit on acidic, boggy ground which is dried for use as fuel” (Cameron, 2014). This fuel source was available for free in the land and it was collected by the population and transported into the households. Today the fuel is still available in Applecross.

The next most anciently known source of energy in Applecross is water. The peninsula has a vast existence of water sources that have been used and can be used as a source of energy given the right conditions. More information about this particular resource will be provided further on in this report.

Finally, in July, 1955 Applecross was connected to the national electricity grid and with it came a transformation in the living conditions of the population (Cameron, Fuel sources in Old Applecross 2014).

With the increase in the prices of electricity, the population of Applecross moved to oil-fired heating systems looking to save money (Cameron, Fuel sources in Old Applecross 2014).

More recently, with the increase in the prices of oil, the population of Applecross is leaning towards wood as a cheap fuel source available locally. And the opportunity of a community hydro scheme lies ahead.

The Peninsula has potential for implementing domestic renewable technologies. In fact, 4 out of 65 households interviewed had already implemented either solar photovoltaic or micro-wind turbines with fully satisfactory results.

2.2. OPTIONS FOR THE FUTURE

2.2.1. POTENTIAL FOR IMPLEMENTING ENERGY EFFICIENCY IN APPLECROSS

Applecross HtT houses have a significant potential to optimize their energy use, reduce energy bills and improve the living conditions of householders. By implementing energy efficiency measures such as replacement of old, inefficient appliances, turning off appliances that are not in use, improving insulation in the house, among others, can help them reduce their energy demand. This section discusses different measures, examples of these and their respective costs that can be taken into consideration when improving the energy efficiency of HtT houses in Applecross.

2.2.1.1. INSULATION

As stated in Section 2.1.1.1, most of the houses in Applecross were built with solid walls, floors were not insulated and lofts were either not insulated or insulated below standards. Basic insulation improvements to the conditions described before are cheap but the more complex measures to fit them to the building are generally more costly. Nonetheless these energy-efficiency improvements can contribute to better living conditions.

For a sample cost reference, Table 2-4 shows the typical savings of a three-bedroom dwelling that can result from insulation improvements. Actual costs and savings will vary depending on the size and type of dwelling, heating source and heating behaviour.

TABLE 2-4 TYPICAL COST AND SAVINGS POTENTIAL OF INSULATION IMPROVEMENTS

Measure	Cost (£)	Annual Saving (£)
Loft Insulation (0 to 270mm)	350	Up to 175
Loft Insulation top-up (100 to 270mm	350	25
Cavity Wall Insulation	350	Up to 135
Internal Wall Insulation	5,500 to 8,500	445
External Wall Insulation	9,400 to 13,000	475
Double-glazing	3,300 to 6,500	165

SOURCE: (ACTION FOR WARM HOMES, 2013, P. 6)

The quality and performance of the insulation material are keys to a low-energy home strategy, whether building a new house or refurbishing an existing one. The domestic insulation market in UK has recently developed high performance aerogel and panel insulators and along with these developments, other traditional insulating materials have also continued to evolve, offering higher thermal performance and being also eco-friendly.

Table 2-5 shows a comparison of some common insulation materials available in UK market with details of thermal conductivity, environmental rating and typical application.

Table 2-5 Common Types of Insulating Material available in UK and their applicability

Type		Environmental Rating	Thermal Conductivity	Typical Applications		
				Roofs	Walls	Floors
Highest Performance	Vacuum Insulated Panels	-	0.008	✓	✓	✓
	Aerogels	-	0.013 – 0.014	✓	✓	✓
Polyurethane	Polyurethane with pentane	A	0.027 – 0.038	✓	✓	✓
	Foil-Faced Polyurethane with pentane	A	0.020	✓	✓	✓
Phenolic Foam	Phenolic Foam	-	0.020 – 0.025	✓	✓	✓
	Foil-Faced Phenolic Foam	-	0.020 – 0.025	✓	✓	✓
Expanded Polystyrene	Expanded Polystyrene (~30kg/m^3)	A+	0.030 – 0.045	✓	✓	✓
Extruded Polystyrene	Extruded Polystyrene with HFC (~35kg/m^3)	-	0.025 – 0.037	✓	✓	✓
Wool and Fibre	Glasswool (~48kg/m^3)	A+	0.030-0.044	✓	✓	
	Stone wool	B to A+	0.034 to 0.038	✓	✓	
	Sheep's wool	A	0.034 – 0.054	✓	✓	
	Hemp Fibre	-	0.039	✓		
	Polyester Fibre	-	0.035 – 0.044	✓		

Source: (Energy Saving Trust, 2010, pp. 2-3)

Table 2-6 shows sample brands of different insulating materials recommended in this study.

Table 2-6 Examples of Insulating Materials

Insulating Material	Thermal Conductivity (W/mK)	Thickness (mm)	Cost per m^2 (£)
Floor			
Kingspan TF 70 Flooring	0.022	50	6.81[a]
Kingspan Kooltherm K3 Floor board	0.021	25	8.30[b]
Spacetherm C 18mm + 5mm Aerogel	0.015	18	34.95[c]

Knauff Polyfoam Floorboard Super	0.029	50	8.07[d]
Wall			
Kingspan K18 ins	0.020	20	12.49[e]
Knauf Polystyrene	0.042	100	10.42[f]
Spacetherm Fermacell Plywood	0.015	10	41.13[g]
Knauff Drywall Thermal Laminate Plus	0.030	55	16.00[h]
Ceiling			
Kingspan Kooltherm K7	0.021	40	9.92[i]
Knauff Loftroll 600 100mm	0.044	100	11.42[j]
Rockwool Flexi Slab	0.037	50	3.01[k]

[a] http://www.insulationexpress.co.uk/Floor-Insulation/Kingspan-Thermafloor-TF70-Floor-Insulation.htm

[b] http://www.insulationexpress.co.uk/Floor-Insulation/Kingspan-Kooltherm-K3-Floorboard-Insulation.htm

[c] http://www.phstore.co.uk/index.php?route=product/product_grouped&product_id=808

[d] http://www.insulationgiant.co.uk/p/knauf-polyfoam-floorboard-std-eco-sl-50-x-1200-x-600-504m2-per-pack/893507

[e] http://www.insulationexpress.co.uk/Thermal-Laminate-Board/Kingspan-Kooltherm-K18-Insulated-Dry-lining-Board.htm

[f] http://www.building-supplies-online.co.uk/building-materials/insulation/polystyrene-sheets/polystyrene-sheets-100mm-x-1200-x-2400-eps70-single-sheet.html

[g] http://www.phstore.co.uk/high-performance-and-specialist-insulation/spacetherm/spacetherm-f-fermacell.html

[h] http://www.insulationexpress.co.uk/Thermal-Laminate-Board/Knauf-XPS-Thermal-Laminate-Plus-Board.htm

[i] http://www.insulationexpress.co.uk/Insulation-Boards/Kingspan-Kooltherm-K7-Pitched-Roof-Insulation.htm

jhttp://www.insulationplace.co.uk/Knauf-Earthwool-loft-roll-44-combi-cut-100mm.html?gclid=CKW13KvRkL0CFWjmwgodyzcASQ

[k] http://www.insulationshop.co/100mm_rockwool_flexi_slab.html

Source: Authors

2.2.1.2. Energy Efficiency in Electrical Appliances and Lighting

The households in Applecross use the typical high-energy consuming appliances for their daily needs. Energy Saving Trust recommends a vast selection of appliances that have a good energy rating should the households want to upgrade their appliances.

Most of the lightings currently used in Applecross' household are now compact fluorescent lamps (CFL) or energy saving lamps (ESL). Energy saving lamps are energy efficient. However, they are not environment-friendly since they contain at least 1.9 mg of mercury and hence, require special disposal measures. (OSRAM ESL, 2014)

Light emitting diodes or LEDs are the new generation lighting, which has evolved into better quality lighting. Its initial cost might be high but it is the most environment-friendly and energy efficient lighting source because of its longer life span and more lumen per Watt. (OSRAM LED, 2014)

3. RENEWABLE ENERGY

3.1. ENERGY FROM THE WIND

3.1.1. MICRO WIND TURBINE SITUATION IN SCOTLAND

Despite the abundance of wind resource in Scotland which Applecross also has a fair share of, micro wind turbines have not yet become an attractive renewable energy technology in electricity generation for households in the community. The initial cost of wind turbine is the major factor that affects householders' decision on purchasing and installing the technology. The Scottish micro wind turbine situation can be characterised by;

- The micro wind turbines available on the Scottish market,
- The current legislation and regulations for installing a micro wind turbine, and
- The current financial support for exporting electricity generated from micro wind turbines.

3.1.1.1. LEGISLATION AND REGULATIONS FOR INSTALLING A MICRO WIND TURBINE IN SCOTLAND

In Scotland, installing wind turbine requires planning permission. However, the installation of a domestic micro wind turbine may be exempted from planning permission except that ifinstalled:

- It would result in the presence within the curtilage of a dwelling of more than one free-standing wind turbine.
- The wind turbine would be situated less than 100 metres from the curtilage of another dwelling.

In addition, before the project begins, the developer must apply to the planning authority for:

- The approval of the authority in respect of the design and size of the proposed wind turbine.
- Determination as to whether the prior approval of the authority will be required in respect of the siting and external appearance of the proposed wind turbine.(Energy Savings Trust 2013)

Normally an export meter will be installed to measure what isexported, unless the project has a rated output of less than 30kW(Energy Savings Trust 2013). Several utilities estimate the share of exported electricity to 50% without export meters installed. The export tariff is 4.5p/kWh, compared to the power price of about 17p/kWh, so it may be a good idea to see how much of the generated electricity can be consumed in the household at the time it is generated.

3.1.2. MICRO WIND TURBINES AVAILABLE ON THE SCOTTISH MARKET

The micro wind turbines available in the United Kingdom market are certified by an independent body. The micro-generation certification scheme certifies micro-generation products and installers for Scotland and the UK in accordance with consistent standards. There is a list available from this scheme of registered micro wind turbines. Producers and suppliers also need a license before they can sell the wind turbines in Scotland and the UK.

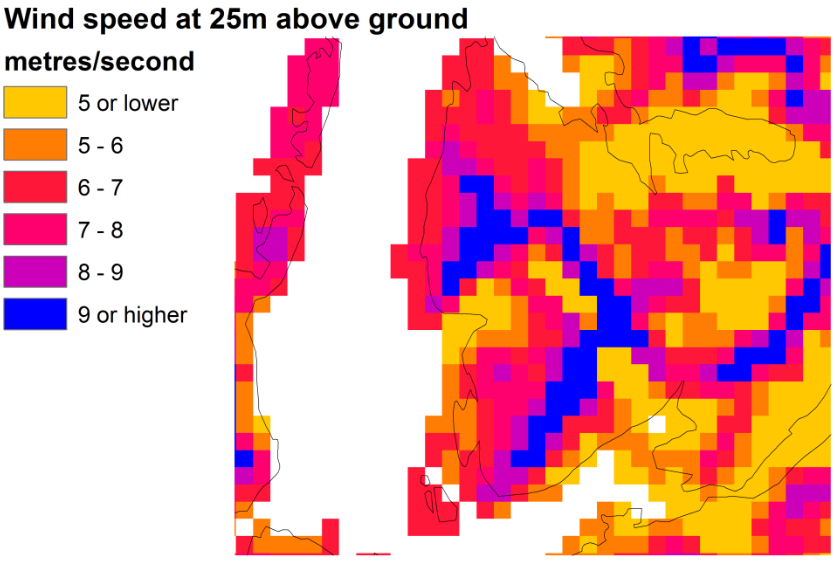
Some of the wind turbines available on the Scottish market are Xzeres 442SR, Gaia-Wind, C&F Green Energy, Skystream 3.7, Evance R9000, Kingspan KW6, Eoltec Scirocco, Qr5, Evoco 10, Aircon 10S and Bergey Excel 10. For the purpose of this project, 2.4kW Skystream 3.7 and 5kW Evance R9000 wind turbines were selected. Most of these small wind turbines have three blades and a direct driven permanent magnet generator.

The degree to which any of these wind turbines would be economically feasible to satisfy Applecross householders' energy needs depends on the specific site assessment and investment analysis. The technical feasibility is subject to location, wind speed and household electricity demand.

3.1.3. WIND ENERGY RESOURCE POTENTIAL IN APPLECROSS

Applecross has enormous potential for wind energy but by virtue of the landscape, not all locations can harness the potential to generate energy. To determine the suitable areas, a preliminary assessment was done in the community to assess wind resource areas based on information such as wind direction, topography, flagged trees, and other indicators like the orientation and the space available (Bailey and McDonald 1997). After that, further screening was done to obtain micro wind turbine installation sites and the economic viability for the selected wind turbines.

FIGURE 3-1 WIND MAP OF APPLECROSS AT 25M ABOVE GROUND



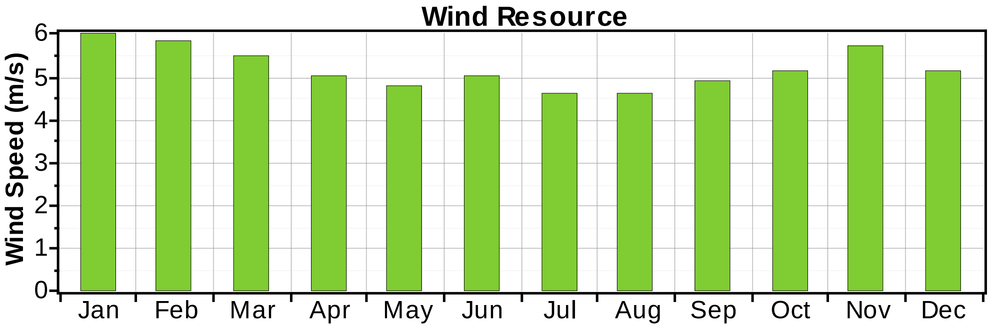
SOURCE: DECC WIND RESOURCE MAPS, 1KM^2 RESOLUTION. BOUNDARIES: SCOTTISH GOVERNMENT

The amount of energy generated from wind depends on its speed. The hourly wind speed data for an entire year in Applecross were unavailable. In order to achieve hourly wind data for wind resource assessment, the Meteonorm software was used to generate monthly data for Applecross for the year 2014, which were then fed into the HOMER software to generate hourly wind speed data. The data produced mimic the characteristics of real wind speed, including windy periods, seasonal and diurnal patterns. In this approach, the monthly average wind speed at the turbine height of 15m is assumed for an average year in Applecross. This also accounts for the fact that wind speed increases with height above ground, as the effect of obstacles reduces wind speed, which decreases with height. The chart below shows a

HOMER display for generating the hourly wind speed data at Applecross. The calculation is based on the average monthly wind speed data at the micro wind turbine hub height and four variability parameters which are

- Weibull k factor,
- Autocorrelation factor,
- Diurnal pattern strength and
- Hour of peak wind speed.

FIGURE 3-2: MONTHLY WIND SPEED DATA AT A HEIGHT OF 15M FOR APPLECROSS



SOURCE: AUTHORS

3.1.4. ENVIRONMENTAL IMPACTS OF INSTALLING A MICRO WIND TURBINE

Renewable energy generation is being promoted as one of the promising ways for reducing greenhouse gas (GHG) emissions. Micro-wind turbines are technologies that are expected to help reduce the GHG emissions from electricity use in the domestic sector and also contribute to the United Kingdom’s climate change targets. Wind turbines emit noise and may cause visual impact, which is why their location has to be chosen carefully, at minimum distances to dwellings, which are also specified in the planning law.

3.1.5. COST AND BENEFITS OF INSTALLING A MICRO WIND TURBINE

With an average annual wind speed of 5-8m/s in Applecross, without much obstacles and low roughness, a mini wind turbine in the range of 1.5 to 10kW can generate about 1,200 – 4,300 kWh per installed kW generator capacity per year, at specific investment costs of around 6,000 GBP/kW. Depending on the priority of the householder, the energy generated from the wind turbine can be connected directly to a water heating system by means of an electric immersion heater; or the turbine would be supplemented with an inverter to convert DC electricity to AC electricity suitable for the households’ appliances and export to the grid.

According to the UK Government’s feed in Tariffs scheme (FITs), electricity generated from renewable or low carbon source such as wind turbine are entitled to some financial incentives from energy suppliers. Thus households would be paid for the energy they generate, even if they use it themselves and supply the surplus to the grid. In this regard households can save money because they would be using their own electricity. In general, households receive 17.78p/kWh of electricity generated and an additional 4.64p/kWh if exported to the grid from a micro wind turbine with a generation capacity from 1.5kW to 15kW in the United

Kingdom.(Energy Savings Trust 2013).This payment tariff is standard from 1st April 2014 to 1st May 2015 and may vary in the subsequent years depending on the amount of electricity sold. This policy of incentive payment tariff is implemented by the UK government in order to encourage householders to utilise micro renewable generation.

3.1.5.1. ECONOMIC ANALYSIS OF A 2.4KW AND A 5KW WIND TURBINE

For two representative average wind speeds, two typical small wind turbines were subject to a simple economic appraisal. A site of 5.2 m/s average wind speed represents the lower range of feasibility, while it should be possible to find locations, which yield 7m/s. The Skystream 3.7 is a 2.4kW wind turbine which costs about £14,000 including installation and electric connection. The larger 5kW Evance R-9000 wind turbine is about £30,000. As the price per kWh of electricity in Scotland is £0.1785 and the generation tariff incentive is £0.1778 per kWh, the 2.4kW wind turbine can generate between 3400kWh and 7200kWh under these conditions, and the householder, assuming uses the electricity for heating and not to feed into the grid, would save about £1217 a year. This indicates that the payback period of the wind turbine would be 12 years. At a site with 7m/s the householder would also save about £ 2566 and the payback period also reduce to 6 years. The 5kW Evance R-9000 wind turbine operating at average wind speeds of 5.2m/s and 7m/s at the same height of 15m would generate about 9,170 kWh and 17,900 kWh of energy respectively. This would save the householder between £3,270 and £6300 per year and get a result in payback periods of 5 to 9 years, assuming that all of the energy can be used for heating.

Despite the fact the Evance R-9000 has a higher initial cost than Skystream 3.7, it also has a faster payback time. This can be explained by the higher efficiency and lower specific cost. SeeTable 3-1for details.

TABLE 3-1 ECONOMIC ANALYSIS OF 2.4KW SKYSTREAM 3.7 AND 5KW EVANCE R-9000 WIND TURBINES

Wind turbine	Wind speed(m/s)	Potential Energy generation(kWh)	Amount saved(£)	Cost(£)	Payback Time(yrs)
2.4kW Skystream 3.7	5.2	3416	1217	14000	12
	7	7202	2566		6
5kW Evance R-9000	5.2	9170	3270	30000	9
	7	17900	6380		5

SOURCE: AUTHORS

3.2. ENERGY FROM THE SUN

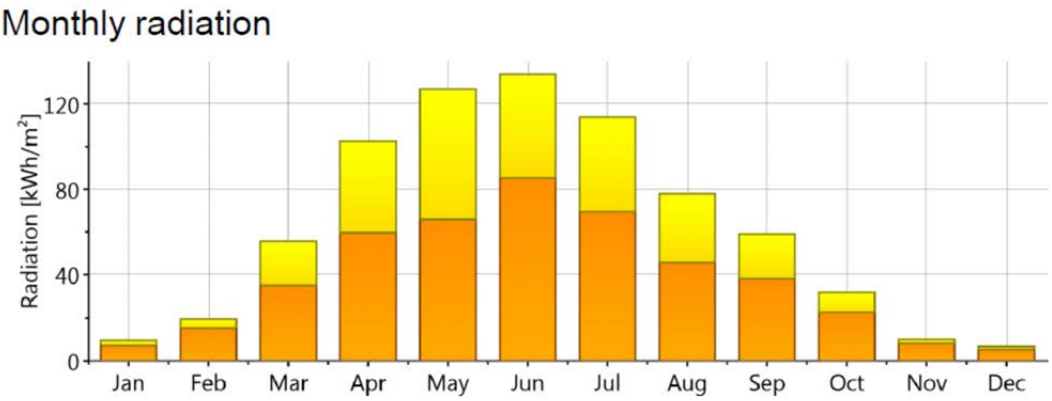
3.2.1. SOLAR RESOURCE POTENTIAL IN APPLECROSS

Figure 3-3shows the distribution of the global horizontal irradiation in Applecross in each month of the year. Applecross receives an average solar irradiation between 78 kWh/m^{2}to 134 kWh/m^2 during the months of June and August and between 7kWh/m^2 to 10kWh/m^2 from December to January. The annual total global insolation on the horizontal surface is 745kWh/m^2.Out of this insolation 458kWh/m^2 reaches the ground in the form of diffuse radiation. The average monthly clearness index is 25% which shows the fact that the sky is overcast 75% of the time during the months of the year.

The yearly average daily global horizontal radiation in Applecross is 2.04kWh/m^{2}day.The average capacity factor for solar electricity in Applecross is in the range of 10% calculated by RET screen software for Lussa on Skye.

The average annual insolation for Applecross is 2.4 kWh/m^{2}day on a tilted surface of 45°, which is a common tilt of the roofs in Applecross. From the above calculations the total solar energy that is available as input to solar energy converters per year in Applecross is 4,818,000 kWh.

FIGURE 3-3: GLOBAL HORIZONTAL RADIATION IN APPLECROSS (YELLOW: DIRECT AND ORANGE DIFFUSE RADIATION RESPECTIVELY)



SOURCE: (METEONORM7, 2013)

A preliminary site observation and survey has been undertaken to evaluate the suitability of buildings for solar thermal and solar photovoltaic installation. The three criteria were:

- Anunshaded roof-top area available for installation of at least 5m^2 for solar-thermal and 35m^2 for solar PV.
- Sufficienthot water demand for the installation of solar water heating systems (single person households were excluded).
- Orientationfrom South-west to South-east.
- Theinclination of the roof pitches which turned out to be within the suitable range for the majority of the buildings.

In addition to the general requirements the specific criterion for the selection of buildings for solar-thermal installations is the compatibility of the existing water heating system. Only buildings which already have a central water heating system installed were considered.

Another criterion which couldn't be assessed in this study is the availability of sufficient space to accommodate a larger DHW cylinder and the strength of the building structure to support the dedicated cylinder on the first floor and the solar collectors on the roof.

3.2.2. SOLAR PV

Out of 65 surveyed buildings 30% are found to be suitable according to the above indicators. From the survey data the average roof-top area available for the installation of the solar PV technology in these buildings is 81m^2.When extrapolated to the total 267 buildings 80 buildings fulfil the minimum criteria for the installation of solar PVsystems. The suitable roof-area is approximately 6500m^2 and 15% of this area is deducted for shading and obstacles. Therefore, the total roof-top area available for solar PV installations in Applecross is estimated to be 5500m^2.

In Applecross a solar photovoltaic system with a capacity of 4kWp and a roof inclination of 45° will produce an annual generation in the range of 3400-3700kWh for South West to South East facing azimuth (calculated with RETscreen software for Lusa, Skye). Based on an available roof surface of 5500 m² an approximate 560 MWh of electricity from 650 kW solar PV capacity could be generated in Applecross if all suitable roof area is used for PV systems.. This is in the range of the total the annual electricity consumption of Applecross and save 263 t of CO_2. This is however only a theoretical value as, without considerable storage capacities only a small fraction of this electricity could be consumed locally and most would have to be exported through the grid.

The cost related to solar PV installation is the initial building cost. The benefit connected to solar PV is policy incentives and feed in tariff. The feed in tariff rate is 14.9p/kWh and export tariff of 4.64p/kWh in the capacity range of 4-10Kwp for domestic scale installations (EnergySavingTrust, 2011). Up to 30kW there is no metering and 50% can be feed into the grid (DECC, 2013).A typical 4kwp generates 3400kWh/year (calculated for skye Lusa by RET screen).

3.2.3. SOLAR THERMAL

Four general preconditions for the installation of solar water heating systems have to be fulfilled: These are the availability of sufficient roof top area, south-east to south-west facing Azimuth, compatibility of the current hot water system with the solar-thermal system and sufficient hot water demand. Out of 65 properties surveyed 17 properties seem to be suitable for solar-thermal installations (See Table 3-2)but the survey did not prove whether the structural strength of these properties can accommodate the extra-large cylinders. In addition there is no proof that all the existing properties have enough space to accommodate large cylinders.

It is assumed that out of 114 full-time residence properties 29 are suitable based on the same criteria.

Based on the assumption that these are on the average households with three persons, solar thermal systems could generate in total 38 MWh of heat for water heating and save 4,850 litres of oil or 12,900kg CO_2.The total investment cost would be in the range of £100,000.

The installation cost of a residential solar home system is in the range of £2,500 -3,000 depending on the number of residents in ahousehold, but that depends largely on the specific situation, in particular the cost of integrating the system into the existingheating system.The cost per kWh depend mainly on the cost of the fuel that is to be replaced and the hot water demand. Therefore a proper sizing of the system is crucial for its financial viability.

From spring 2014 the installation of solar water heating systems will be supported by the Renewable Heating Incentive with 0.192 £/kWh for a duration of 7 years.

TABLE 3-2 TABLE SHOWING PROPERTIES WITH DOMESTIC HOT WATER SYSTEMS

Detail	Survey	Whole Applecross (extrapolated)
Total number of permanently inhabited buildings	65	114
Of these: South-east to south-west facing	17	29
Of these: Buildings with sufficient unshadowed roof space	17	29
Of these: buildings with a central DHW system (buildings with an existing DHW cylinder	17	29
Of these: Buildings with two permanent residents	17	29

SOURCE: AUTHORS

3.2.3.1. COST AND BENEFITS OF INSTALLING A SOLAR SYSTEM

The cost related to solar PV installation is the initial building cost. The benefit connected to solar PV is policy incentives and feed in tariff. The feed in tariff rate is 14.9p/kWh with an export tariff of 4.64p/kWh in the capacity range of 4-10Kwp for domestic scale installations (EnergySavingTrust, 2011).Up to 30kW there is no metering and 50% can be feed into the grid (DECC, 2013).A typical 4kWp generates 3400kWh/year(calculated for Skye Lusa by RET screen).The following table shows the cost and benefit of the generation to the owner assuming 75% export to the grid and 25% for home consumption.

TABLE 3-3 SHOWING THE COST AND NET BENEFIT CALCULATION OF DOMESTIC SOLAR PV INSTALLATION IN APPLECROSS (4KWP)

Cost **component**	**Amount**
A typical 4kW solar PV system cost	£7000
Green deal loan(32% of the total cost)	£2240
Contribution of home owner	£4760
Annual income from Fit+ Export tariff Generation tariff(14.9p/kWh) and export tariff(4.64p/kWh)	£625
Electricity saved(17p/kWh)	£144
Total annual income saving	£769
Annual repayment to green deal	£ 145
Net annual saving	£625
20years GD & Fit financing assuming interest rate of (144.5×20years=2890	£2890
Net saving to owner	**£4758**

SOURCE: AUTHORS BASED ON (ENERGYSAVINGTRUST, 2011)

3.3. ENERGY FROM THE WATER

3.3.1. HYDROPOTENTIAL IN APPLECROSS

In general Scotlandhas a hugehydro resource potentialespecially in the Highland areas with many run-off rivers. These hydro potential could be harnessed to generate electricity. The Applecrosspeninsula is not an exception. Many rivers flow from the western parts of the peninsula towards the coast. Some of these rivers are geographically located closer to the townships and could be harnessed through mini hydropower schemes to meet local energy demands.

At the time of writing this report, the electricity grid connection for Applecross has been limited only to 50 kW which is already occupied by the proposed hydro scheme for the Shore Street district.

3.3.2. PRE SELECTION OF SITES

Based on this potential, hydro pre-feasibility studies have been carried out by Highland Eco-Design for some of these rivers in Applecross. The studies include rivers from the far south and also the northern part of Applecross. However, the purpose of these studies was to explore the optimal capacity for grid connected hydro schemes, which seems not to be a realistic option for the near future. Based on that, our study focused on exploring ways of using the hydropower resource to meet local heatdemand.

Estimated monthly average flow data as well as monthly power production from the pre-feasibility studies provided the basis for the selection of sites for further assessment.

Depending on the potential and the residential density, this study looked at various townships in Applecross with the possibility of installing off-grid hydroelectric scheme. Even thoughArina has a significant number of scattered houses, the river flowing through the township has limited head to produce enough energy. In Cuaig only two permanently-occupied houses were found andthese houses were scattered.River Abhainn Chuaige in the area has a huge potential for a run off hydro scheme. The river in Culduie has a good potential with 10 houses which are located beside each other, but only 3 of them are full time occupied.

According to housing density,Burnside (council houses)and the southern part of Camusterrachand Applecross houseswere selected for further study.

Figure 3-4shows the three districts.

FIGURE 3-4 THREE DISTRICTS FOR HYDRO SCHEME IN APPLECROSS[7]

Camusterrach

Camusterrach (Burnside)

Estate Buildings near Bramble

SOURCE: AUTHORS

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[7] All green and blue pines show permanently occupied houses

3.3.3. Assessment of hydro potential for local electricity supply

The river Alt na Chriche hydro scheme is close to two clusters of houses in Camsuterrach and a burn, flowing into river applecross is close to the Applecross Houses. The potential of these two rivers are assessed for local electricity supply.

3.3.3.1. Allt naChriche Hydro scheme to supply upper Camusterrach

The geography and hydrology of this river allow for a possible hydro scheme with minimal impact on the environment (Alt na Chriche Micro-Hydro Desk-top Feasibility Study, 2009). The flow of this river starts from west Applecross crossing part of Camusterrach and spilling into the sea near Camusteel. The river catchment area was determined and the flow duration curve was calculated (FDC) by correlating with data from the pre-feasibility study. A site walk through was undertaken and some digital pictures were taken near the three proposed river intakes at elevations of 139m,127m and 104m. Figure 3-5 shows the pictures.

Figure 3-5:Digital Pictures of the river Alt na Criche.

Source: Authors

Issues related to impacts on species, landscape and habitat resulting from the scheme were discussed in the feasibility study report prepared by Highland Eco Design. According to the study construction of hydro scheme on this river will not fall foul to the SNH(Scottish Natural Heritage) regulations for protecting the landscape.

Energy demand in burnside, camusterrach

There are 10 houses in Burnside, Camusterrach in addition to the primary school. According to our survey the houses have two stories with an average space heating area of 70 m^2. Average heat demand of 249kWh/m2/yr for semi-detached houses built between 1965-1983 was taken as reference heat demand (Heat Mapping a Guide, 2013). Out of the three households surveyed only one could provide annual energy demand of 23,000kWh/yr.The result for the 10 houses are shown in Table 3-4.

TABLE 3-4 THEORETICAL SPACE HEAT DEMAND FOR BURNSIDE

Specific consumption, Scottish Heat Atlas kWh/m^2/yr	Average Area (m^2)	Heat energy consumption according to Scottish heat map(kWh/yr)	No. of Hoses in Burnside	Total Consumption(kWh/yr)
249	70	17,430	10	174,300

SOURCE: AUTHORS

Depending on monthly heating degree day for Applecross, the profile of the monthly heat demand is presented in Table 3-5. Figure 3-6 shows the estimated monthly heat demand.

TABLE 3-5 TOTAL AND MONTHLY HEAT DEMAND FROM HEATING DEGREE DAY FOR APPLECROSS[8]

Month	Heating Degree Day	Monthly Percentage	Monthly Heating Demand (kWh)
1/1/2013	329	0.129	22,515
2/1/2013	321	0.126	21,967
3/1/2013	370	0.145	25,320
4/1/2013	296	0.116	20,256
5/1/2013	206	0.081	14,097
6/1/2013	104	0.041	7,117
7/1/2013	46	0.018	3,148
8/1/2013	66	0.026	4,517
9/1/2013	109	0.043	7,459
10/1/2013	159	0.062	10,881
11/1/2013	274	0.108	18,751
12/1/2013	267	0.105	18,272
Total	2547	1	174,300

SOURCE: WWW.DEGREEDAYS.NET

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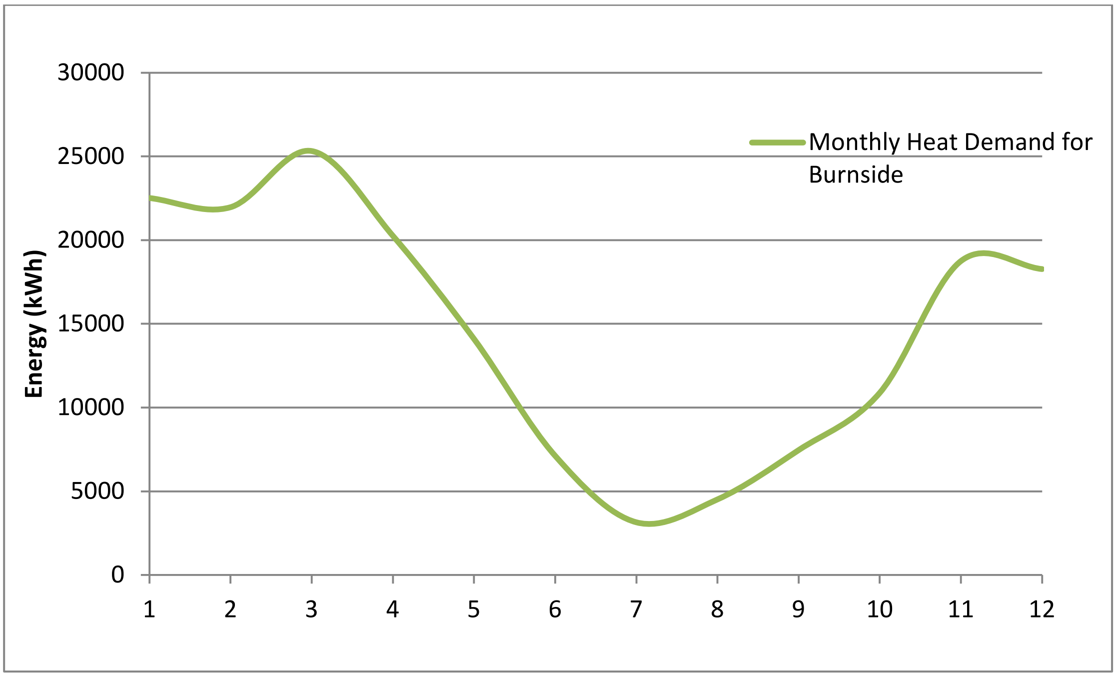
[8] As there is not weather station in Applecross, Skye station has been taken as reference.

FIGURE 3-6 MONTHLY HEAT DEMAND FOR BURNSIDE



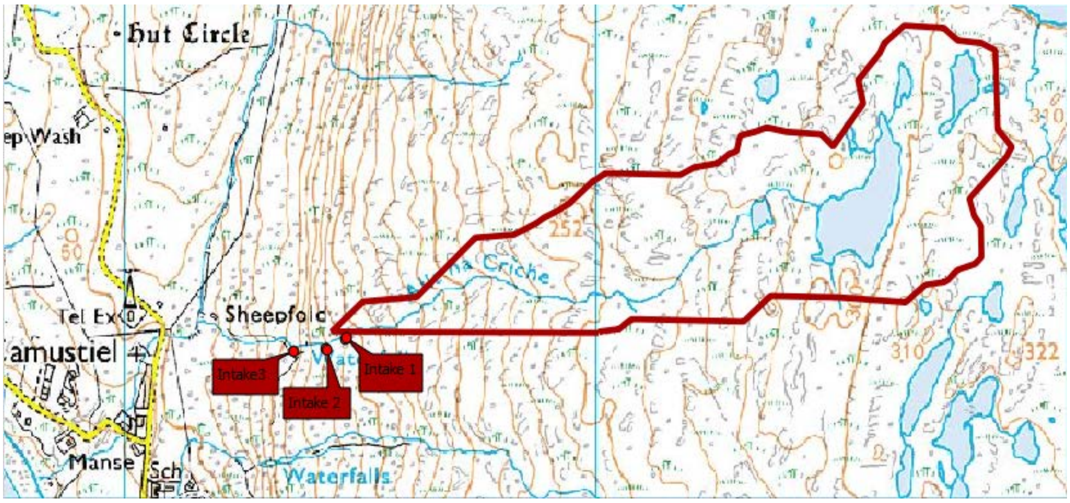
SOURCE: AUTHORS

HYDRO POTENTIAL

Catchment Area

The catchment area for this option was calculated by using the ArcGIS Hydrology Toolbox with a digital elevation model derived from the OS 2m contour line theme. The result can be seen in Figure 3-7. The hydrology tool also calculates spatial attributes such as the highest and lowest points in each catchment area. The basin starts nearly from contour line 310 and ends almost at the mentioned intakes elevation and the area until the first intake is 0.405 km^2. As the three intakes are near to each other; there was no difference between the areas. Therefore, the first intake with higher elevation is chosen for further discussion here. Actually, suitability of terrain and economical aspect had the role for selecting these intakes during the walk through survey.

FIGURE 3-7 CATCHMENT AREA OF ALLTNACRICHE



SOURCE: AUTHORS

Gross Head

By putting the turbine house near the main road and it is approximately at contour line 50, the obtained gross head with regard to the first intake will be 87 m.

Hydrology

Based on Catchment Area Relation (CAR), the catchment area for the area was estimated by correlating with the existing catchment area in the existing feasibility study. As a result the flow duration data was derived from the existing study for this river assuming similar hydrological conditions and also monthly average flow rate. Table of calculated correlation can be seen in Annex C.

Flow Regime

By considering SEPA's threshold the flow regime will be as follows: (Guidance for developers of run of river hydro power scheme, 2010)

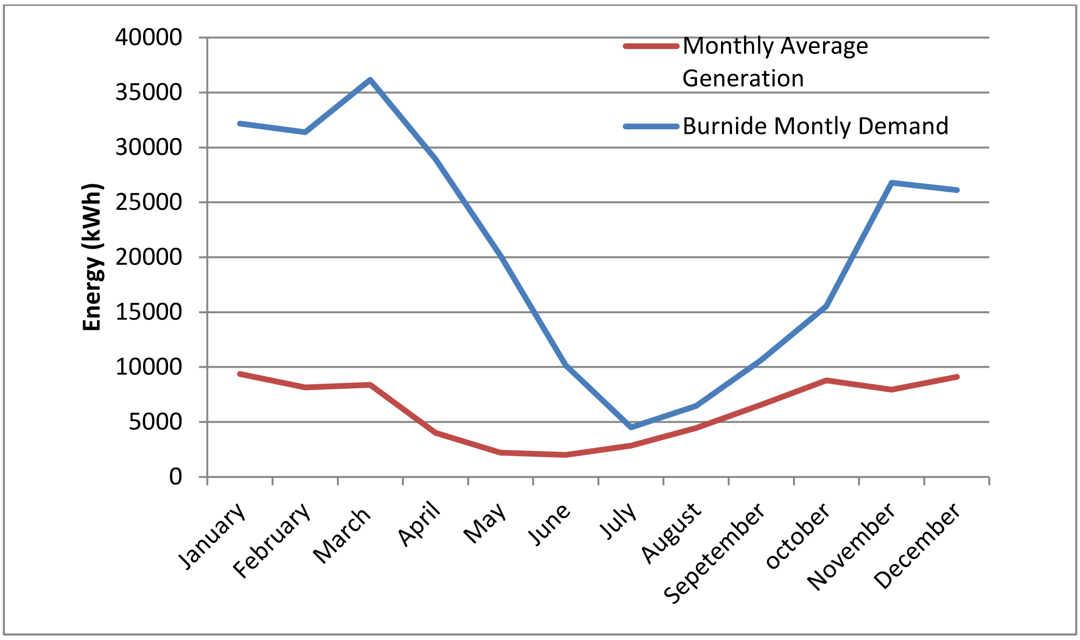
- Minimum abstracted flowequal to0 l/s
- Maximum abstracted flow equal to 24.8 l/s
- Environmental release: minimum of Q (95) 2 l/s

Design Capacity

- Overall efficiency of 67% was assumed for the loss of the penstock and turbine efficiency as well as generator efficiency.
- Maximum power or designed power: 13 kW
- Annual energy yield: 51,499 kWh
- Capacity factor: 42.2%

The monthly average energy from abstracted flow is shown Figure 3-8.

FIGURE 3-8 MONTHLY AVERAGE GENERATION COMPARED TO DEMAND



SOURCE: AUTHOR 2014

Comparison between monthly average generation from this river in Figure 3-8shows that this option is too small regarding energy productionto cover all the demand by houses in Burnside. Nevertheless, this option is presented as a possibility for small scale hydro scheme. Otherwise, the proposed study results by Highland eco-design could be used as an alternative for the combination between hydro energy and biomass for district heating for southern part of Camusterrach.

3.3.3.2. ALLT NA CHRICHE COMBINING CAMUSTERRACH PLACE WITH BURNSIDE

Another proposed option is a combination between Allt na Criche and the neighbouring burn. Based on this combination, an energy surplus can be delivered to Camusterrachwhere a district biomass boiler has been proposed. Two options exist for this case; an intake at an elevation of 139m like the previous catchment for both rivers and the other is an intake at an elevation of 200m as found in the study of the Highland Eco Design.

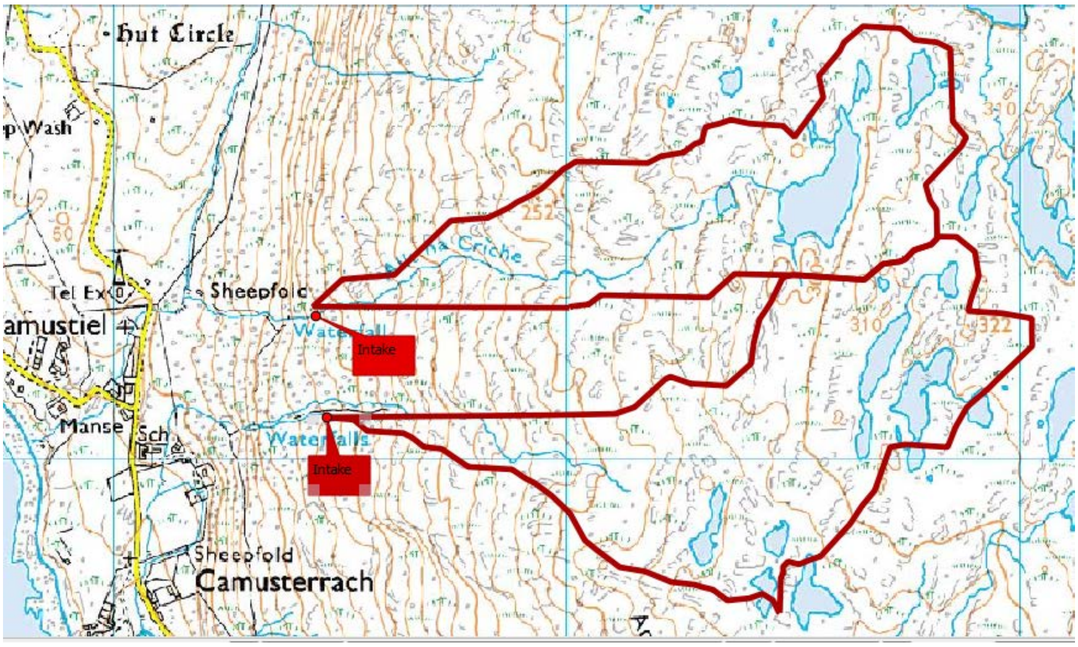
ENERGY DEMAND OF HOUSES WITHIN REACH OF THE HYDRO SCHEME

The demand is the same for Burnside in Camusterrach which can be seen from Table 3-5 and Figure 3-6.

HYDRO POTENTIAL

The same methodology has been implemented for indicating the boundary of the neighboring river’s basin area and also the intake has been decided to be at the level of elevation of the other one asFigure 3-9 illustrates. The obtained area is 0.48 km^2.

Figure 3-9 the Catchment area of Allt na Criche's Neighbouring River



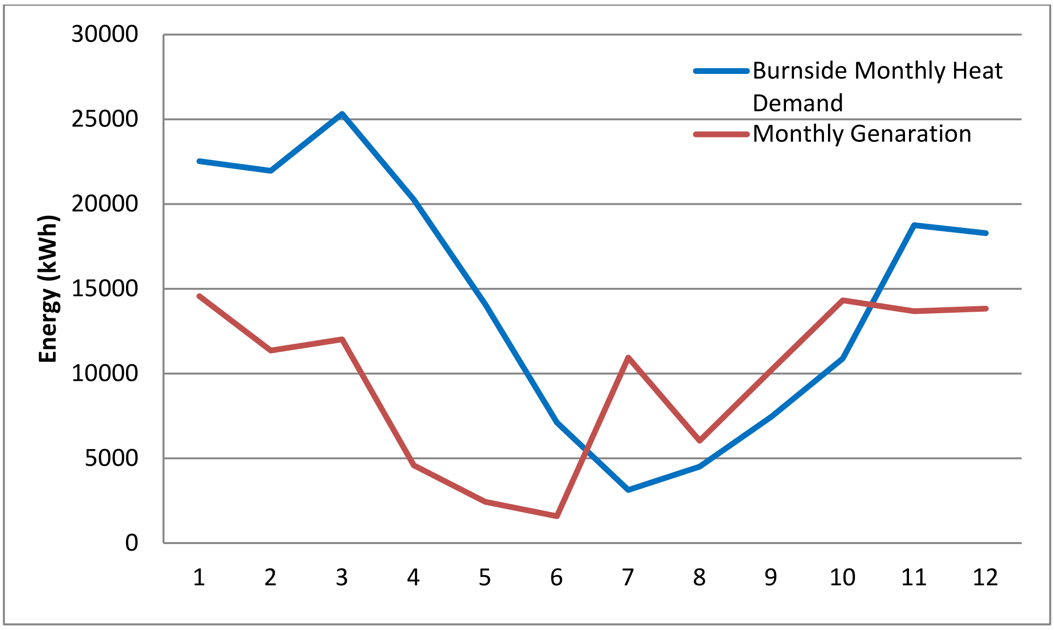
Source: Authors

The FDC and monthly mean flow of the river was obtained by correlating with the flow data from Allt Na Criche. Considering the place of turbine near the primary school and at contour line 40, the gross head is 107m. If an overall efficiency of 67% is assumed,the flow regime will be follows:

- Minimum abstracted flow: 0 l/s
- Maximum abstracted flow: 0.039 m^3/s
- Environmental release: minimum of Q 95 for each river 2 l/s

This designed flow will give 26 kW as a design capacity with annual energy yield of 14,493.4 kWh. However, comparison between monthly generation and heat demand is seen in Figure 3-10.

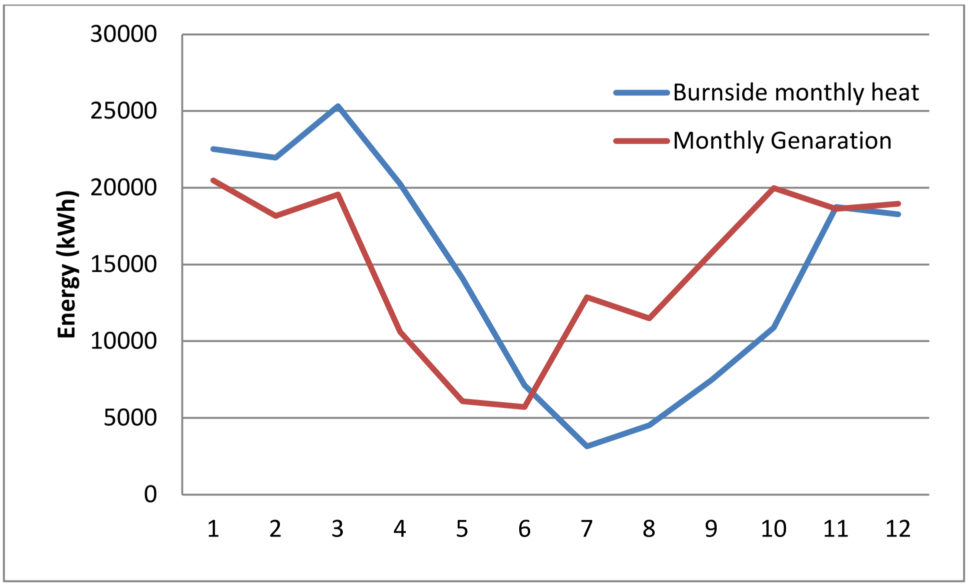
FIGURE 3-10 GENERATION AND DEMAND COMPARISON RESULTED FROM RIVERS OUT OF ALLT NA CRICHE



SOURCE: AUTHORS

Figure 3-10 shows that there is a surplus of generation from this combination during June to October, but there is a shortfall in other months. Consequently the second option for combining the two rivers as proposed by Highland Eco-Design was considered as a better option. Using design parameters of 49.3 kW capacity, flow rate of 0.051m^3/s and 0.84 km^2 catchment area, Figure 3-11 illustrates the monthly generation and demand curve.

FIGURE 3-11 DEMAND AND GENERATION ACCORDING TO SECOND CASE.



SOURCE: AUTHORS

As in the previous case, there are energy surpluses and shortfalls. The surpluses are higher in the later than the former. The shortfalls are also smaller in the latter than in the former. This concludes that the hydro scheme alone cannot be used to supply all the heat demand throughout the year. Hence the decision to implement the combination of heating from hydro and biomass with further investments in energy efficiency.

3.3.3.3. APPLECROSS ESTATE SCHEME

The location of this scheme is on the burn beside Applecross Houses. The purpose of this scheme is to supply energy to Applecross estate houses as previously mentioned. The available feasibility study shows that such a scheme is possible (Applecross House Feasibility Report, 2009). It is therefore imperative to do further analysis to determine the suitability of the scheme to meet the heat demand of these houses.

ENERGY DEMAND OF HOUSES IN REACH OF THE HYDRO SCHEME

Our survey relating to the residential building in this area shows the existence of 2 semi-detached houses, an estate office and 2 flats. According to the Scottish Heat Atlases guide the overall heat demand of these houses will be as shown in Table 3-6.

TABLE 3-6 SPACE HEAT DEMAND CALCULATION FOR ESTATE TOWNSHIP

Type of Dwelling	Number	Intensity value (kWh/m^2/yr)*	Area m^2	Yearly energy demand kWh
Semidetached houses	2	240	100	48,000
Flat	2	129	47	12,126
Office	1	129	47	6,063
Total				66,189

SOURCE: (SCOTTISH HEAT ATLAS , 2013)

From heating degree day of Applecross, the monthly heat demand for these houses is found in Table 3-7.

TABLE 3-7 MONTHLY HEAT DEMAND FOR APPLECROSS HOUSES

Month	Heating Degree Day	Monthly Percentage	Monthly Heating Demand (kWh)
1/1/2013	329	0.129	8,550
2/1/2013	321	0.126	8,342
3/1/2013	370	0.145	9,615
4/1/2013	296	0.116	7,692
5/1/2013	206	0.081	5,353
6/1/2013	104	0.041	2,703
7/1/2013	46	0.018	1,195
8/1/2013	66	0.026	1,715
9/1/2013	109	0.043	2,833
10/1/2013	159	0.062	4,132
11/1/2013	274	0.108	7,120
12/1/2013	267	0.105	6,938
Total	2547	1	8,550

SOURCE: WWW.DEGREEDAYS.NET

HYDRO POTENTIAL

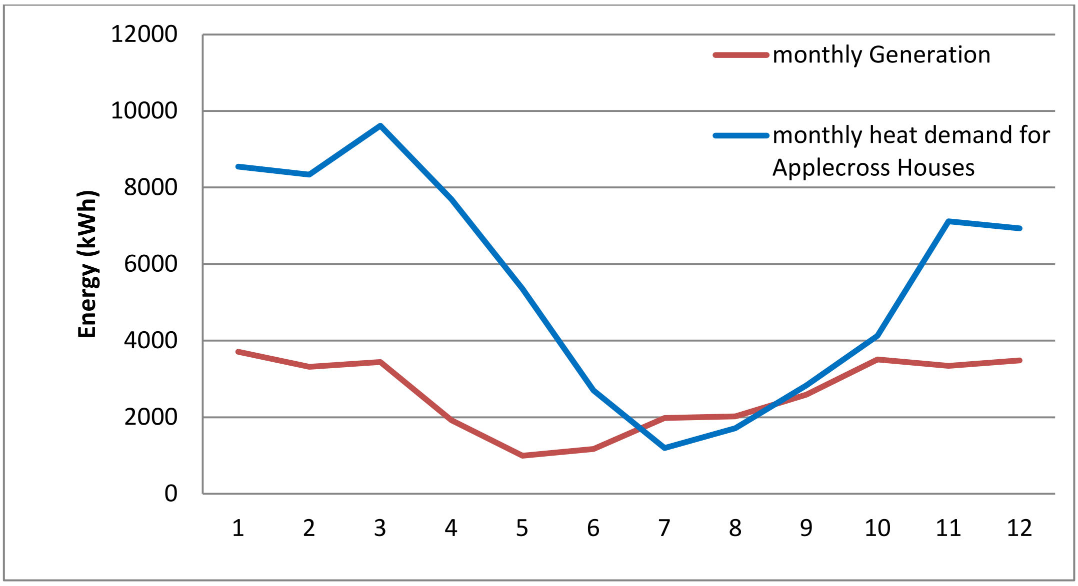
Relatively this river has a very small catchment area and consequently low flow discharge. The selected coordination for intake gives 65m gross head, which is also not so sufficient if it is compared with that flow; therefore for confidence awalk through the site was done and it was found that the design proposed by Highland Eco –Design was the optimum option for such head height and flow rate.Figure 3-12 shows some pictures of the site.

FIGURE 3-12 PICTURES FOR BURN BESIDE APPLECROSS HOUSES

SOURCE: AUTHORS

The hydrology of the river was detailed in the feasibility report and based on that, a designed capacity of 9.1 kW and a flow rate of 0.024 m^3/s was chosen (Applecross House Feasibility Report, 2009). Thus, returning to the existing flow duration data, analysis was conducted to determine whether the energy produced by this river can cover the heat demand in this district throughout the year. The result of the monthly energy productionfor these calculations in comparison with the heat demand is shown in Figure 3-13.

FIGURE 3-13 MONTHLY DEMAND AND GENERATION IN THE APPLECROSS HOUSES SCHEME



As in the previous two cases the energy heat demand for Applecross Houses is too high to be covered by this hydro scheme especially in the cold seasons; therefore grid electricity and biomass could serve as back up for these houses as well.

4. BIOMASS

Wood fuel (biomass) is one of the major source of heating in Applecross. This chapter discusses three aspects. First the biomass resources in Applecross with the current demand for fuel wood based on household survey conducted and the sustainability of meeting these demands through local biomass resources. The second aspect is biomass based district heating system and the third is a combination scheme of biomass based central heating system and micro-hydopower.

4.1. CURRENT SITUATION

4.1.1. FOREST RESOURCE

The woodland of Applecross peninsula once used to comprise of diverse origin and mixed native broadleaved species of silver and pubescent birch, sessile oak, hazel, holly, wych elm, ash and various willows. However, most of these forests are non-existent. Some remnants can be found in some areas particularly around the central part of the Applecross peninsula.

Forest cover in Applecross peninsula is concentrated mainly in the northern and central regions covering only 928 hectare as calculated from Scottish Forestry Comission'sOrdnace Survey Mapping. (http://maps.forestry.gov.uk/ 2014) This is merely about 3.27 percent of the total Applecross peninsula; most of the land area is rocky and covered by grassland. The total volume of wood from these forests is estimated at 60,000 tons. (Strategic Timber Transport Funds 2013)

The northern region covers about 589hectares of forest. This forest was planted between 2000-2004 and is yet to mature. The map showing the forest cover of this area is shown in Figure 4-1. This forest was planted with mixed native tree species.

FIGURE 4-1 NORTH APPLECROSS FOREST COVER

SOURCE: ORDNANCE SURVEY 1:25,000 RASTER MAP, AUTHOR, 2014

TABLE 4-1 DETAILS OF NORTH APPLECROSS FOREST

Forest ownership	Area (ha)	Volume (m^3)	Comment
Estate (Arina)	94	6,000	Volume of trees are concentrated in 33.02 ha only as most of the areas are rocky and unplantable
Croft Township	495	-	Forest still juvenile
Total Forest Area	**589**		

SOURCE: AUTHOR BASED ON (TAYLOR 2010/11)

The total forest cover in the central part of Applecross is 338 ha (Taylor 2010/11). The forest cover in this region is shown in Figure 4-2. Few areas around the Estate township and Shore street consist of historic natural trees and most of them are regenerated woodlands. These new woodlands are Smiddy woods and Gateway plantation. Most of these new woodlands are planted mainly with conifers of Sitka spruce (*Picea sitchensis*).

Figure 4-2 Central Applecross Forest Cover

Source: Ordnance Survey, http://maps.forestry.gov.uk/imf/imf.jsp?site=fcscotland_ext&, Author, 2014

Table 4-2 Details of Central Applecross Forest

Central Applecross (Applecross Estate ownership)		
Forest Type	**Area (hectare)**	**Volume (m^3)**
Ancient Woodlands	88	No estimate
Planted Woodlands (Conifers)	250	60,500
Total Forest Area	**338**	

Source: Author and (Taylor 2010/11)

The natural woodlands are sparsely distributed around the Estate with a total area of 88 hectare. These trees are restricted from felling for fuel wood thus doesn't play a major role in meeting the wood demand, hence not considered in the biomass supply system.

4.1.2. Management of Existing Forest

The Applecross Trust has their own forestry management plan that has been in operation to restore and preserve woodlands in the peninsula and to accrue social, environmental and economic benefits from it. By the end of 18th Century original native woodlands in Applecross deteriorated to a state of almost negligible as a result of deforestation and overgrazing. Importance of woodlands and reforestation in Applecross history started from the 18th century. The major plantation carried out during 1960-1970s was able to restore woodlands in Applecross but especially with conifers and no native species. These plantations areas were carried out for providing deer wintering, farmland shelter and future revenue from timber production. (Taylor 2010/11)

The natural woodlands are sparsely distributed around the Estate with a total area of 88 hectare. These trees are restricted from felling for fuel wood thus doesn't play a major role in meeting the wood demand, hence not considered in the biomass supply system.

Figure 4-3 Devastated Woodlands behind Hartfield

Source: Authors

The woodlands planted during 1960s-70s are not in good condition and some of them such as Gateway woodlands and woodland behind Hartfield were observed to be devastated during site visit. The major cause of this is due to poor forestry management practice and significant strong storms. The cost of harvesting in such areas outweighs the revenue generated.

According to the forestry management plan 2010/11 of the Applecross Trust, felling is planned in an area of 204.93 hectare with an estimated volume of 38,700 m^3 in the period of 2012-2021. The trees that are planned to be felled are roughly around 40 years old. During the same period, restructuring is planned in an area of 108.76 hectare with new plantations in an area of 94.57 hectare by 2019. The details are attached in Table 9-4, Table9-5, Table9-6 in Annex E Biomass Section**.** (Taylor 2010/11)

4.1.3. Properties of Wood fuel

The assumptions considered for the properties of the wood fuel for this study are:

- The tree species used for fuel wood is mainly of Sitka Spruce with some native tree species such as Birch and Ash. For the calculation Sitka Spruce is considered.
- The moisture content of the wood fuel is 15 percent.
- The calorific value of wood fuel is 4.2kWh/kg. (Wood Fuel South West Advice Service n.d.)
- All the wood fuel supply is assumed to be in chopped log woods of 33 cm in average and firmly stacked volume. Thus, the conversion of 1 m^3 of choppedlog woods of Sitka Spruce is equivalent to 304 kg. (Valter Francescato, Eliseo Antonini, Luca Zuccoli Bergorni 2008, 13)

4.1.4. Demand for woodfuel

Out of 65 households surveyed, 53 (81.5%) use biomass/wood as primary or secondary fuel source for space and water heating purposes of which 13 respondents are using wood as their secondary heating source for space heating. However, only 30 respondents (46.15%) of the surveyed households provided the wood consumption data for their respective households.

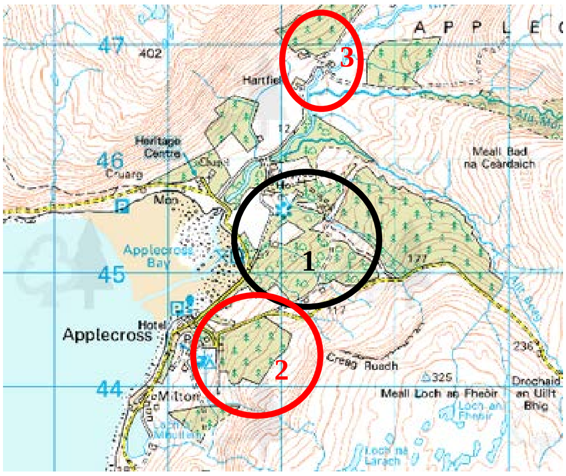
Taking 114 fully occupied households into consideration, it is found that the consumption of fuel wood in Applecross is 262.5 ton per annum. For calculation, 15% moisture content and a conversion factor of 1 m^3 to 304 kg is considered as mentioned in earlier chapter.

4.1.5. SUPPLY SYSTEM

Only some areas of the woodland in Applecross are permitted to harvest for fuel wood. These areas are shown in the Figure 4-4below which are, Estate Woods (represented by number 1), Smiddy woods (represented by number 2), area behind Hartfield woods (represented by number 3). In fact, earlier only dead and naturally felled trees were allowed to be collected for fuel wood. Recently, from December 2013 onwards the local wood cutter (Mr. Ian Gillies) has been granted permission in thinning of Smiddy woods (2) & plot 3 and cut live trees as well.

Mr.Gillies is working as local wood-cutter and supplier of fuel wood to households in Applecross since November, 2011. Following the Applecross Landscape Partnership Scheme (ALPS) meeting in 2011, the project decided to provide training to him along with 7 other community members on chainsaw use and forest management. 9 He invested a total of £6,000 to buy a chain saw, one second-hand pickup truck (with capacity to deliver 1.2 m3 of wood) and other small harvesting equipments. Applecross Trust takes no charge for the fuel wood as Ian's work is also beneficial for the proper management of Applecross Woodlands. His current customer number is 40 and it's been growing steadily over the years. He supplies according to customer's need – either log, round or split load and with different price range depending on the product delivered. A profiling of his customers in different townships and costs for products is presented in Table 9-7 in Annex E. His total annual delivery is 294 m^3 or 89 ton.

FIGURE 4-4 WOOD FUEL SUPPLY SOURCE



SOURCE: ORDNANCE SURVEY 1:25,000 RASTER, AUTHORS

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[9] Interview with Valerie Hodgkinson, Development Officer – Energy Efficiency at Applecross Energy Efficiency on 12th March, 2014

Besides the supply from the local wood-cutter, individual households collect fuel wood themselves which is found 173 ton annually. Locals collect wood from the dead or felled trees which they are allowed to take.[10]

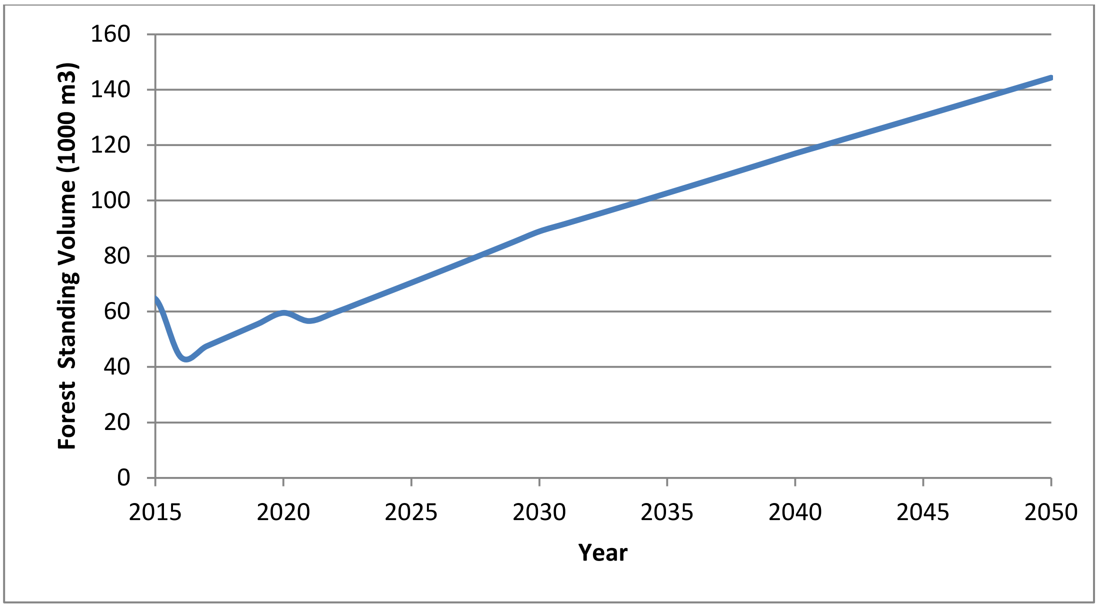
4.2. FUTURE SCENARIO

4.2.1. Future Business-As-Usual (BAU) Scenario

The total annual demand for fuel wood (fire wood) in Applecross peninsula is found to be 863.5 m^3 based on household survey conducted. 85% of the households are located in the centre and southern Applecross where the demand is also 85% of the total demand. 15% of the households are sparsely located in the northern parts of Applecross who mainly collect fuel wood themselves. For a Business-As-Usual (BAU) scenario, all the households in central and southern Applecross are only considered.

The current standing tree volume for the central Applecross forest area of 250 hectare is calculated as 60,500 m^3 assuming 242 m^3/ha (Source:European Forestry Institute, 2014). The scenario of standing tree volume (forest resource) till 2050 is shown inFigure 4-5, taking into account annual increment of tree volume based on the age, felling and plantation scheme as per the forest management plan. The sharp decrease of standing tree volume between 2015-16 and 2021-22 is the result of the felling plan.

Figure 4-5 Standing Volume Projection of Central Applecross Forest



SOURCE: AUTHORS

Considering constant demand for the scenario till 2050, the proportion of demand and supply is shown in Figure 4-6. The supply volume is taken as the annual increment in tree volume in

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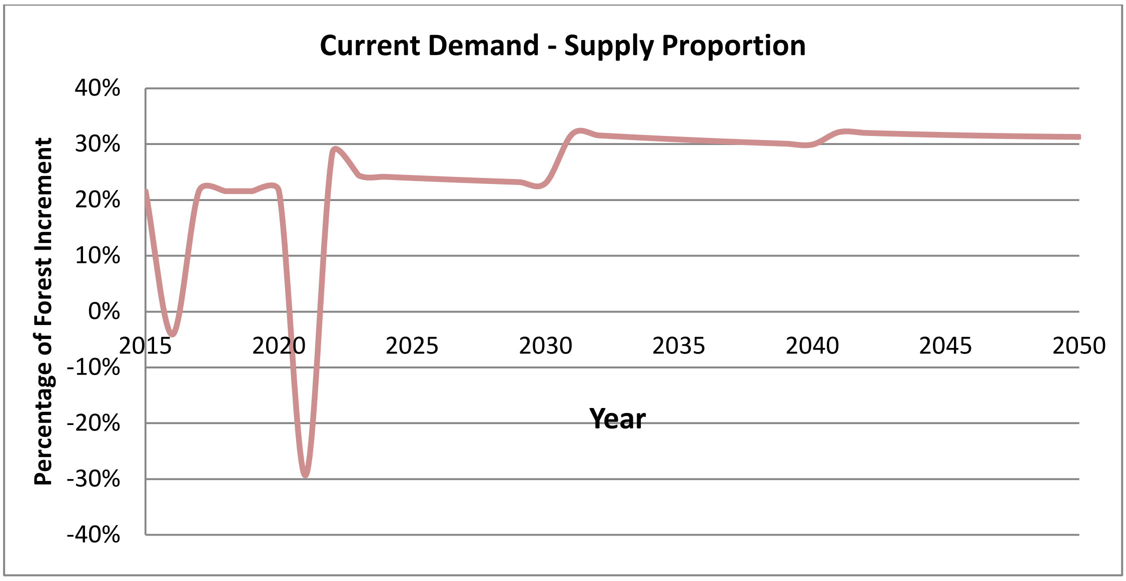
[10] Interview with Applecross residents during survey

this area. From the Figure 4-6,currenlty with this supply volume about 20% needs be extracted in order to meet the current demand of fuel wood (863.5 m^3) till 2030 except in period of 2015/16 and 2021/22 where there will be excess supply from the felling plan. This timber from felling plan is mainly for export, but can be consumed for local fuel wood supply. However, from 2030 onwards the extraction percentage needs to be increased to 30% to meet the demand and similar projection continues till 2050.

FIGURE 4-6 PROPORTION OF CURRENT DEMAND AND SUPPLY



SOURCE: AUTHORS

From the calculation, the projection shows with the current demand, the fuel wood supply can be met till 2050 with maximum around 30% extraction from the annual standing volume increment.

4.2.2. 100 PERCENT BIOMASS FUTURE SCENARIO (WITHOUT EFFICIENCY)

Meeting the heat demand in the house with Oil and Electricity is more expensive than biomass and it is considered as a potential future fuel resource for space and water heating in Scotland. Therefore, a scenario of 100 percent biomass based heating in Central Applecross is also analysed to have an overview of how it will affect the forest resources in this area. For this, it is assumed that all the households will have high efficient wood stove with back boiler (80% efficiency). To meet the heating demand (avg. 22,996 kWh/household) a household in Applecross would consume 22.5 m^{3}of wood.[11] This results to 2,180 m^3 annual demand of fuel wood for central and southern region of Applecross.

Based on this new demand, now the extraction for wood fuel is increased to 50% from the annual increment of standing volume, which can be seen in Figure 4-7. This is more than double to that of the current BAU scenario. As in the BAU scenario during the felling period

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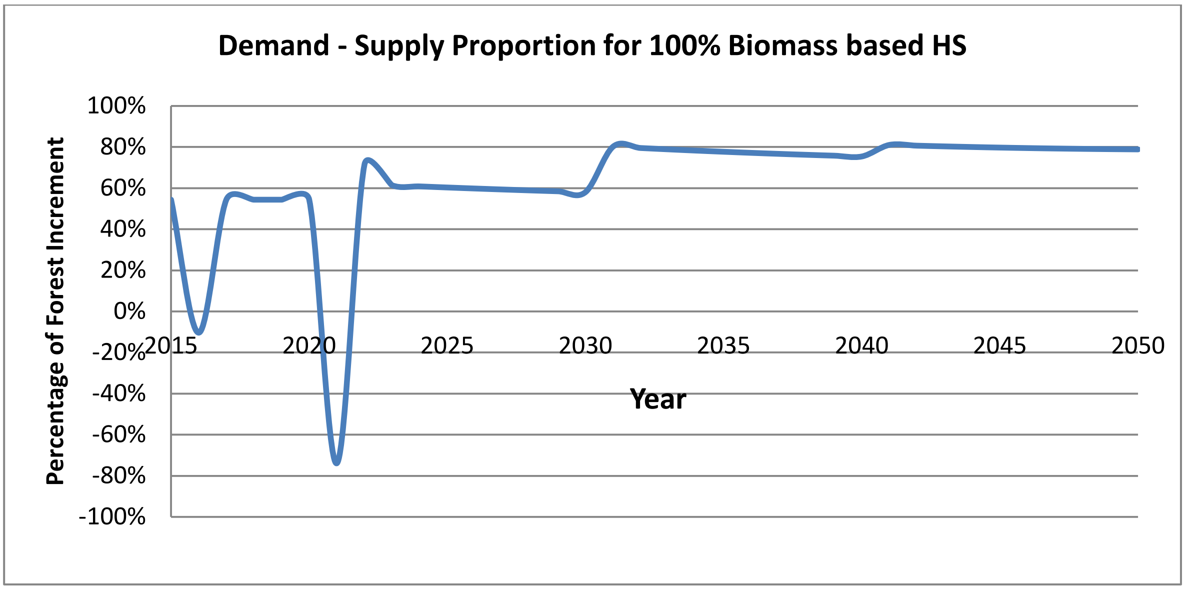
[11] Author calculation

there will be excess supply and till 2030 will need to extract 50%. From 2030 onwards extraction will have to increase upto 80% maximum from 2030 onwards.

FIGURE 4-7 ALTERNATIVE SCENARIO - 100% BIOMASS BASED HEATING SYSTEM (HS)



SOURCE: AUTHORS

This is even more worse case than the BAU scenario. It will require more new plantation and woodlands to meet the demand in a sustainable way.

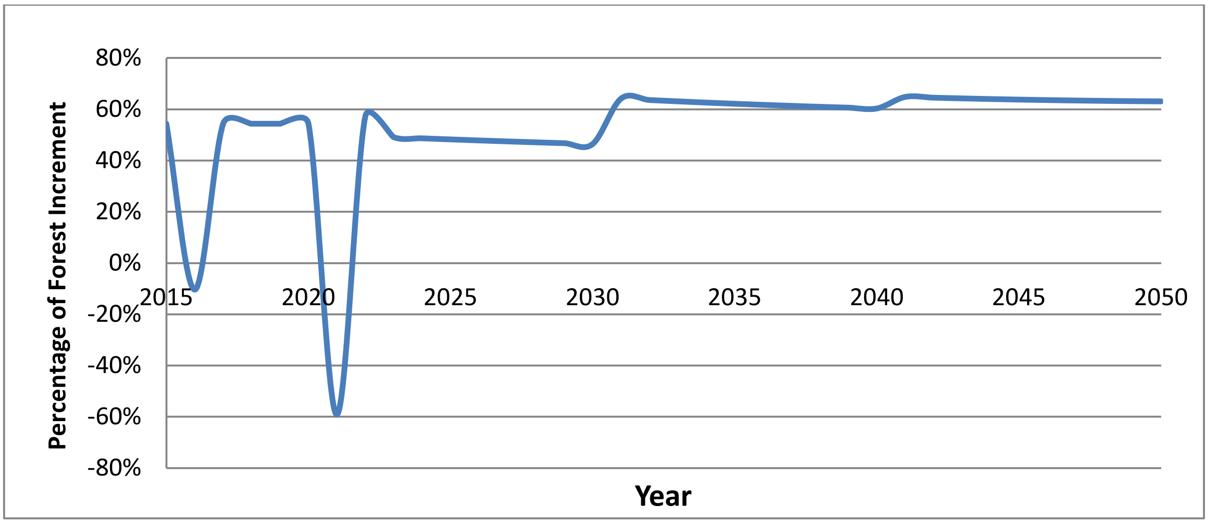
4.2.3. 100 PERCENT BIOMASS FUTURE SCENARIO (WITH EFFICIENCY MEASURES)

According to Scottish Government Policy the new built houses should be 20 percent more efficient compared with the current level after year 2015.(Business Green, 2013) Based on the estimation that the houses in Applecross will reduce its heating demand by 20% by year 2020, a new energy efficiency scenario is developed for central and southern Applecross houses post-year 2020. Thus, the starting year of the scenario is also taken as 2020.

WITH THE INCREASE IN EFFICIENCY STILL THE DEMAND/SUPPLY FRACTION REMAINS 50% AS WITHOUT EFFICIENCY MEASURES. THE PROJECTION WITH THIS SCENARIO IS SHOWN IN

Figure 4-8. Similar to the 100% biomass based heating system without energy efficiency scenario a sharp increase will occur from 2030 onwards reaching 65% maximum. The projection till 2050 remains around 60% which is slightly better than without efficiency measures.

FIGURE 4-8 ALTERNATIVE SCENARIO - 100% BIOMASS BASED HEATING SYSTEM (HS) WITH ENERGY EFFICIENCY



SOURCE: AUTHORS

4.2.4. ECONOMIC ANALYSIS AND CO_2 SAVINGS

An economic analysis for 100 percent biomass based heating system for whole Applecross is calculated based on the replacement of oil boilers and electrical heaters that are used currently as primary heating system. The oil boilers will be replaced by 12 kW wood boilers that would cost £2,500. Similarly the households that have electric heating system will be replaced by similar wood boilers and wet radiators and need to invest around £5,000. This cost includes £1,500 for wood boiler and the cost for eight Stelrad Compact Single Panel Radiators (450mm x 1800 mm of 1361 W each) is total £472at £59 each). The saving is calculated based on the cost difference of oil or electricity and cost of wood. The investment with savings per household and for whole Applecross is shown in Table 4-3. The CO_2 savings for replacing oil boilers and electric heater is also depicted in Table 4-3. The total investment for changing to 100 percent biomass based heating system is £96,608 and the total savings from this investment per year is £95,159. Likewise, the total CO_2 savings per year is 15,752 kg. The assumptions for calculations are attached in Table 9-12 in Annex F.

TABLE 4-3 COST OF REPLACEMENT OF EXISTING HEATING SYSTEMS TO WOOD BASED HEATING SYSTEM IN APPLECROSS

System Change	Cost £/ HH	Total Investment (£)	Annual Savings (£)/ HH	Total Saving in Applecross (£/yr)	CO_2 Savings (kg/yr)
Oil boiler to wood based heating system	2500	115,000	1059	48,723	5,519
Electric Heater to Wood based heating system	5000	70,000	3,317	46,436	10,233
Total		**185,000**		**95,159**	**15,752**

SOURCE: AUTHORS

4.2.5. UNCERTAINTIES

As the scenario takes into account the condition of 100% biomass based heating system in Applecross, which increases the demand for fuel wood from 262.5 tons to 865 m^3 per annum. Uncertainty lies with the current supply system which is a very small scale, and will not be able to deliver the increased demand with the current tools and equipments. The scale of the supply system should be adopted accordingly.

Likewise, the Applecross Estate Trust's forest management plan is of 10 years period and this plan will be updated with new schemes of plantation, restructuring that will change the forest resource and thus the supply.

4.3. SUGGESTIONS

4.3.1. CROFT LAND AND COMMON GRAZING LAND AS AN OPTION FOR WOODLAND

The Crofter Forestry (Scotland) Act 1991 gave crofters a qualified right to establish and manage woodlands on the croft and the common grazings. This gives an opportunity for Applecross Crofters to consider using common grazing land for woodland creation. There are total 17 crofting townships in Applecross, with 7 in the north and 10 in the south with a total area of 9,245 hectare including individual croftlands and common grazing land.[12] The details of the croft townships is presented in Table 9-9 and Table 9-10 in Annex E. Only few crofters are engaged actively to a larger extent in their crofting land by raising domestic animals and growing vegetables covering a small area of their total croftland.

The Applecross Trust have identified areas in the common grazing land that could be applicable for woodlands based on the criteria established by the Scottish Forestry Commission that are also applicable for grants. But most of the area is with poor soil condition and consists deep peats that are restricted for woodland plantation schemes.

The active crofters who are using their croftland are not interested to provide their land for future woodland creation. However they welcome the idea of using common grazing lands for plantation that will secure their future fuel wood demand. [13] This would help in improving the ecological environment of Applecross in terms of biological diversity and also provide social benefits such as good firewood supply, recreational opportunities and many more.

This has been initiated in the northern part of Applecross through a collaboration between North Applecross Woodlands Company and Applecross Estate 1400 ha of Caledonian Scots Pine and native Broadleaved woods were planted in 2000/01 and a 20 km long deer fence was built to prevent the sheep straying from the crofter's land deer from coming into it. The project brought encouraging result and similar future project is under consideration in South Applecross. (Scotland 2011)

The use of common grazing land needs engagement of all the crofters to get on board to take unanimous decision and proper management of the plantation (timely thinning and

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[12] Interview and email communication with Mr. Donald Archie MacLellan, Administrator, Applecross Trust on 10th March, 2014

[13] Interview with Marion Macroe, Michael Summers, Gordon Cameron and other locals during 2-10th March, 2014.

harvesting). The Applecross Community Company should take the lead to facilitate such future projects, enable discussion and conversation with various entities like Applecross Trust, Crofting Township Management Committee and the Scottish Crofters Federation.

Creation of woodland in common grazing land will secure the future fuel wood supply for the community in case of any policy change of Applecross Estate.

4.4. DISTRICT HEATING SCHEME IN APPLECROSS

4.4.1. POTENTIAL LOCATIONS FOR DISTRICT HEATING SYSTEMS IN APPLECROSS

Probable sites were identified for Central Biomass based Heating Systems taking into consideration factors such as density and proximity of households in different locations, occupancy factors and available biomass resources. Table 4-4 shows these identified sites in Applecross.

TABLE 4-4 POTENTIAL SITES FOR CENTRAL BIOMASS BASED HEATING SYSTEM

Township	Property Name/Address	Number of Households/ Properties
Shore Street	Applecross Inn and other flats	10
Borrodale	Craite Barn	8
Estate	Applecross Trust Houses	6
Camusterrach	Camusterrach Place	6
Camusterrach	Burnside	10

SOURCE: AUTHORS (BASED ON HOUSEHOLD DATABASE PROVIDED BY APPLECROSS ENERGY EFFICIENCY)

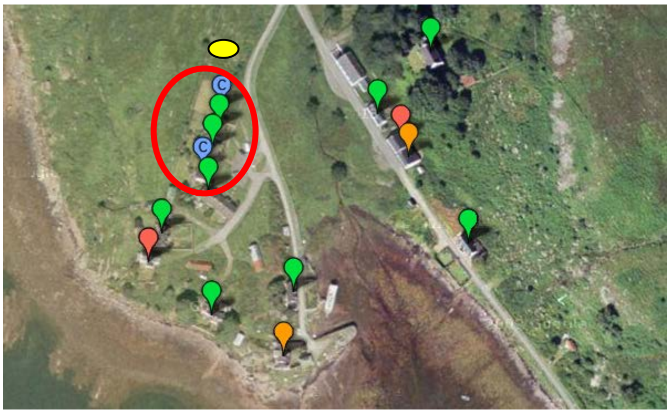
Borrodale, Shore Street, Estate and two locations in Camusterrach are the locations that the study team identified for the combination scheme of hydropower (micro) and possible central heating systems. Detail studies and assessments havealready been conducted for Shore Street and Borrodale by the Applecross Community Company with hydro scheme (Allt na Breugaireachd – 90 or 180 kW) and excess electricity for heating. Therefore, this study concentrates on the Estate and two locations in Camusterrach where a combined Hydro-District Heating Scheme is further explored to provide necessary insight how the scheme would work. This model shall be representative for other possible future schemes in Applecross.

4.4.1.1. OPTION 1 - CAMUSTERRACH PLACE

Option 1 for District Heating System (DHS) identified by the study team is in Camusterrach Place where six houses (House number 1 to 6) are considered. The blue pin indicates rented council houses and the green pin indicates individual owned houses. The houses were built by Highland Council in 1985 for residential and official purpose. Currently 5 houses are fully occupied and 1 is unoccupied. The houses have an average floor area of 75m^2. All of these houses have an attic, but mostly unused or used for storage purpose. The residents either own the houses (3 no.) or rent (2 no.) from Highland Council. 4 houses were surveyed in this location during the household survey conducted. Based on the survey it was found that most of the houses have open fireplaces with chimneys. Out of 4, three responded that they use biomass/wood for space heating. Other fuels for space heating includes electricity, coal, oil, anthracite eggs. The average biomass used in these houses is 3 tons/year. The main heating systems are boilers with radiators, open fire with radiator or wood burning stove. The secondary heating systems are either electric heaters or wood burning stoves. The houses heat their water from the main heating system, back boiler, secondary heating system and instant electric water heater.

A nearby location is identified for boiler house which is very close to House number 1 (10 m) as shown by yellow dot in Figure 4-9. Approximate piping distance is 50-60 m.

FIGURE 4-9 OPTION 1 - CAMUSTERRACH (HOUSE NUMBERS 2-6 CAMUSTERRACH PLACE)



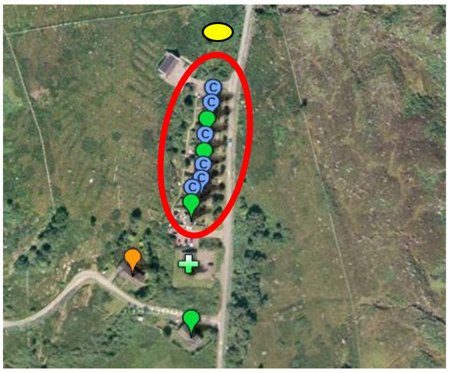
SOURCE: GOOGLE FUSION TABLE PROVIDED BY APPLECROSS ENERGY EFFICIENCY

4.4.1.2. OPTION 2 - BURNSIDE, CAMUSTERRACH

Option 2 is in Burnside of Camusterrach with ten houses are considered for DHS. As the houses in Camusterrach place these houses were also built by Highland Council in 1979 for residential and official purpose. Currently all the houses are fully occupied. The houses have an average floor of 70 m^2. All of them have an attic, but mostly unused or used for storage purpose. The residents either own the houses (3 no.) or rent (6 no.) from Highland Council. 4 houses were surveyed in this location. Based on the survey it was found that most of the houses have open fireplaces with chimneys. The houses have electricity based heating systems but some of them are using electricity as their main source and others as secondary source. The survey showed that the houses also use biomass and coal for either primary or secondary sources for space and water heating. According to the survey, the main heating systems are storage heaters and open fires with radiator. The houses normally heat their water by electric immersion heaters.

A nearby location is identified for boiler house which is very close to the first house (20 m) as shown by yellow dot in Figure 4-10. Approximate piping distance is 50-60 m.

FIGURE 4-10 OPTION -2: CAMUSTERRACH (1-10 BURNSIDE)



SOURCE: GOOGLE FUSION TABLE PROVIDED BY APPLECROSS ENERGY EFFICIENCY

4.4.1.3. OPTION 3 - ESTATE HOUSES

Option 3 is in the Estate (Applecross Houses owned by the Trust) with six properties considered for DHS. There are two holiday houses in this township. The properties have an average floor of 50 m^2. The attics on the top floor are used for storage purposes or house water tanks. All the properties were surveyed in this location. Based on the survey it was found that the properties on the top floor have open fireplaces with chimneys. The main fuel used for space heating is either electricity or oil. One responds the use of anthracite egg as the main source for space heating. Two properties don't have any secondary heating system. The others use electric heater or wood burning stove for space heating. The houses heat their water from the main heating system, electric immersion heaters and instant electric water heaters.

FIGURE 4-11 OPTION - 3: ESTATE BUILDINGS NEAR BRAMBLE (5 PROPERTIES)

SOURCE: GOOGLE FUSION TABLE PROVIDED BY APPLECROSS ENERGY EFFICIENCY

4.4.2. BIOMASS BASED DISTRICT HEATING SYSTEM IN CAMUSTERRACH PLACE

Out of the three options identified, we finally selected one for our case study, which is option 1 for biomass based district heating system. Option 1 is in Camusterrach Place. Though there ar 6 households inthis area, for this study only 5 households are considered based on fully occupied status. The demand for each householdwas taken from the Scottish Heat map Atlas value of 276 kWh/m^2. This was then used to size the components of the district heating system as shown in Table 4-5 below. A suitable location of the boiler house (Figure 4-12 Camusterrach Place and location of boiler houseFigure 4-12) was identified to be on a common grazing land about 20m away from the first house in this block. This is situated on a hill and thus needs a route to be created to be able to deliver the wood.

FIGURE 4-12 CAMUSTERRACH PLACE AND LOCATION OF BOILER HOUSE

SOURCE: AUTHORS

The boiler house has been sized to be able to create enough room for storing 30m^3 ofwood. The annualamount of wood required is 82m^3 and thus the storage will lessen the delivery times for supply of wood.

The boiler considered for this design is the 77kW Angus Max Boiler. (Eco Angus kein Datum).

A thermal storage tank with a capacity of 4000 litres has also been considered (Eco Angus). Heated Water will then be circulated into each house by underground pipes through the use of pumps and back to the storage tank. Sizing of the pipes was done from Rauvitherm manufacturer tables (Rehau, 2011)

Each household will be fitted with a Hydraulic Interface Unit (HIU)that comprises a single heat exchanger (for hot water use) and a heat meter to record individual household heat consumption (Harton).

Table 4-5 Sizing of different components of Camusterrach DHS

Description		Cost per unit	Total cost (pounds)
Boiler House		300 £/m^2[14]	14700
Height (m)	2.4		
Length (m)	7		
Width (m)	7		
Angus Max Boiler (kW)& Installations	77	1 x 15000 £[15]	15000
Buffer Heat Storage (Lt)	4000	1 x 3500 £[16]	3500
RVT Duo Pipe Dimensions		180 £/m[17]	12150
Diameter (mm)	40		
Length (m)	70		
Circulation Pump	GrundfosMagna3	1 x 1017.6 £[18]	1017.6
Hydraulic Interface Unit		2000 £/Unit	10000
Expansion Tank		1 x 81.83 £	81.83
Flue wall		1 x 1121.13 £ [19]	1121.13
Diameter	250mm		
Height	4500mm		
Road construction	20m	110294 £/m	2206
Land		1 x 3000 £[20]	3000

Source: Authors

The highland council needs to be consulted on the allowed policies regarding NO$_x$ particulates (Biomass Energy Centre 2011)

4.4.2.1. ECONOMIC ANALYSIS

The following factors were considered for the financial evaluation of the District Heating System

- The interest rate used is 5%
- Lifetime has been taken as 20 years for all the 3 scenarios
- Renewable Heat Incentive is taken as 8.6p/kWh for Tier 1 and 2.2p/kWh for Tier 2for a period of 20years (OfGem, 2014)

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[14] Perkins_ Methodology for supply chains 11-12-20 Report page 12

[15] http://www.ecoangus.co.uk/prices.html

[16] http://www.ecoangus.co.uk/prices.html

[17] Perkins_ Methodology for suply chains 11-12-20 Report page 9

[18] http://www.anchorpumps.com/grundfos-magna3-32-120f-220-variable-speed-single-head-circulator-240v?gclid=CILetaSRjb0CFagKwwodig0AKw

[19] http://www.fluesupplies.com/index.php?cPath=22_34

[20] Land price gotten from an interview with Alison Macleod from the Applecross Community Company

- Selling price of heat has been set at 7p/kWh

The total investment costs were calculated to be £ 62,776 with annual running costs of £ 7084. The same calculations were repeated with two future cases of consumption increasing and decreasing by 20% with the result shown in Table 4-6Table 4-6 below.

TABLE 4-6 FINANCIAL ANALYSIS OF DHS

Description	**Sensitivity Analysis**		
	Case 1 Current Demand	Case 2 Demand with 20% decrease	Case 3 Demand with 20% increase
Investment (I_o) £	62,776	62,776	62,776
Annual Revenue (£)	10,634	9,775	11,493
NPV (£)	69,748	59,045	80,452
Dynamic Payback Period (yrs)	8	8	7

SOURCE: AUTHORS

The above sensitivity analysis shows that for a demand decrease (case 2), while maintaining the same system capacity for example in case the houses take energy efficient measures our District Heating system is still financially attractive. In case study 3 with a demand increase for example in the case of behavior change the system will also still be financially attractive. This is because we are now paying back the same investment with a higher revenue.

4.4.2.2. CUSTOMER SAVINGS

The households using oil and electricity will also make savings of £ 248 and £2396 per year respectively which also gives off an attractive investment for these households if they change to the DHS. The households with Oil based heating system will have have no investment while those with electricity based heating systems will need to invest in radiators[21]. The financial analysis for these two types of Households is shown in Table 4-7 below.

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[21] Number of radiators was taken as 8 from an average of 8 rooms for each house in Camusterrach place taken from the survey

TABLE 4-7 FINANCIAL ANALYSIS HOUSEHOLDS' INVESTMENT

Description	Household heating System	
	Oil based	Electricity based
Total Investment (I_o) £	Nil	1966
- *8 No. 600x1400mm Stelrad Compact Radiator 1.37kW*[22]		466
- *Installation costs £*		1500
Annual Savings (£)	248	2396
NPV (£)		27890
Dynamic Payback Period (yrs)		1

SOURCE: AUTHORS

4.4.2.3. UNCERTAINTIES

The savings of the households are based on the assumptions that they maintain their current heat energy consumption. Due to availability of a cheap alternative source, individuals could change their behavior that may lead to an increase in heat consumption. However, this behavior (increase of heating demand) increases the yearly sales of DHS and financially more attractive.

4.4.3. HYDRO-BIOMASS DISTRICT HEATING SYSTEM (DHS) SCHEME FOR CAMUSTERRACH TOWNSHIP

Among the three options mentioned in section 4.4.1, option 1- Camusterrach Place and option 2 – Burnside, Camusterrach is considered for the combination of a micro-hydropower and biomass based district heating systems. A total of 15 houses (10 in Burnside and 5 in Camusterrach Place) are considered for this scheme. The following sub-section describes the assessment of the energy demand and the supply that can be met by the proposed scheme.

4.4.3.1. HEATING DEMAND

The households heating demand is calculated based on the heating degree days, types of dwellings, average space area and per area heating demand according to the Scottish Heat Atlas. The annual heating demand for Camusterrach place was found to be 110400 kWh/year and 249,000 kWh/yearfor Burnside. As shown in chapter 3.3.3.2, a hydropower scheme that supplies the Burnside houses with electricity for heating could produce excess electricity during the months of July to October. If the hydroelectric district heating system in Burnside would be interconnected to the biomass based district heating system in Camusterrach Place, described in 4.4.2, a considerable amount of biomass could be replaced by electricity and the financial feasibility of both systems would improve. The combined annual heating demand for both the locations is 284,700 kWh.[23] The monthly heating demand distribution for

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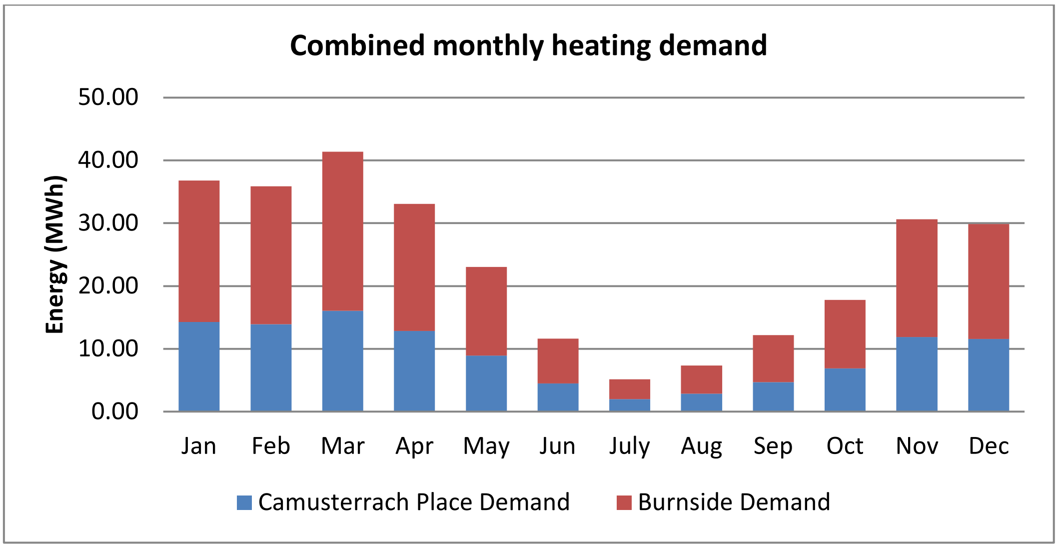
[22] http://www.plumbnation.co.uk/site/stelrad-compact-single-panel-single-convector-radiators/

[23] Author calculation

Camusterrach Place and Burnside is represented in Figure 4-13. The detail calculation is presented in Table 9-14 in Annex G.

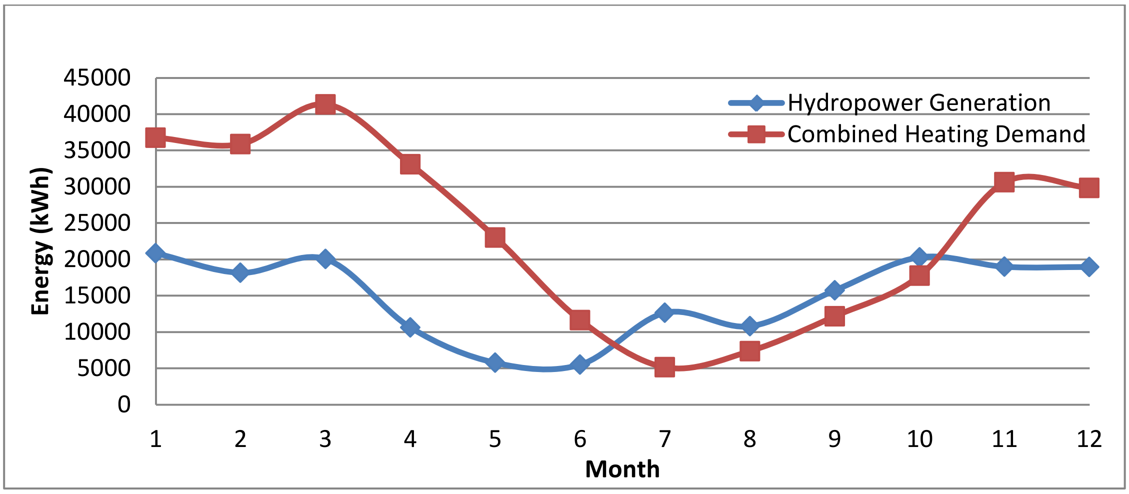
FIGURE 4-13 SPACE AND WATER HEATING DEMAND FOR CAMUSTERRACH PLACE AND BURNSIDE



SOURCE: AUTHORS

The monthly combined heating demand and monthly hydropower generation of Allt na Chriche follows the profile shown in Figure 4-14, high in winter periods and less in summer periods. This indicates the possibility of having a hydropower scheme to meet the heating demand of the studied location.

FIGURE 4-14 MONTHLY COMBINED HEATING DEMAND AND MONTHLY HYDROPOWER GENERATION PROFILE



SOURCE: AUTHORS

4.4.4. SUPPLY SCENARIO

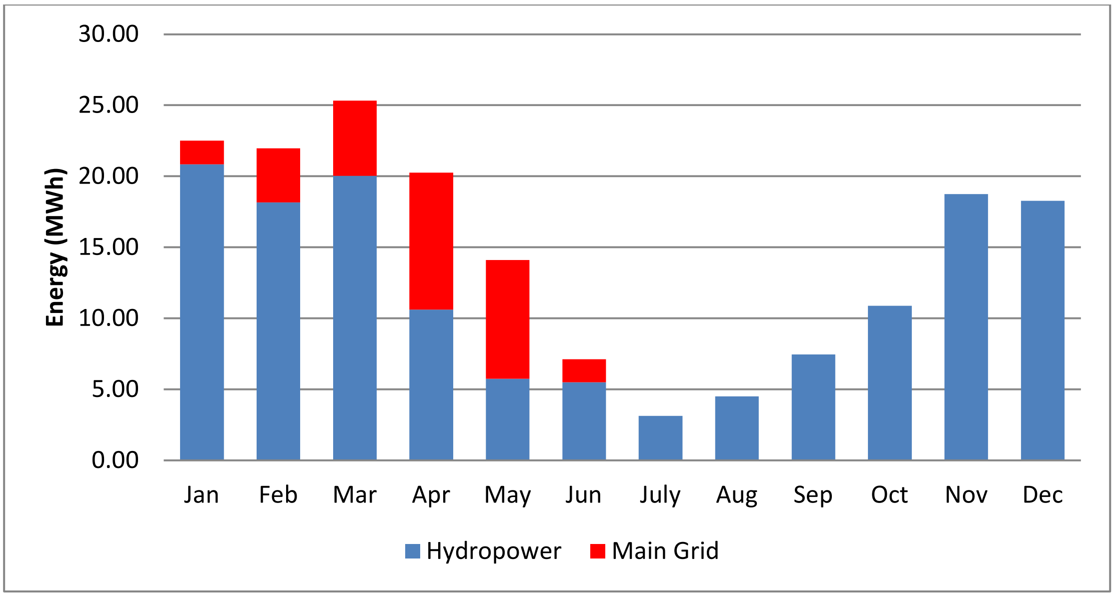
In the proposed combined scheme, micro-hydropower is given priority over biomass. The electricity from hydropower will first meet the heating demand of Burnside. If it cannot meet the demand, extra electricity will be needed from the main grid. If additional electricity is available after meeting the heating demand of Burnside,this will be fed into the hot water storage tank of the biomass district heating system in Camusterrach Place. Extra energy required to meet the demand in Camusterrach Place will be supplied from the biomass district heating system.

The economy of district heating systems is strongly affected by the implementation of energy efficiency measures. An alternative scenario therefore considers a reduction of the heat consumption by 20% due to efficiency measures after 2015.

4.4.4.1. BURNSIDE WITH CURRENT DEMAND

The annual generation from micro-hydropower is 178,000 kWh and the annual demand in Burnside is 174,300 kWh. The monthly supply mix from micro-hydropower and main grid for Burnside is shown in Figure 4-15. From the proposed 49kW micro-hydropower scheme the combined heating demand can be met during summer months of July, August,September and October. During the winter period (January-June), 27% of the demand should come from the grid to meet the heating demand of these 6 months. Yearly 17% (30353 kWh) of the demand needs to come from grid to meet the demand.

FIGURE 4-15 BURNSIDE HYDRO-MAIN GRID COMBINATION

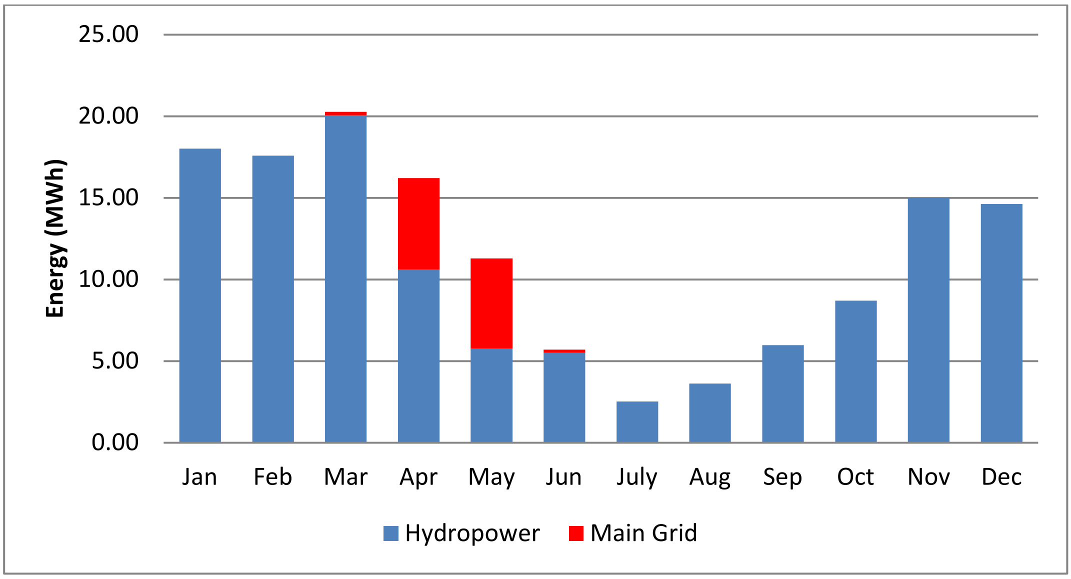


SOURCE: AUTHORS

4.4.4.2. BURNSIDE WITH ENERGY EFFICIENCY MEASURES

With the efficiency measures applied to the households after 2015, only 8% of the annual demand needs to come from the grid compared to the 17% in regular demand condition. So, 92% of the annual heating demand of the households considered in Burnside will be met by the micro-hydropower scheme only.

FIGURE 4-16 BURNSIDE HYDRO-MAIN GRID COMBINATION WITH 20% ENERGY EFFICIENCY

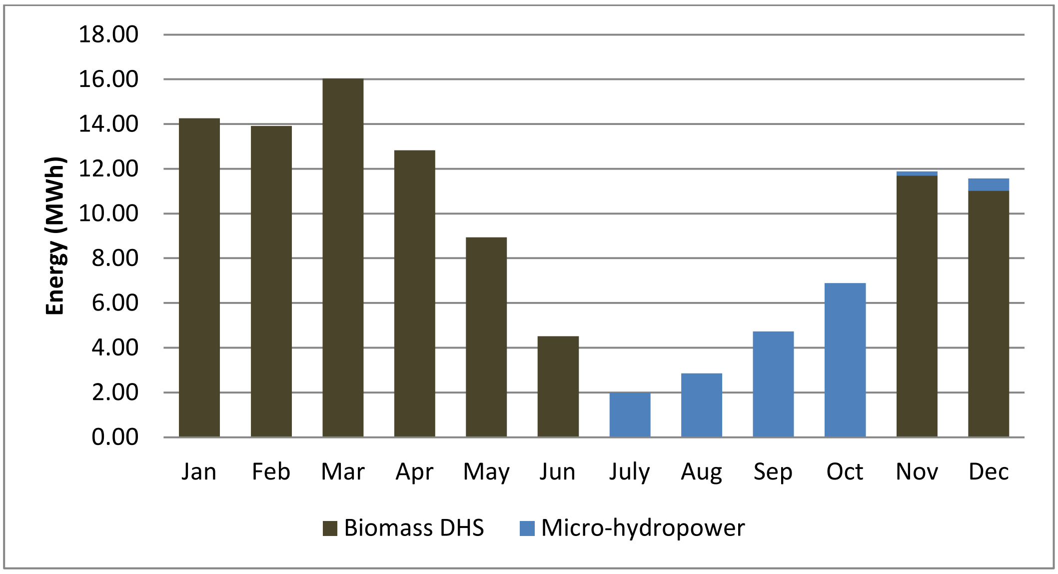


SOURCE: AUTHORS

4.4.4.3. CAMUSTERRACH PLACE WITH CURRENT DEMAND

The monthly supply mix from biomass based DHS and micro-hydropower for Camusterrach Place is shown inFigure 4-17. The heating demand of Camusterrach Place can be met completely by micro-hydropower during July-October. In November-December, only 3% demand can be supplied from the micro-hydropower and remaining will come from DHS. During other months (January-June), the complete demand will be met by DHS alone because there will be no available hydro electricity after meeting the demand in Burnside.

FIGURE 4-17 CAMUSTERRACH PLACE DHS-HYDRO COMBINATION

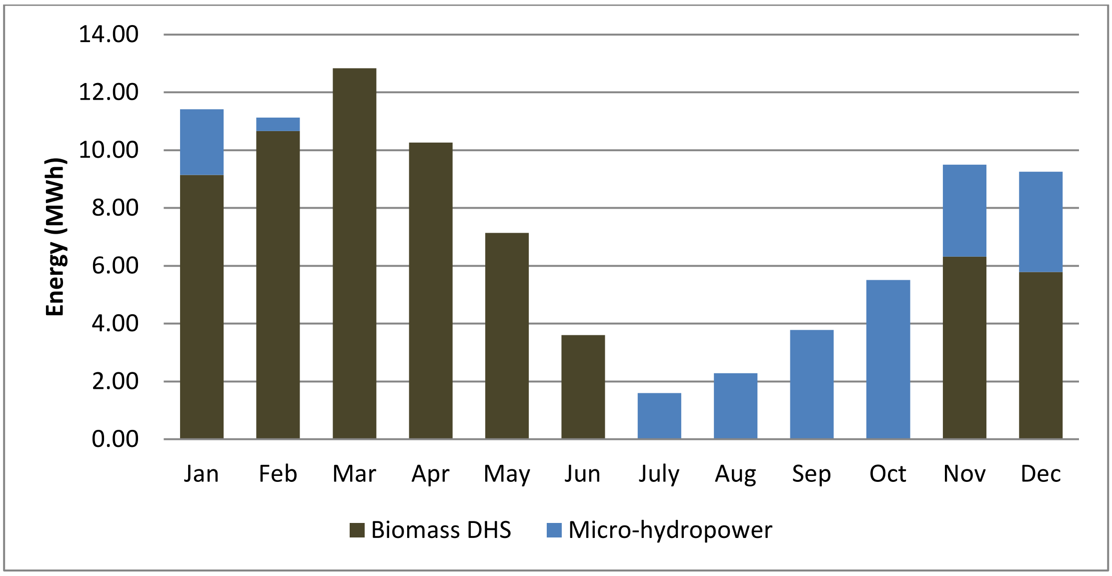


SOURCE: AUTHORS

4.4.4.4. CAMUSTERRACH PLACE WITH ENERGY EFFICIENCY MEASURES

In Camusterrach Place, with the implementation of the efficiency measures, there is access electricity supply from the micro-hydropower scheme for four months completely as shown in Figure 4-18. During November-February, partial demand will be met from hydro; whereas the remaining will come from Biomass.

FIGURE 4-18 CAMUSTERRACH PLACE HYDRO-DHS COMBINATION WITH 20% ENERGY EFFICIENCY



SOURCE: AUTHORS

4.4.5. ECONOMIC ANALYSIS

4.4.5.1. CURRENT DEMAND CONDITION

CUSTOMER COST-BENEFIT ANALYSIS

For Burnside:

17% of the electricity has to be supplied from the main grid to meet the heating demand of Burnside. Per unit cost of the electricity from the main grid is 17.85p/kWh (current price, 2014). So each customer needs to pay £1550/year. If the customers were to meet the same demand from grid only they would need to pay £3111/year. So each year, they would save £1550/year. However, currently the customers are not paying this amount for their heating. With the similar cost (£1550/year) they can keep their house warm.

TABLE 4-8 ENERGY COST FOR BURNSIDE

Burnside	Energy (kWh)	Per unit cost (£/kWh)	Total cost (£)
Supply from Hydro	143,947	0.07	10,076
Supply from Main Grid	30,353	0.1785	5,418
Total cost			15,494
Individual cost			1,550

SOURCE: AUTHORS

For Camusterrach Place:

The hydro scheme will provide 15.6% of the heating demand to Camusterrach Place and the remaining will be supplied from the Biomass based DHS. Individual residents need to pay £1,545/year which is equal to the cost that they would pay if they are connected to the stand alone DHS, as the cost of energy from hydro and DHS are kept same for the combined scheme.

TABLE 4-9ENERGY COST FOR CAMUSTERRACH PLACE

Camusterrach Place	Energy (kWh)	Per unit cost (£/kWh)	Total cost (£)
Supply from Hydro	17,206	0.07	1,204
Supply from DHS	93,193	0.07	6,523
Total cost			**7,728**
Individual cost			**1,545**

SOURCE: AUTHORS

4.4.5.2. ENERGY EFFICIENCY CONDITION

In the energy efficient condition, when the demand will reduce by 20%, the heating demand will lower that will affect the financial feasibility and cost-benefit analysis for the customers.

CUSTOMER COST-BENEFIT ANALYSIS

For Burnside:

The residents in Burnside will need to get only 9% of their electricity from the main grid to meet the heating demand. This will reduce the extra cost of consuming high rate electricity from the grid. Each customer will need to pay £1101/year compared to the cost of £1550/year in current demand. The benefit is even higher when the cost is compared with the total ideal electricity cost (£3111/year) that they would need to pay to have similar warmth level in their households.

TABLE 4-10 ENERGY COST FOR BURNSIDE WITH ENERGY EFFICIENCY

Burnside	Energy (kWh)	Per unit cost (£/kWh)	Total cost (£)
Supply from Hydro	127,924	0.07	8,955
Supply from main Grid	11,515	0.1785	2,055
Total cost			**11,010**
Individual cost			**1,101**

SOURCE: AUTHORS

For Camusterrach Place:

The hydro scheme will provide 16.18% of the heating demand to Camusterrach Place and rest will come from the DHS. Individual resident needs to pay £1236/year which is equal to the cost that they would pay if they are connected to the stand alone DHS. This is because the cost of energy from hydro and DHS are kept same for the combined scheme.

TABLE 4-11 ENERGY COST FOR CAMUSTERRACH PLACE WITH ENERGY EFFICIENCY

Camusterrach Place	Energy (kWh)	Per unit cost (£/kWh)	Total cost (£)
Supply from Hydro	225705	0.07	1580
Supply from DHS	65750	0.07	4,603
Total cost			6,183
Individual cost			1,236

SOURCE: AUTHORS

4.4.6. FINANCIAL ANALYSIS OF THE COMBINED HYDRO-DHS SCHEME

For the financial analysis of the combined system, the investment, operational costs of the hydro scheme and DHS are combined together. Additional investment of £20000 for replacing the boiler, circulation pumps etc. is considered after 25 years. All future values are brought to current value by using an interest rate of 5%. The yearly sales from Hydro and DHS are added together for the combined energy sale. The time period of getting RHI and FIT are estimated 20 years respectively. The Annual FIT gotten for the Hydro scheme is taken as 20.21p/kWh (OfGem 2014). In the combined system, the DHS doesn't need to be under operation during July-October that reduces the fuel wood cost and other operational costs. The Table below provides the financial parameters:

TABLE 4-12 FINANCIAL ANALYSIS OF COMBINED HYDRO-DHS SCHEME

Parameters	Current Demand (kWh)	Reduced Demand due to Energy Efficiency (kWh)
Total Investment Cost (£)	344269	344,269
Total Operational Cost (£)	8986	8,141
Yearly Energy Sale (£)	17804	15,137
Annual FIT (£)	33272	31422
Annual RHI (£)	8014	5,654
Annual Revenue (£) (up to 20 years)	50105	43228
Annual Revenue (£) (after 20 years)	8818	6151
NPV (£)	280150	194443
Payback Period (Year)	9	11

SOURCE: AUTHORS

With current demand the dynamic payback period for the combined system is better than the case of demand decrease. The annual revenue decreased after 20 years as the cash flow from both FIT and RHI will stop.

The Combined Hydro-DHS Scheme is financially more attractive than setting up one DHS and Hydro separately. The sum of revenues, NPV of two separate systems is lower than the combined system. So economically it is more feasible to consider setting up one combined system for Burnside and Camusterrach Place rather than two separate systems.

TABLE 4-13 COST COMPARISON BETWEEN DIFFERENT SCHEMES

Parameters	**Various systems**			
	DHS (£)	Hydro (£)	Sum of DHS & Hydro (£)	Combined Hydro-DHS System (£)
Investment	62,776	265,587	328,363	344,270
NPV	63,842	169,393	233,236	280,150
Dynamic Payback Period	8	10	10	9

SOURCE: AUTHORS

The combined Hydro-Biomass DHS offers more flexibility and security to the customers. Due to the backup system (either by hydro or DHS), the customers in Camusterrach Place will have more flexible and secured source of energy to meet their heating demand. On the other hand, a stand-alone hydro would have lower energy sale in this context. Because currently the grid capacity in Applecross is such that no other Hydro Scheme except Alt na Breugaireachd - the one already planned for Shore Street can't be put into the grid. So with the combined system, the hydro scheme can deliver all the generated energy to meet the heating demand (for Burnside and Camusterrach Place) and a small un-used fraction during summer time (when the heating demand is low) to meet the electricity demand of Burnside.

5. CASE STUDIES

5.1. PURPOSE OF THE CASE STUDIES

Working to achieve sustainable development is not an easy task; it requires effort and coordination from all the stakeholders involved. It also requires a common vision, information, transparency and persistency. The following case studies aim to inform the population of Applecross about currently available measures to improve their living conditions and savings on fuel, CO_2 emissions and on energy expenditure. Moreover, investing in energy efficiency means investing in economic growth, productivity and skilled labour capable of implementing and selling their services on the market (Scottish Government, 2014)

Therefore, this chapter is divided in two sections. The first section illustrates suggestions to save on energy consumption and on energy expenditure. In order to accomplish this task, three examples of common dwellings in Applecross are shown and their particularities are described. Then, a respective financial assessment of each of the alternatives is conducted.

5.2. SELECTION OF THE CASE STUDIES

In order to assess the home energy efficiency in Applecross, three houses were selected for our case studies. The three houses were selected based on the analysis of the data from the survey and HtT parameters mentioned above plus the amount paid in the last year for electricity. In detail, these are the steps followed for the selection of the candidates:

- The surveyed houses are filtered and clustered into two main groups, based on the owners' expenditures on fuels. The first group consists of those houses in which the owners had spent above 10% of their income on fuels and electricity. The second group are those houses in which the owners had spent below 10% of their income on fuels and electricity. As a result, the first group adds up to 47.7% of the surveyed houses in Applecross; the second group represents 43.08%, and the remaining 9.22% are those householders who at the time of the survey didn't know the share of their income spent on fuels and electricity;
- The first group is clustered again based on the types of dwellings found which are detached, semi-detached, end-terraced houses and flats. As mentioned before, most of the houses in Applecross are detached houses; they represent 67.7% of the surveys conducted. Semi-detached houses account for 22.6%, end-terraced houses 3.2%, and flats 6.5% of the surveys conducted;
- A cross-reference table is generated with a statistics software to list the households that meet the selection criteria.7 households out of our survey meet the criteria and those 3 with the highest electricity bill are chosen.

5.3. METHODOLOGY FOR ENERGY AUDITS

In order to assess the energy requirements of the three selected houses the following methodology was used:

1. A brief interview was conducted with the owner of the house to identify the heating-related habits such as which rooms are heated, how often, and the temperature settings of the heaters and radiators.Data was also collected on the electrical

appliances more often used; the structures of walls, roofs and floors; and data from energy and water bills;

2. A sketch of the house was made based on site measurements of the dimensions of the walls, wall-thickness and height to calculate the volume of the rooms;
3. An inventory of doors, windows, light bulbs and radiators was made, recording measurements, temperatures and wattage where appropriate;
4. The most high energy consuming appliances and most often used appliances were measured with an energy monitor when possible, if not the rated power of the appliance was noted along with information such as brand and model;
5. Calculation for total electricity consumption was made with data from lighting and electrical appliances;
6. Calculations for total heat losses and total heat demand were done with data from the structure of the building and the heating system.

5.4. BUILDINGS

5.4.1. COMPARISON OF 3 SELECTED HARD-TO-TREAT BUILDINGS

5.4.1.1. LOCATIONS

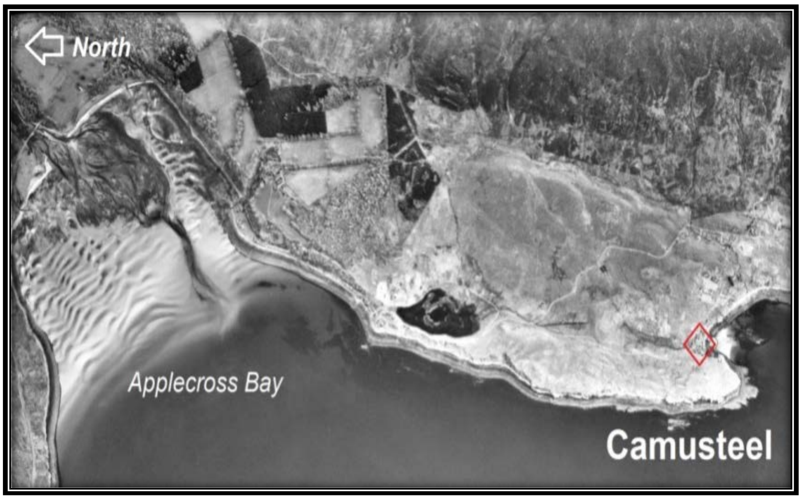
The first house is occupied by an elderly couple. It is a detached house located in Milltown, Applecross (see Figure 5-1).

FIGURE 5-1 LOCATION OF MILLTOWN IN THE APPLECROSS PENINSULA

SOURCE: (CAMERON, 2014)

The second house is a detached house occupied by a small family (husband, wife and a child). The house is also used as Bed and Breakfast with up to 6 tenants from April until September every year. It is located in Camusteel, Applecross (see Figure 5-2).

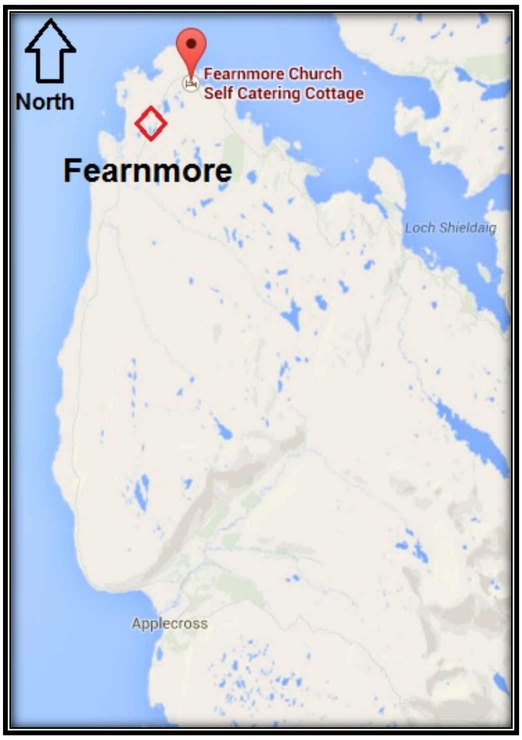
FIGURE 5-2 LOCATION OF CAMUSTEEL IN THE APPLECROSS PENINSULA



SOURCE: (CAMERON, 2014)

The third house is detached as well, and occupied by a retired individual. It is located in Fearnmore, Applecross (see Figure 5-3)

FIGURE 5-3 LOCATION OF FEARNMORE IN THE APPLECROSS PENINSULA



SOURCE: (GOOGLE MAPS, 2014)

5.4.1.2. DESCRIPTION OF THE BUILDINGS

TABLE 5-1 CHARACTERISTICS OF 3 SELECTED HARD-TO-TREAT BUILDINGS

No.	**Descriptions**	**Hard to Treat House**		
		Hard to treat house 1	**Hard to treat house 2**	**Hard to treat house 3**
1	Location	Milltown	Camusteel	Fearnmore
2	Year of Construction	1972	2004	1914
3	Number of storeys	1.5	1.5	2
4	Wall Structures	250 mm of stones	6” of timber framed	600 mm of stones (old walls)
		100 mm of cavity	100 mm Rockwool	25 mm of joist (old walls)
		12,5 mm of plaster board	50 mm cavity	20 mm of concrete (new walls)
			150 mm concrete block	150 mm of bricks (new walls)
			25 mm of plaster board	100 mm cavity (new walls)
				12.5 mm of plaster board (new walls)
5	Loft Insulation thickness	50 mm (Rockwool)	100 mm (Rockwool)	Water proof membrane*
6	Coombed Ceilings	Yes	Yes	Yes
7	Main heating system	Oil-fired boiler	Oil-fired boiler	Electricity
8	Secondary heating system	-Open fire (wood)	- Wood stove (wood)	- LPG stove
		-Rayburn (wood)		
9	Secondary heating system location	Living Room	Living Room	Living Room
10	Annual fuel consumptions (Main heating system oil)	3700 litres	2500 litres	-
11	Annual fuel consumptions (Secondary heating system)	395 kg wood**	395 kg wood**	47 kg LPG
12	Annual Electricity Bills (£/year)	1122	1620	1584
13	Annual electricity consumption (kWh/year)***	6286	9076	8874 (including heating)
14	Windows type	Double glazing	Double glazing	Double glazing
15	Age of the windows	More than 15 years old	Less than 15 years old	More than 15 years old

*Based on interview with owner of HtT house 3, but he did not know the material type

We assumed the lambda value and the thickness with the waterproof membrane that is available in UK
http://www.natural-building.co.uk/sites/natural-building.co.uk/files/pdf/48/20131122technicalmanualpitchedroof.pdf
**It is based on interview with the owners of the selected houses that each house in Applecross buy 1 trailer of log wood (equivalent with 1,3 m^3) every year
It is assumed that 1 m^3 of Log wood with 15% moisture content equal with 304 kg of log wood
*** The price of electricity is 17,85 p/kWh including VAT and excluding the daily service charge

SOURCE: AUTHORS

As observed in Table 5-1, houses built pre-1983 have similarities in their structure and architecture whilst the house built post-1983 have different characteristics such as structure of the walls and roof.

5.4.1.3. ENERGY INDEXES

During the energy audits performed, energy demand was estimated by dividing the requirements into heating and electricity. An energy index for each of these divisions was calculated and finally, a total energy index was estimated for every household audited. In addition, two heating demands were calculated: one based on theoretical calculations of heat losses and gains within the entire house, assuming a comfortable indoor temperature in all rooms, and another one based on fuel consumption and energy bills. There is a difference between the calculated heat demand from the audits and the demand based on fuel consumptions since the latter considers only the most often occupied places in the house as “heated areas”. However, in HtT2, the calculated heating demand is lower than the demand based on fuel consumptions, because of some possible factors such as:

- Higher heat losses due to ventilation caused by frequent opening and closing operations of the main entrance door due to business activities in the house;
- The possible air leakages from windows, doors, and others;
- Rooms being overheated (above 20° C);
- Efficiency of the boiler assumed to be 75% due to high use of hot water in summer. It might in fact be lower.

TABLE 5-2 ENERGY INDEXES OF 3 SELECTED HTT HOUSES

Energy Indexes		HtT House 1	HtT House 2	HtT House 3
Electricity	**kWh/y**	**2,543.23**	**2,922.84**	**1,160.95**
Lighting	kWh/y	657.73	859.94	383.25
Appliances	kWh/y	1,885.50	2,062.90	777.70
Heating	**kWh/y**	**43,708**	**12,377**	**45,102**
Heating Demand (Calculated)	kWh/y	43,708	12,377	45,102
Heating Demand (Bills)	kWh/y	27,520	19,120	9,480
Household Area	**m^2**	**149.63**	**138.81**	**125.68**
Electricity Requirement Index	**kWh/m^2**	**17.00**	**21.06**	**9.24**
Heating Requirement Index[24]	**kWh/m^2**	**292**	**89**	**359**
Heating Requirement Index (Bills)	**kWh/m^2**	**184**	**138**	**75**
Scottish Heating Index	**kWh/m^2**	**404**	**276**	**594**
Total Energy Requirement Index	**kWh/m^2**	**309**	**110**	**368**

SOURCE: AUTHORS

HEATING REQUIREMENTS

As seen in Table 5-2, all the heating demands of the chosen houses are below the Scottish average of comparable buildings according to the Scottish Heat Atlas. This amount becomes even smaller when the real consumption of Oil and Wood is converted into kWh units and divided by the surface area of the dwelling. The reasons behind these differences rely particularly on the attitudes and behaviour of consumption of fuel by the occupants of the dwelling. Due to the cost of the fuel and behaviour regarding saving, they tend to only heat the rooms where they will be performing a specific task. Therefore, mainly the kitchen and the living room are heated, leaving the other areas mostly unheated.

ELECTRICITY REQUIREMENT

The total electricity consumption of the houses was calculated based on instant readings of the appliances and estimations of consumption based on frequency of use, and rated power of the appliance or light bulb. Despite the sizes of the houses being relatively similar, the electricity consumption varies from one to another because of differences in the behaviours and habits of the occupants.

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[24] Based on theoretical calculations

5.4.1.4. ALTERNATIVE SCENARIO 1: ENERGY EFFICIENCY

A series of energy efficiency measures were considered to improve the energy requirement index of these houses. These measures focus on insulation to reduce heat losses and are listed below in Table 5-3.

TABLE 5-3 COMPARISON OF ENERGY EFFICIENCY MEASURES IN THE 3 SELECTED HTT HOUSES

Categorization	Descriptions	Hard to Treat House						
		HtT - 1			HtT – 2	HtT - 3		
Insulation Detail	*Insulation Material*	Polystyrene	Rockwool Flexy	Kingspan KoolTherm K3	No need of further insulations because the calculated U-Values of each wall, roof and floor are below 1 W/mK (seeSection **Error! Reference source not found.**)	Polystyrene	Kingspan KoolTherm K7	Kingspan KoolTherm K3
	Thickness (mm)	100.00	50.00	25.00		100	40	25
	Insulated Area (m^2)	131	60	21		47	68	35
	Board size (m^2)	3	9	3		3	3	3
	Board Price (£)	30	26	24		30	29	24
Cost per Improvement	*Board Price (£/m^2)*	10	3	8		10	10	8
	Material Cost (£)	1,370	179	178		493	677	290
	*Installation Cost (£)**	870	395	900		870	395	1000
	Investment (£)	2,240	574	1,078		1,363	1,072	1,290
	Energy savings (kWh/year)	19,016	1,144	1,487		4,266	11,696	5,177
	Energy savings (£/year)	855	51	67		761	2,088	924
	Payback Period (years)	**3**	**17**	**34**		**2**	**0.6**	**1.5**
Cost for total improvement	*Material Cost (£)*	1,727				1,460		
	Installation Cost (£)	2,165				2,265		
	Investment (£)	3,892				3,726		
	Energy savings (kWh/year)	21,648				21,139		
	Energy savings (£/year)	974				3,773		
	Payback Period (years)	**4.6**				**1.1**		

* Installation cost of walls insulationfrom http://www.energysavingtrust.org.uk/Insulation/Cavity-wall-

insulation, detached house
Installation cost of floor insulation from http://www.energysavingtrust.org.uk/Insulation/Floor-insulation, lower edge of the given range
Installation cost of loft insulation from http://www.energysavingtrust.org.uk/Insulation/Roof-and-loft-insulation, detached house

******* The floor improvement is only applied in the living room, due to the most occupied place in the house

******** The floor improvement is only applied in the kitchen, due to the most occupied place in the house
The kitchen area also includes the dining room and office room

SOURCE: AUTHORS

The insulation material chosen for each energy efficiency measure here described were based on the existing wall structures (for example the presence of wall cavity), the affordability of prices, payback period and the age-related-requirements of the owner.

The calculated U-Values for HtT house 2 are below 1 W-mK for walls, roofs, and floors, even when the roof insulation thickness is below 270 mm (current minimum standard of roof insulation thickness). The chosen thicknesses of the insulation material are based on its affordability in the UK market and their thermal conductivity in order to achieve a new U-Value below 1 W-mK.

5.4.1.5. Alternative Scenario 2:Biomass

In this section of the report, the total replacement of the current oil-fired boiler by a wood-fired boiler is assessed. Log wood boilers were chosen over pellets considering the availability of fuel from local suppliers and costs.

In order to size the boiler based on a quick estimate, two methods suggested by (Dunster Wood Fuel Group 2012) were used. The first method consists of multiplying the total floor area of the household by pre-determined factors to obtain the total power of the boiler. These factors are as follows:

1. 60 Watts for new-build i.e. very well insulated properties;
2. 90 – 100 Watts for older properties which have some insulation (double glazing, loft insulation);
3. 120 – 150 Watts for old non-insulated houses.

The second method consists of multiplying the total volume of the household by the factors listed below to obtain the power of the boiler:

1. 0.05 – 0.06 kW for older non-insulated houses;
2. 0.04 – 0.05 kW for older houses with some insulation;
3. 0.03 – 0.04 kW for well-insulated or new build properties.

Table 5-4 Comparison of Biomass Alternatives for 3 Selected HtT Houses

Descriptions	Hard to Treat House		
	HtT - 1	HtT - 2	HtT - 3
Heating Demand (Calculated) (kWh/year)	43708	12377	No feasibility for biomass boiler because he has electricity as the heating source (dry-based system) and biomass boiler is wet-based system
Log Wood needed (kg/year)	11845	3354	
Log Wood Cost (£/year)	1,364	235	
Log Boiler Size Estimation			
Total Floor Area (m2)	150	139	
Total volume (m3)	343	322	
Rule of thumb 1 (kW)	15	8	
Rule of thumb 2 (kW)	14	10	
Boiler Output (kW)*	16	10	
Boiler Price (inc. VAT)**	1509	1049	
Installation Cost (£)***	6,912	4,315	
Total Cost (£)	8,421	5,364	
Payback Period (years)****	**7.1**	**22**	

*It considers 90% efficiency of the boiler

**http://plumbing4home.com/solid-flow-multi-fuel-boiler-ksw-coalwoodpellet-9kw&currency=GBP&language=en

http://plumbing4home.com/sas-uwt-solid-flow-multi-fuel-heating-boiler-with-controller-14kw&currency=GBP&language=en

***average value from Biomass Energy Center

****without total improvement in insulation

Source: Authors

5.4.1.6. ALTERNATIVE SCENARIO 3: RENEWABLE ENERGY

Installation of renewable energy is another alternative to reduce energy bills. In the three Case Studies, each dwelling was assessed to determine its renewable energy potential.Table 5-5shows the detailed comparison of these options. Potential annual savings and investment costs are also computed to get the return on investment and savings in CO2 emissions as well.

SELECTION OF A WIND TURBINE

With an average annual wind speed of 5-8m/s in Applecross, without much obstacles and low roughness, a mini wind turbine in the range of 1.5 to 10kW can generate about 1,200 – 4,300 kWh per installed kW generator capacity per year, at specific investment costs of around 6,000 GBP/kW. Depending on the priority of the householder, the energy generated from the wind turbine can be connected directly to a water heating system by means of an electric immersion heater; or the turbine could be fitted with an inverter to convert DC electricity to AC electricity suitable for the households' appliances and exported to the grid.

SELECTION OF SOLAR WATER HEATING SYSTEMS

HARD TO TREAT HOUSE NO 1

Solar technologies are not feasible on this house due to roof orientation.

HARD TO TREAT HOUSE NO 2 (CAMUSTEEL)

In this case study of bed and breakfast the demand pattern is in such a way that from April to September (tourist season) there are on average 6 B&B guests with 3 permanent residents. Therefore the average number of residents for the whole year is 6. The average domestic hot water consumption for an adult is assumed to be 40l/day. The average daily hot water consumption for 6 people is therefore 240l. There is, however, a higher demand in summer and a lower demand in winter.

The existing heating system is an oil boiler and the DHW storage tank of 144 litre volume is located on the first floor under the south-east roof. The building is used as a casestudy to integrate a solar water heating systems into an existing building.

An 11m^2 evacuated tubes collector and a DHW tank of a volume of 600 litre is assumed to be integrated into the existing water heating system. The evacuated tube collector is selected because of its good thermal insulation in areas with low temperature and high wind speeds which leads to low heat losses compared to flat plate collectors.

The resulting annual supply from this system is 3,050kWh. This figure represents 65% solar fraction from the total hot water energy consumption of the bed and breakfast .The following graph shows the consumption of energy and solar fraction.

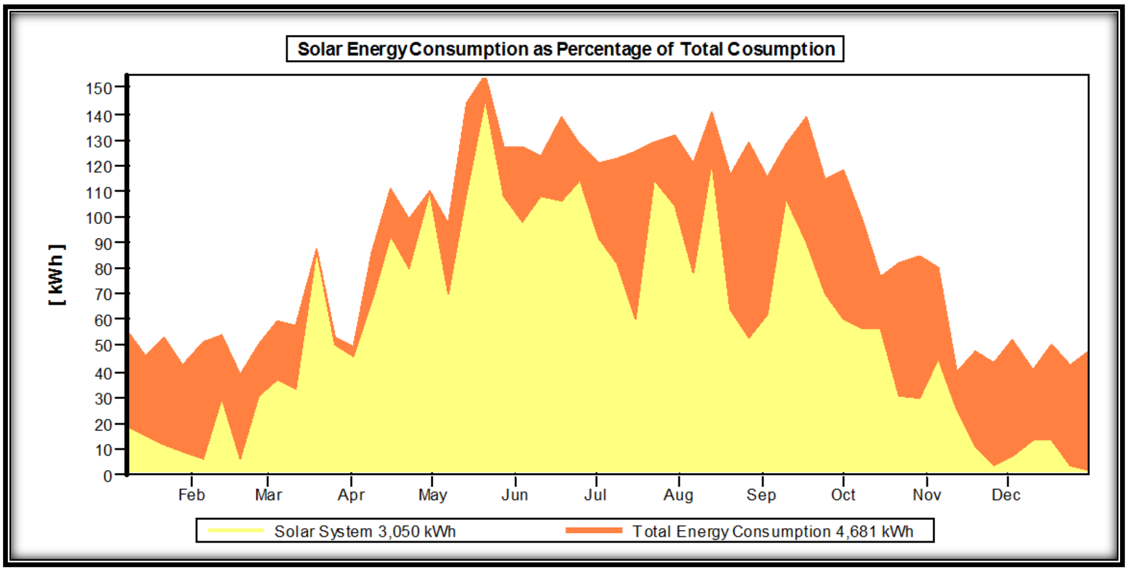
On the economic efficiency side for the life span of 20 years and according to the capital value method (interest rate on capital, energy use and running cost increase of 5%, 3% and 1.5%) the net present value (NPV) is £1,598 and the cost of solar energy is £0.06/kWh.The system would save 1,013 kg of CO_2per year.

Table 5-5 Showing economic parameter and output for case of bed and breakfast

System yield	3050kWh
Active solar surface	11m^2
Annual fuel saving	382.5 l
Life span	20
Interest on capital	5%
Price increase rate-Energy	3%
Price increase rate-Running cost	1.5%
Investment	£-5000
Subsidy (Renwable heat incentive, 19.2 p/kWh)	595 £/year for 7 years
Saving	229£/year
Running cost	£-54
NPV	£1598
Cost of solar energy	0.06£/kWh

Source: Calculation based on TSOL

Figure 5-4 Solar fraction of the total Domestic hot water energy consumption



Source: (Valentine, 2014) TSOL Software

HARD TO TREAT HOUSE NO 3 (FEARNMORE)

As the building has only one resident a solar thermal system was not considered for this case.

SUMMARY OF RECOMMENDATIONS REGARDING DOMESTIC RENEWABLES

Table 5-6 shows the summary of alternatives regarding domestic renewables that could be applicable for some of the Hard-to-Treat houses selected. In the case of HtT house 3, none of the domestic renewables' alternatives are feasible considering that there is only one full-time resident on this dwelling.

TABLE 5-6: COMPARISON OF RENEWABLE ENERGY ALTERNATIVES FOR 2 SELECTED HTT HOUSES

Description	HtT - 1	HtT - 2		
	Wind	Solar PV	Solar thermal	Wind
Inclination of the roof (Degrees)	N/A	45	45	N/A
Size of the roof (m^2)	N/A	66.77	66.77	N/A
Size of the water cylinder (litre)	N/A	N/A	600	N/A
Water temperature (°C)	N/A	N/A	70 / 55	N/A
Size (kWp or Vacuum Collector area)	2.4 kWp	4 kWp	11 m^2	2.4 kWp
Renewable Heat incentive/ Feed-in-Tariff (£/kWh)	0.178	0.142	0.192	0.178
Efficiency (%)	30	15	30	30
Description of the system	2.4 kW Skystreamer	Mono-crystalline	Vacuum Collector	2.4 kW Skystreamer
Lifespan (years)	20	25	20	20
Investment (£)	14,000	7,080	5,000	14,000
Income/ Savings over life time (£)	17,981	7,683	8,745	17,981
Payback period (years)	16	14	9	16
Annual energy generated (kWh/year)	4,800	3,400	3,050	4,800
Annual Savings in $kgCO_2$ ($kgCO_2$/year)	1,782	1598	1,012.3	1,782

Wind turbine

Name of the Supplier: XZERES Wind Europe Ltd Headquarters. Address: 527miles (From Equipoint- Birmingham to Applecross)

The wind turbine selected was Skystream 2.4, because of its availability in the UK market. It is assumed to be operating at an average wind speed of 5.2m/s at a height of 15m in Applecross. The energy production increases as the wind speed increases. The service life of the turbine is projected to be 16 years.

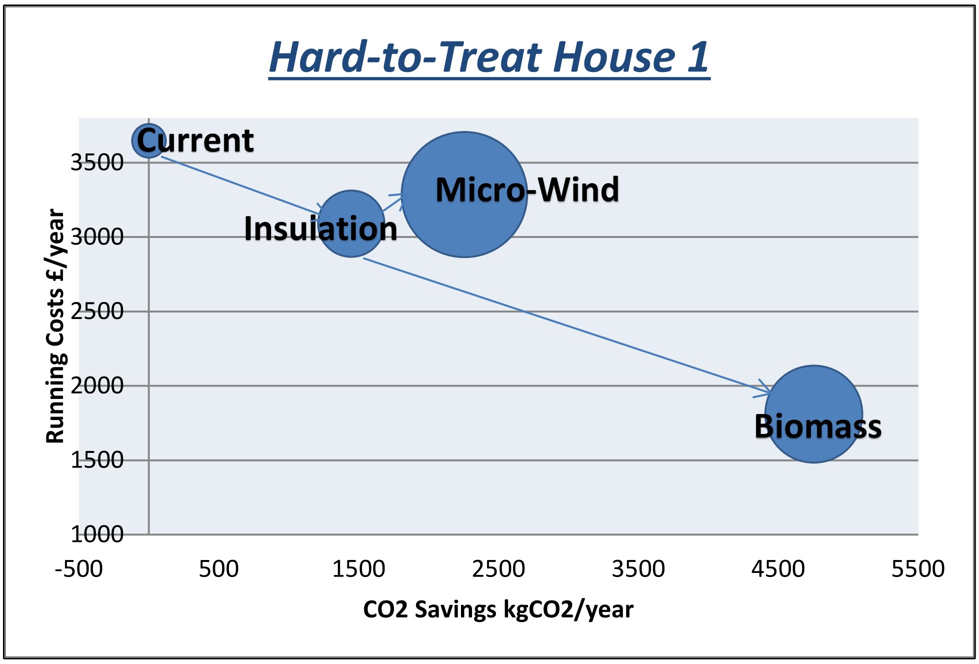
5.4.1.7. DECISION MAKING PROCESS

In order to facilitate the process of decision making and to evaluate the feasibility of proposed alternatives for each of the Hard-to-Treat houses, a bubble diagram was created. In these diagrams, total investments (size of bubble) of the alternatives, annual running costs (y-axis) and annual CO_2 savings (x-axis) are examined. With this kind of comparisons, end-users are able to prioritize their preferences and make an informed decision.

HARD-TO-TREAT HOUSE 1

Current running cost for HtT House 1 is £3,648 annually. Based on the comparison of options presented in Figure 5-5, the lowest investment cost is by improving their insulation however it yields highest running cost and a low CO_2 savings annually. Biomass has the highest potential CO_2 emissions saved yet the investment is quite high. By considering a micro wind turbine, HtT House 1 saves less CO_2 than biomass, still has a higher energy running cost and investment is considerable larger.

FIGURE 5-5: DECISION MAKING PROCESS ON HARD-TO-TREAT HOUSE 1

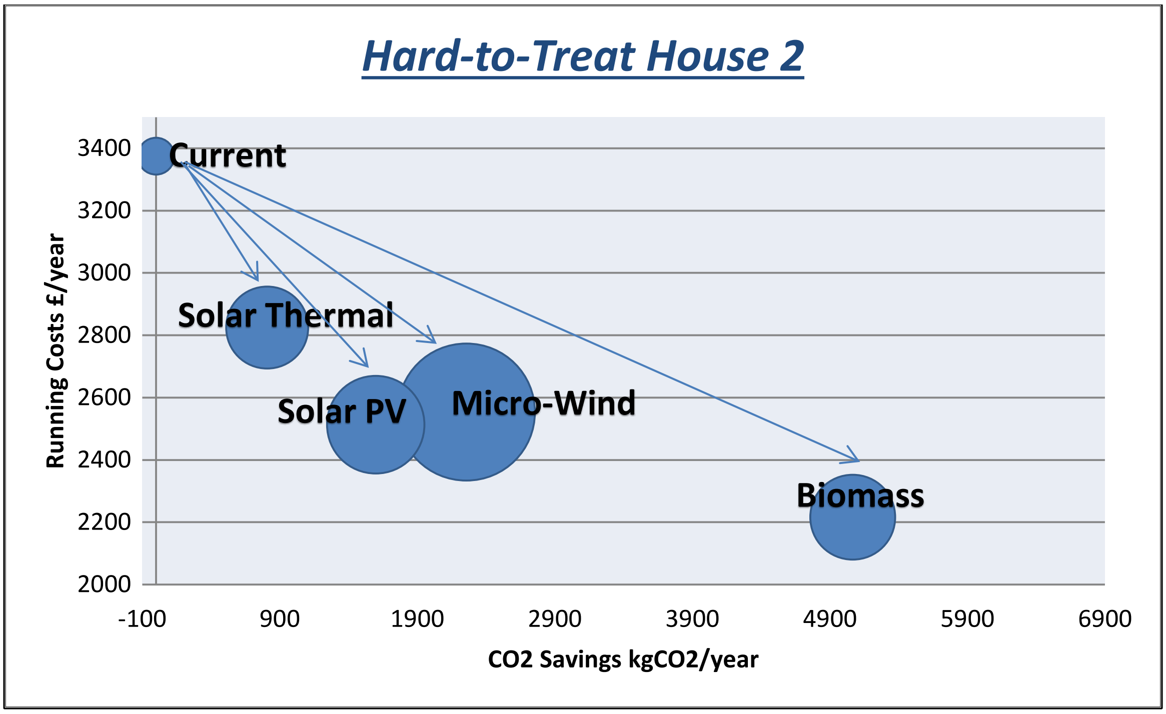


SOURCE: AUTHORS

HARD-TO-TREAT HOUSE 2

HtT House 2 is currently spending £3,375 for energy cost. Referring to Figure 5-6, the least cost alternative is by investing in Solar Thermal however, it also yields the least CO_2 savings. By investing in biomass boiler, HtT House 2 can save the most CO_2 and less running cost annually to run the house.

FIGURE 5-6: DECISION MAKING PROCESS ON HARD-TO-TREAT HOUSE 2

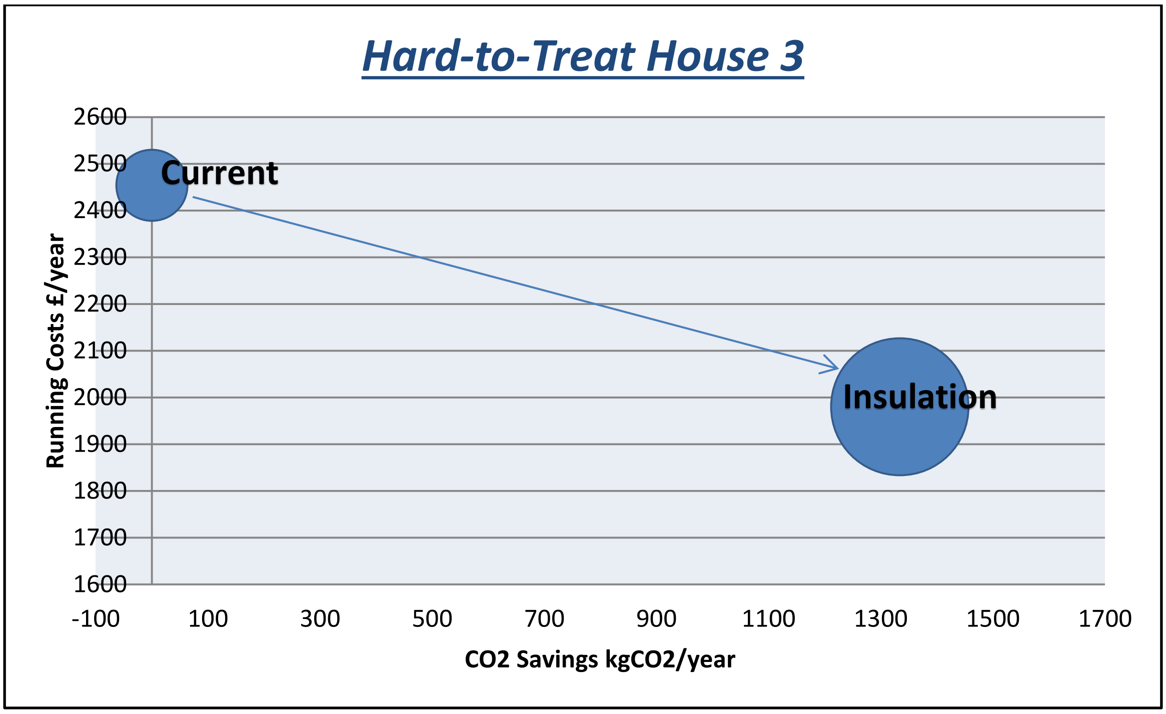


SOURCE: AUTHORS

HARD TO TREAT HOUSE 3

After looking at all the factors in assessing possible alternatives, the only feasible alternative for HtT House 3 is to consider improving the insulation.

FIGURE 5-7: DECISION MAKING PROCESS ON HARD-TO-TREAT HOUSE 3



SOURCE: AUTHORS

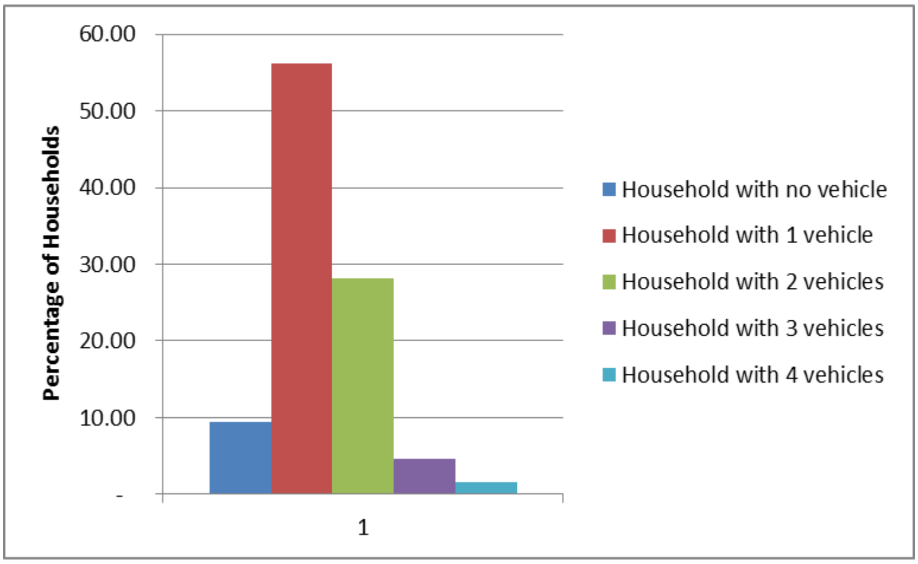
6. TRANSPORT

6.1. CURRENT SITUATION

6.1.1. ACCESS TO TRANSPORT AND VEHICLE OWNERSHIP

The study covered 65 households. Every household has access to transportation in one way or the other. About 90% of the households have access to at least one private fossil fuelled vehicle for their day to day transportation activities. 56.25% of respondents own one vehicle. Those without access to private cars are fewer than 10%. Such households rely on public transportation for their day to day transportation needs. One single household owns four vehicles and that is the maximum number of vehicles owned by any single household in the community. (See Figure 6-1)

FIGURE 6-1 DISTRIBUTION OF VEHICLE OWNERSHIP



SOURCE: AUTHORS

6.1.2. TRANSPORT FUEL DEMAND

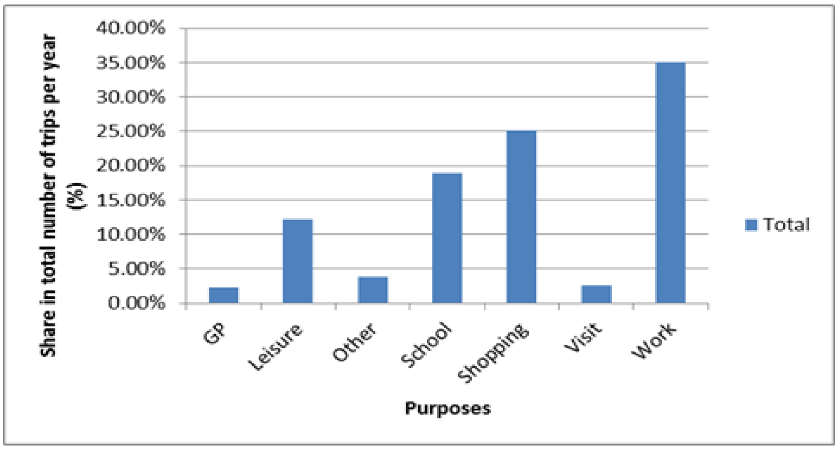
Residents in Applecross rely heavily on private cars for their transportation. The total demand for transport fuel is estimated at 1,688 litres per household. There are two main fuels: petrol and diesel. Diesel accounts for a greater share of demand representing about 80% of total demand with petrol accounting for 20%. The total estimated transport fuel cost per household is £2,421per annum.

6.1.3. DESTINATIONS AND PURPOSES OF TRAVEL

Age distribution of a population has a profound impact on transportation needs. A young and working population tends to require more transportation services. In their study of the impact of demographic change on transport needs, Ballingall & Steel (2004) argued that as population ages, the overall transportation expenditure decreases. The survey conducted indicates that the average age is 56 years. 76% of the respondents fall within the working age bracket of 16-60.

From the data gathered during the study, it is evident that the most important transportation need of many residents in Applecross is for work purposes. It constitutes 35% of all trips undertaken in a year. This is to be expected considering the age distribution of residents in the community. Following in the order of descendency is shopping which constitutes approximately 25% of all trips. The third is school making up approximately 18% of all trips. Details are provided in Figure 6-2.

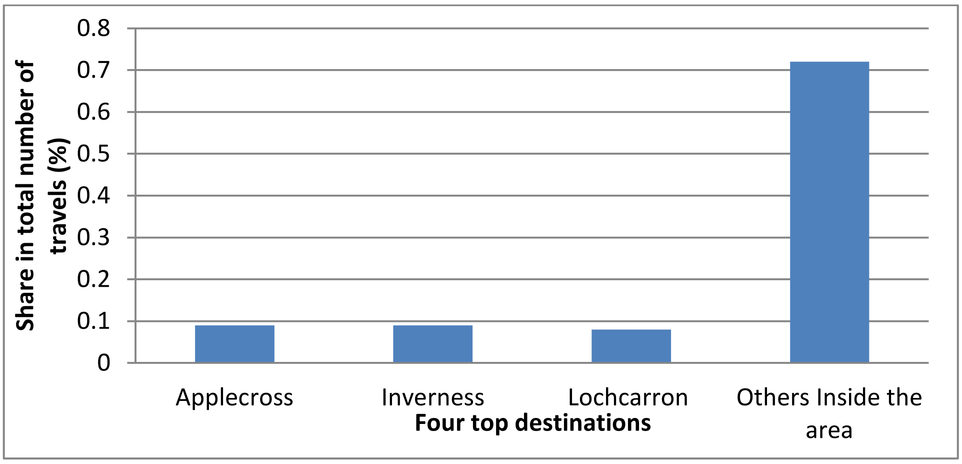
FIGURE 6-2 DISTRIBUTION OF TRAVEL PURPOSES



SOURCE: AUTHORS

Inverness, Lochcarron constitute the top destinations outside the immediate surroundings of Applecross. Another category of destinations is “others inside the area”. These destinations are those to be found more than 5 miles from Applecross Shore Street with Shieldaig and Lochcarron as boundaries. related to work and followed by Within Applecross most trips are shopping.The distribution is illustrated in Figure 6-3.

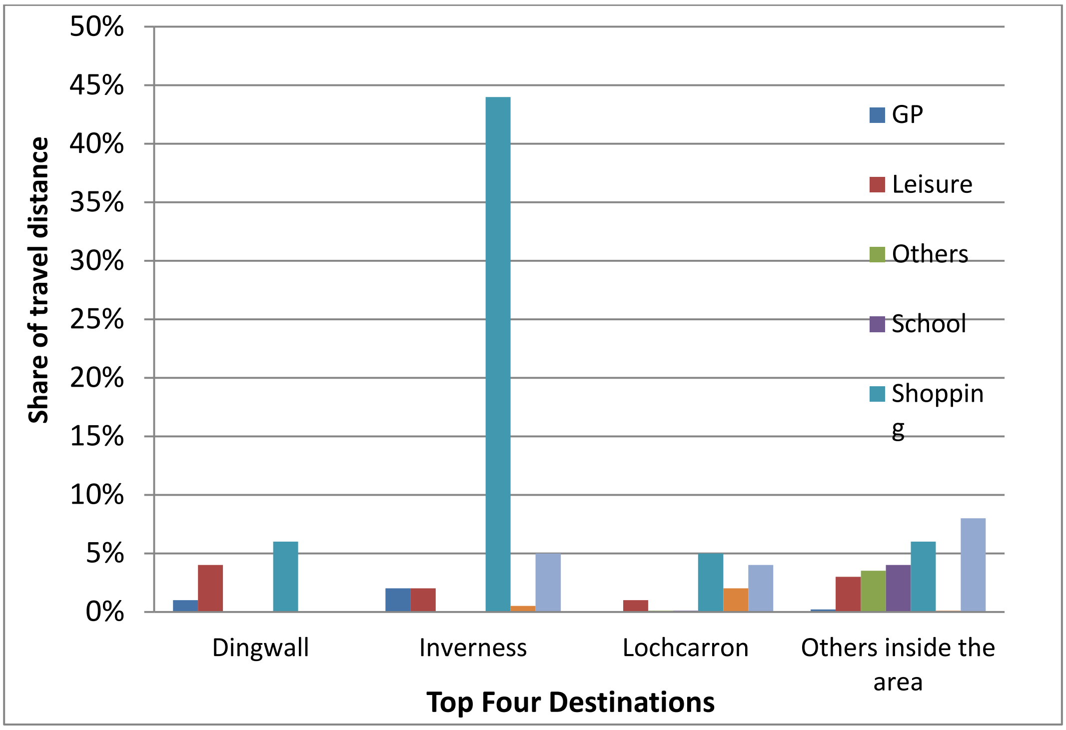
FIGURE 6-3TOP FOUR DESTINATIONS



SOURCE: AUTHORS

According to Figure 6-4 shopping serves as the main purpose for trips to Inverness and Lochcarron. Within Applecross most trips are related to work followed by shopping.

FIGURE 6-4TRAVEL PURPOSES FOR TOP DESTINATIONS



SOURCE: AUTHORS

The findings play a critical role in the decision making towards the further reduction of carbon emission. This phenomenon will have to influence future plans In Applecross.

6.1.4. CARBON EMISSIONS FROM TRANSPORTATION

The average life cycle carbon emissions per litre of petrol and diesel are estimated at 2.328kg and 2.614kg respectively (Biomass Energy Centre). The estimated road private transport CO_2 emission per household is 4,070kg tonnes per year. On the average the CO_2 emissions due to road transportation is estimated at 1,760kgper capita per year.

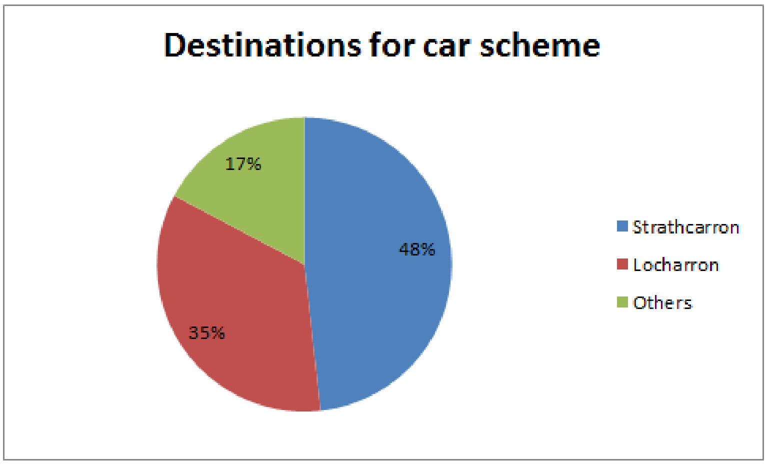
6.1.5. PUBLIC BUS SERVICE

A shuttle bus operated by Lochcarron garage provides services twice a week on Wednesday and Saturday. The bus operates on a demand basis. Commuters would have to book in advance. The journey commences at 07:45 at Toscaig and returns to Applecross at 18:00. Typical journey duration from Applecross to Inverness bus station is 3.6 hours. There is a waiting time of 3.5 hours before the return journey back to Applecross commences. Many residents seldom patronize this bus services. Only about 3% of respondents use the services. Majority of the reasons adduced to their inability to use the services bordered on the time of service. They are unable to meet appointment times due to the departure times of the bus. In addition, the window of opportunity in relation to the waiting time provided in Inverness is too short to do anything meaningful before the bus returns to Applecross. This explains their preference to use their private cars for journeys up to Inverness.

6.2. COMMUNITY CAR SCHEME

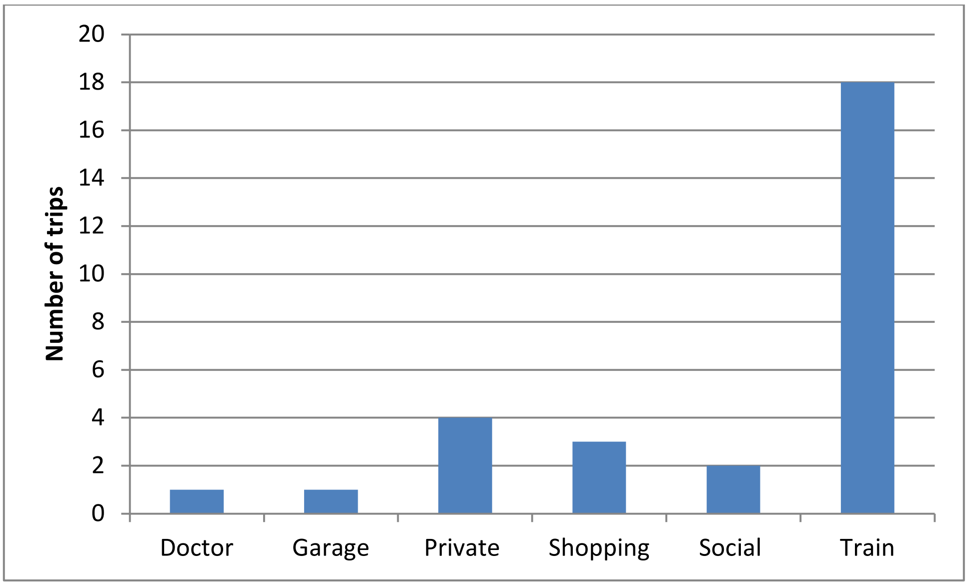
The South West Ross Community Car scheme offers services to residents of Applecross. This service was designed for people who are unable to use public transport for their journey and have no means of private transport. Data obtained from the scheme shows that some residents from the community have used the service in the last year. From our survey 12 persons responded as having used the service in 2013. 29 trips were made from Applecross. The most requested destination for trips outside Applecross was Strathcarron. According to information gathered during an interview with the coordinator of the scheme, most of the trips undertaken by passengers to Strathcarron were made to connect the train for an onward journey. Figure 6-5shows the percentage distribution of destination requests received in 2013. Figure 6-6 andFigure 6-7 shows the number of trips and purposes for journeys involving Applecross.

FIGURE 6-5: SHARE OF DESTINATIONS FOR COMMUNITY CAR SCHEME



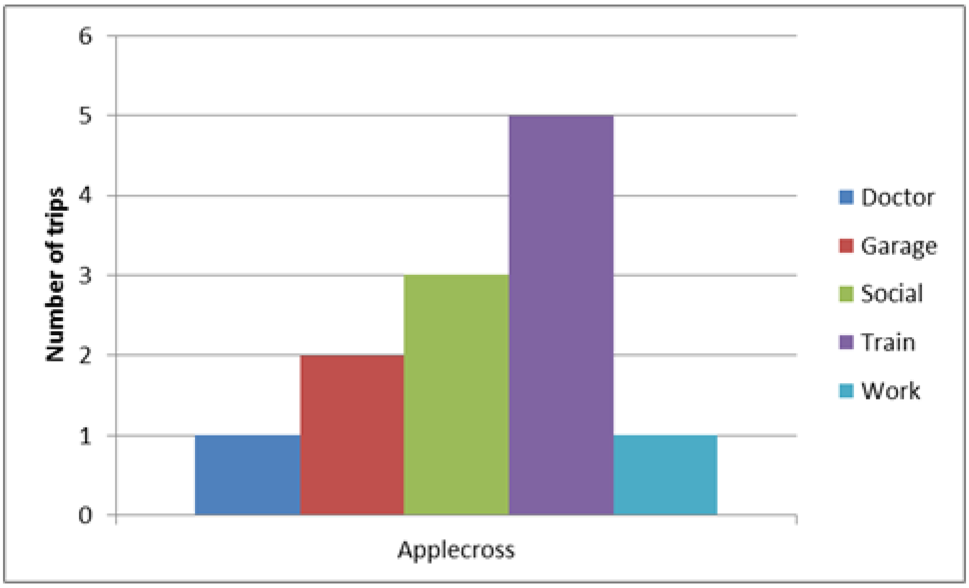
SOURCE: AUTHORS

FIGURE 6-6: NUMBER OF COMMUNITY CAR SCHEME TRIPS FROM APPLECROSS IN 2013



SOURCE: DATA FROM SOUTH WEST ROSS COMMUNITY CAR SCHEME

FIGURE 6-7 NUMBER OF COMMUNITY CAR SCHEME TRIPS TO APPLECROSS IN 2013



SOURCE: DATA FROM SOUTH WEST ROSS COMMUNITY CAR SCHEME

6.3. TRANSPORTATION NEEDS IN APPLECROSS

This section of the report highlights the transportation needs (with focus on private transport) identified as a result of the study. The most frequent need for transportation is shopping. Most respondents prefer to shop from Inverness. This journey covers approximately 80 miles. The average fuel consumption of vehicles surveyed is 40miles per gallon. So a return trip to Inverness in a private car would require 4 gallons (18 litres) of fuel. A diesel car making this journey will emit 47.05kg of CO_2 (life cycle). The fuel costs for the journey is approximately £26. The study found out that every single household makes at least one trip per month to Inverness for shopping. A total of 114 occupied households in the community will therefore spend an annual amount of £35,568. The annual CO_2 emitted for shopping destinations to Inverness is approximately 64,000kg. Hence there is an opportunity to provide alternatives to reduce the annual cost of shopping trips to Inverness by the community.

When asked whether they have used the public shuttle bus before, 97% of respondents answered in the negative. Therefore there is a need to look into how a lot more people could be encouraged to use this service.

The study showed that every household travels on average 9,479 vehicle miles in a year. 35% of all vehicle miles travelled are within a 26 mile radius in Applecross. Therefore there is a need to investigate what options the community could have in the absence of a local public bus service to cover these annual miles in order to reduce both financial and environmental costs.

The next section of the report will analyze some alternatives to address these transportation needs identified.

6.4. ANALYSIS OF TRANSPORTATION ALTERNATIVES

The alternatives in the next few sections are analysed taking into account the findings of the survey. The assessment is done based on potential CO_2 emissions and financial cost implications and overall impact on the quality of life in Applecross.

6.4.1. TRANSPORT ALTERNATIVES FOR SHOPPING

There are limited alternatives for shopping. This study identified two options. The first one is shopping through car sharing. The other is through a shopping delivery service or the expansion of the local shop. Public transport was found not to be a viable option for shopping at least two weeks supply of household consumables.

6.4.1.1. COMMUNITY CAR SHARING

It was evident during the field interviews that residents are willing to share their travel to destinations outside Applecross. Hence there exists a huge potential for a car sharing scheme in the community.

To illustrate the potential benefit, a return journey from Applecross to Inverness in a car with an average fuel consumption of 40miles/gallon will have CO_2 emissions of approximately 42kg.So for every shared trip to Inverness, assuming three other passengers that will otherwise have driven in their own cars would provide a potential CO_2 savings of 126kg. Some cost benefits could also be derived if both drivers and passengers share the cost of the trip at rates less than what they would have actually paid for if they were to travel in their separate cars. Despite the willingness to share trips, the inadequacy of information flow limits the wider adoption of this means of travelling.

6.4.1.2. SHOPPING DELIVERY SERVICE

Results of the study analysis showed that many residents spend the highest amount of time travelling to Inverness to shop. This journey time could be reduced if an effective delivery service is established. The community company could establish a joint venture with the local shop owner for such services. This could lead to a reduction of the time that residents spend to shop.

6.4.1.3. IN-COMMUNITY TRANSPORTATION ALTERNATIVES

The study finding that 35% of all vehicle miles travelled within a 26 mile radius in Applecross provides an opportunity for the consideration of e-mobility. Two already know technologies are worth considering: e-vehicles and e-bikes. The next two sections would look at the possible impacts of these two mobility options in Applecross.

6.4.1.4. ELECTRIC VEHICLES

The potential of hydro power holds a promise for the introduction of electric vehicles in Applecross. Faced with the challenge of exporting power to the grid, e-mobility provides an opportunity for the local use of power. It is in this light of this that a future Applecross with electric vehicles (EV) is envisioned. The study findings show that there is no single household in Applecross with EV. 48% of respondents interviewed during the survey expressed a desire to own an electric vehicle in the future. However the initial investment costs still remain a barrier to the wide adoption of this technology. They further raised concerns about the range of currently available models and in view of that they believe its use for trips to Inverness could pose a challenge.

The financial strength of respondents was not assessed so it is difficult to assess their ability to pay for electric vehicles. However it appeared they may not be aware of financial incentives available from government to own EV. The Scottish government has introduced funding programmes to support the purchase of EV. The policy dubbed “plug-in car grant” aims to provide up to £5,000 for cars and £8,000 for vans as grants to citizen towards the purchase of electric vehicles. The typical cost of an electric vehicle is £25,000. The grants also offers full cost funding for charging infrastructure.

The use of electric vehicles in the community could help reduce the environmental cost of fossil-fueled vehicles. The annual estimated fuel cost per household is £2,420, see above. If all travels within a 26 mile radius in Applecross will be replaced with EV, it will lead to a potential fossil fuel cost savings of £847 per annum per household. Electric vehicles on the other hand create a demand for electricity. Results of our analysis show that the average household in Applecross will require 1,788kWh (assuming a typical EV performance of 35kWh/100mile) of electricity to meet the energy demands of EV. The cost of this demand at current electricity prices is £319. So the net fuel cost savings is £528 per annum per household assuming all other vehicle expenses remains the same for both fossil-fueled vehicles and electric vehicles.

Assuming all the energy required to charge the EV is sourced from hydro, then a net saving of CO_2 emissions of 1.4 tonnes per household could be achieved.

6.4.1.5. ELECTRIC BIKES

The study shows that journeys of less than 13 miles made by car constitute 17% of all trips made in a year in Applecross. This converts to 78 tonnes of CO2 emissions. All of these journeys cost the community approximately £10,472 a year (assuming £1.45 per litre of Diesel and £1.37 per litre of Petrol). Some of these journeys could as well be covered by electric bikes.

Table 6-1 provides a typical household cost saving implications for adopting e-bike for short distance travel within Applecross. The calculations are based on one e-bike per household. Electricity price of £0.1785/kWh was assumed. The payback period comes up to 5 year not accounting for the additional health benefits to be derived.

TABLE 6-1 ECONOMIC COST ANALYSIS FOR TYPICAL E-BIKES

Average saving for fuel per household/year (£)	283
Total electricity used per year (kWh)	165
Cost of electricity per year (£)	29
Cost of bike (£)*	1,259
Interest rate %	5
Payback period (years)	5

SOURCE: (ELECTRIC BIKE STORE, 2014)

6.4.2. COMMUNITY MINI BUS

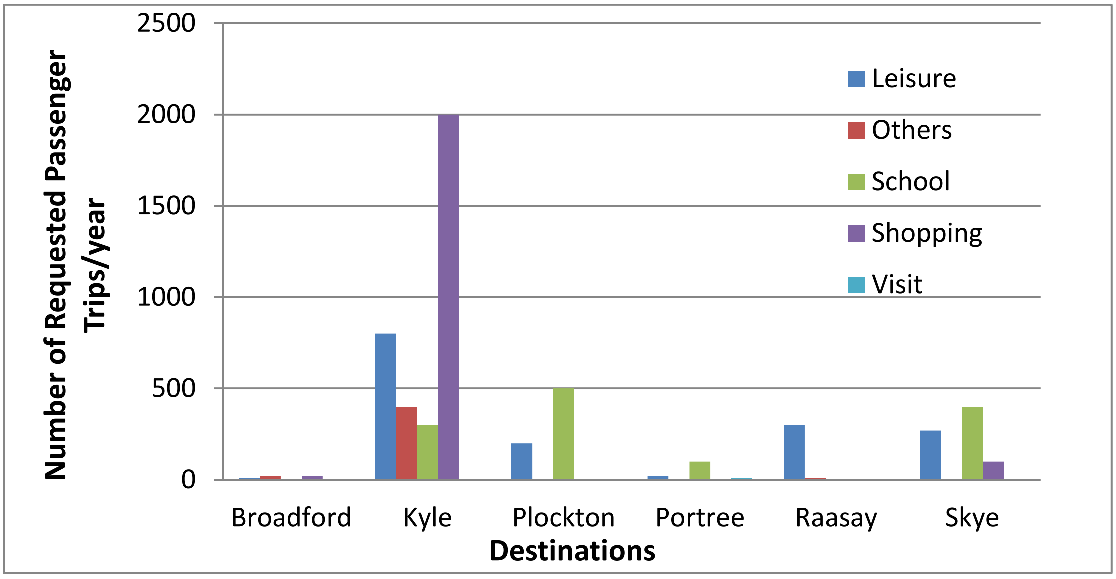
Applecross community owns a community bus. The bus is currently only available for use by the local school that has a section 19 permit. Section 19 of the Transport Act 1985 require certain organisations concerned with education, social welfare or other activities of benefit to communities to be issued with a permit to make a charge without having to comply with the full public service operator requirement. The permit does not require a driver to have a PCV (Category D1 or D) entitlement.

Concerns have been raised by the community to put the bus to use beyond the only usage by the school. However the lack of a section 19 permit makes it difficult. Information gathered from interviews conducted indicates that with the acquisition of the permit the minibus could be available for more uses.

6.4.3. FERRY TRANSPORT

Respondents who took part in the survey showed interest in using a ferry. The three top destinations requested were Kyle, Plockton and Skye in the order of descending number of trips. Shopping recorded the most frequent reason for a ferry trip to Kyle. School was recorded as the most frequent purpose for trips to Plockton and Skye. Figure 6-8 shows all the destinations and the number of trips survey respondents would want to have if they would have to use a ferry connecting Applecross and other communities.

FIGURE 6-8 PREFERRED FERRY DESTINATIONS & PURPOSE



SOURCE: AUTHORS

Looking into the future, an e-ferry is recommended as an alternative to fossil-fuelled ones. Table 6-2 provides an insight into probable costs for a 12 passenger ferry. The energy requirements were based on similar estimates for the world's first electric ferry being built by the Norwegian shipyard Fjellstrand. The cost of electricity is the price prevailing at the time of the study.

TABLE 6-2 ANALYSIS OF E-FERRY

	Diesel Ferry	E-Ferry
Number of trips per week in summer	14	14
Number of trips per week in winter	3	3
Time of travel with return journey (min)	40	40
Speed (knots)	25	25
Passengers capacity	12	12
Net tonnage	11	11
Diesel Consumption (liters/hour)	60	-
Electricity power needed for each two ways trip (kW)	-	176
Annual fuel needed (Diesel liters/Electricity kWh)	16,973	77,792
Annual cost of fuel (Diesel/Electricity)	24,610	13,886
Annual CO2 production (tonnes)	44	-

SOURCES: (CALEDONIAN MARITIME ASSETS LTD, 2010) (NORDIC FOLKCENTER FOR RENEWABLE ENERGY, 2012)

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6.4.4. SUGGESTIONS FOR ECO-FRIENDLY TRANSPORTATION

6.4.4.1. SHORT TERM SUGGESTIONS

Having identified the lack of adequate channel to support the car sharing scheme we hereby suggest the following:

- The introduction of internet based platforms such as webpage and facebook for residents to advertise their trips.
- The introduction of a travel information display board at a convenient location of choice to assist residents who would want to have and share information but do not have access to or are unfamiliar with the use of the internet.
- To support the wide adoption of car sharing we propose a community wide campaign dubbed “Earn through Sharing” to disseminate information about the cost and environmental savings impact of car sharing.
- The community may enter into a partnership agreement with the local shop owner to provide a shopping delivery service.
- It is suggested for the community council to take steps to acquire a section 19 permit for the use of the community minibus. If that is done it could be used for shopping trips to Inverness.

- It is suggested that an awareness campaign be launched to sensitize residents about the “plug-in grant” that exists for purchasing electric vehicles.

6.4.4.2. LONG TERM SUGGESTIONS

- As a long term measure, the community could look into creating an EV leasing scheme due to the capital costs in purchasing such vehicles. The community could look into a leasing agreement with manufacturers to provide leased EV during the tourist season. Such a system may serve as a catalyst to attract more tourists to the community. To demonstrate the potential of electric vehicles the Applecross Community Company could also look into establishing a business partnership with the local wood supplier. The nature of the partnership could be in the form where the Community Company provides an electric van/truck for the wood delivery.
- The community could look into an e-bike sharing scheme in Applecross. It is therefore recommended for an e-bike sharing scheme to be established in the community. In that regard, it is recommended for the Applecross Community Company to be engaged in the e-bike sharing scheme. This scheme in addition to reducing CO_2 emissions of the community will also create demand for any hydro scheme considering the constraints of exporting power to the grid.
- Based on the study findings it is recommended that a ferry route between Applecross and Kyle be investigated further. Leisure and shopping served as the most frequent reasons for such trips. The service could therefore be started with trips during the summer tourist season.
- It is suggested for the community to engage authorities at the Highland Council to find possible ways of using the community bus to transport students of the community to Plockton high school.

7. AN ENERGY VISION FOR APPLECROSS

In this section the previous chapters are brought together into one common goal. This attempts to answer the question “How can we make the Applecross Community Self Sufficient in Energy.” However before looking at how the different parts can be integrated; a definition of what is understood by Energy Self-sufficiency is needed.

Energy sufficiency can be explained as the ability to use local in resources in a sustainable way to produce the energy required for self-need and to generate income. Hereby the economic dependency will be reduced, as less money will leave the community for paying energy bills, and an increasing share of the energy budget will circulate within the community. Self-sufficiency is also the ability to generate ideas, and to carry them out in the community. Information dissemination and education in energy and environment are crucial, from kindergarten and school to the community as a whole. Finally, self-sufficiency can be the common vision needed to push forward the many energy projects, which is hard work and often without immediate reward. The common vision may be an encompassing idea where community members can visualise themselves as active stakeholders in the project, a story that needs to be re-invented and re-told, and the proud manifestation of a strong, rural community, which sees the opportunities of the particular location of Applecross.

Major challenges and opportunities have been identified in making the building mass more energy efficient. Measures to insulate homes have been described and evaluated. In many the cases the improvement of energy performance is technically and economically feasible and desirable for better living conditions as well as lower household costs.

The replacement of the largely oil- and electricity based heating sector with a number of small district heating systems here and there will make use of local resources, improve employment and the environment and may generate income to finance future projects, start-ups and community initiatives. It will make the community less dependent on grants, eventually, and turn the area into a showcase.

Renewable energy sources are feasible on the household and the community scale. Hydropower, biomass, if carefully managed, as well as solar and wind energy solutions may be harvested to feed the sustainable energy system. Along with the hardware, software in the form of knowledge and new forms of organisation are being developed, which so far had to be imported or adopted from elsewhere.

Transport is a challenging subject, but several ways have been described to organise transport better before looking at new technologies in the field of e-mobility, which may comprise good opportunities to replace fossil fuels in transport with renewable energy, while addressing specific transport problems in the community.

This leads to consider that every future decision of the community needs to integrate the three areas of sustainability which are: people, economic development and the environment. The problems of the present can’t be solved with the same mentality that was used to create them. Therefore, perhaps a different approach is needed.

A self-sufficient energy system in Applecross should be one that integrates five main components: stakeholders, technologies, locally available resources, the market and awareness creation - in the community. The following story tries to illustrate a potential future scenario for Applecross, what can be possibly achieved when these five components are integrated.

A letter from an Applecross resident:

Applecross, 19th of March of 2020

"People are flexible and ready toaccept the changes required to reduce their carbon footprint and to cope with them. Also, goals are shared and a common vision towards a sustainable use of energy exists. There is a trust in the technology, stakeholders like Community Energy Scotland, Applecross Trust and members of the Applecross Community Company work together, respect each other and look for the best interests of the community.

Dwellings have become more energy efficient. The community uses energy produced by hydro and biomass for heating in two small district heating systems and for rural communities in Scotland Applecross has become a show case for local electricity supply. The demand for biomass has increased and a new forest management plan includes targets for local fuel wood supply from a sustainable forest plantation. Thefuelwood sector employs 4 people at the moment, one permanent and three part-time workers. To minimize the carbon footprint of the fuelwood an electrical pick-up is employed for its delivery.

Some of the households also have implemented solar and other renewabletechnologies to reduce their energy bill and their carbon footprint. The Applecross Community exports excess electricity to the grid and the members of the community share these benefits as shareholders of the "Applecross Energy Cooperative", an institution created to manage the electricity produced by renewables in the community. This institution also offers loans to householders to improve energy efficiency or to install small renewables in their dwellings and invests the income from renewable energies in the development of the community. The energy systems are maintained by local businesses that offer this service. Opportunitiesfor employment have improved as well as opportunities for affordable housing which has brought young families to Applecross.

The school has become acentre for knowledge and innovation in the community. A small training lab was created and the children, residents and tourists can learn about sustainable technologies and make real time observations and measurements. Applecross holds a yearly conference about energy matters and sustainable community systems, where people from different areas of Scotland come to learn about this energy self-sufficient community.

The food store has become one of the employers of the community and a delivery service is offered for the community. Many food supplies are found locally, and in consequence people now go fewer times to Inverness, Lochcarron and Dingwall to shop for food. Also, the public transport is more frequent and now the first train in the morning that departs from Lochcarron to Dingwall can be reached by public transport three times a week: on Monday, on Wednesday and on Friday.

Applecross has been selected as a test site for a new high-speed electrical ferry that is supposed to connect Applecross and that is currently under development. It will replace the speed boat that currently connects Applecross with Plockton, Kyle and Skye on Tuesday, Thursday and the weekend.

Also, thanks to the support of the Scottish Government the Applecross Community Car Scheme now has two electric cars that are being used for the community for different deliveries or being rented out to tourists.Many of the tourists now come by the improved public transport and hire a bicycle, an electric bike or one of the electric cars to visit the new tourist attraction, such as the Ice Cream productionpowered by Wind and the Solar Coffee shop."

The research team thanks the Applecross community for their hospitality during these 5 weeks of study. We hope we meet your expectations.

Yours sincerely,

International Class 2014
Master of Energy and Environment Management
University of Flensburg

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9. ANNEXES

ANNEX A SURVEY QUESTIONNAIRE

Assessment of the current energy situation of Applecross

Students and Staff of the Energy and Environmental Management Master programme at the University of Flensburg, Germany, in cooperation with the Applecross Community Company are conducting a field research to explore sustainable energy development options in Applecross. The research requires the collection of information from community members and field surveys. We kindly ask you to help us by completing this questionnaire. Your answers and feedback will provide us baseline information to assess your current energy situation. Later on we will use this information to suggest cost-effective measures for a greener Applecross.

This survey is divided in three sections: energy efficiency, access to renewable energy and current transport situation. A part of the information on your building will be kept in a database of the Community Company, but only if you agree to it at the end of this questionnaire, otherwise your answers will be treated in way that it cannot be linked to personal data. All questionnaires will be destroyed at the end of our stay in Applecross.

If you have any questions about the questionnaire, please contact our team leader at alejandraclaure@gmail.com or call in the evenings at 0152-744-372.

Personal Information:

1. Contact Name: ____
2. Address/Property name: ____
3. Phone: ____
4. Postcode: ____
5. Age: _______________________
6. E-mail: _________________________________-

SECTION 1: ENERGY EFFICIENCY QUESTIONNAIRE

General

7. Type of dwelling:

   __ Detached[1]

   __ Semi-detached[2]

   __ Mid-terraced[3]

   __End-terraced[4]

   __ Flat[5]

   __ Other (Please specify: ____________________________)

8. Do you own this house? __ Yes [1] ___ No [2]

9. Year of construction: _______

10. Do you have an attic? ___ Yes[1] ___ No[2]

11. Is it **being used**[25]? ___ Yes [1] (specify usage:________) ___ No [2]

12. How many open fireplaces with chimneys do you have: _____

13. Size of the dwelling

    13.1. Number of rooms: ___ (including hall, stairs, landing as one room, kitchen, bathrooms etc.)

    13.2. Ground floor area:_____m² or ft² (please circle appropriate unit)

    13.3. Number of storeys:____

14. What is the use of this building:

    ____Business/commercial/public[3] (Proceed to question 15)

    ____Business and residence[4] (Proceed to question 16)

    ____ Holiday house[1] (Proceed to question 18)

    ____ Second home

    ____ Permanent residential[2] (Proceed to question 19)

15. If Business/commercial/public, please specify:

____ Shop[1]

____ Hotel[2]

____ School and Nursery[4]

____ Church[5]

____ Pub[6]

____ Restaurant[7]

---

[25] Means that is a use area for staying, for a room, for a guestroom

____others

(specify ________)

16. If business and residence please specify:

___ Shop^{1} (Proceed to question 19)

___ Office^{2} (Proceed to question 19)

___ Bed and Breakfast^{3} (Proceed to question 19)

___ Others(e.g. fish-storage, farm stock, etc.)_____________ (Proceed to question 19)

17. Number of bednights per season (bed and breakfast, hotel):

17.1. ____ Off season

17.2. ____ Tourist Season

18. Number of weeks per season (holiday houses):

18.1. ____ Off season

18.2. ____ Tourist Season

19. Number of full time residents:

19.1. ___Adults (above 16 years old)

19.2. ___Children (from 0-16 years old) (including hostel residents)

20.What type of electricity meter do you have?

____Single^{1} ____Dual ^{2} ___ Don't know ^{3}

21.What is your annual electricity consumption?

	£/year	kWh electricity
Standard Meter	21.1.	21.2.
White Meter (if applicable)	21.3.	21.4.

22. Would you say you spend above 10% of your income to pay for energy on average? (excluding transport)

___ Yes ^{1} ___ No ^{2} ___ I don't know^{3}

23. Have you carried out any energy efficiency measures in the past?

(insulation, windows' replacement, new heating system, etc.)

__ Yes[1] __ No[2] ___ Don't know[3]

23.1. What kind?___________________________________

24. Does your property have an Energy Performance Certificate (EPC/EER)?

__ Yes [1] __ No [2] ___ I don't know[3]

25. Has there been any energy audit conducted before? __ Yes [1] __ No [2]

If you answered "NO" go to question 27.

26. Can you please provide us a copy of the report?

__ Yes [1] __ No [2]

27. During our visit to Applecross, a limited amount of households will be chosen to perform a detailed energy audit in order to assess energy consumption and suggest energy efficiency measures. If no energy audit has been conducted yet, are you interested in a detailed energy audit carried by our group?

__ Yes [1] __ No [2]

Energy Use Information

28. What is the main fuel you use for cooking?

__ Bottled LPG [1]

___ Bulk LPG[2]

___ Oil [3]

__ Wood [4]

__ Electricity [5]

__ Coal [6]

__ Others Please specify:__________

29. Aside from the standard **high energy consuming appliances**(Fridge, Electrical oven, washing machine, clothes dryer and dish washer), do you have any additional high energy consuming appliances?

__ Yes [1] __ No [2]

If yes, please specify ____

30. How many of your lights are:

30.1 LED

30.2 Incandescent

30.3 Energy Saving Lights

30.4 Halogen

30.5 Others (specify)

Space Heating Information

31 Is your loft insulated?

__ Yes [1] __ No [2] __ Unknown [3]

32 If yes what is the depth of the insulation? (the recommended is 270mm)

___ 12 mm (1/2")[1]	___ 100 mm (4")[5]	___ 300 mm + (12"+)[9]
___ 25 mm (1")[2]	____ 150 mm (6")[6]	___ Don't know
___50 mm (2")[3]	____ 200 mm (8")[7]	
___ 75 mm (3")[4]	___ 250 mm (10")[8]	

33 What is your main wall type?

___ Cavity as built[1](go to question 34)

___ Stone without insulation[3] (go to question 35)

___ Stone insulated[4] (go to question 35) (kingspan)

___ Timber framed[5] (go to question 35)

___ Dorran[6] (go to question 35) (prefabricated construction elements)

34 Is this cavity insulated?

___ Yes [1] ___ No [2]

34.1 Material: _______________________

35 Does your property have double or triple glazing?

___ None ^{1} (go to question 37)

___ Double glazed, more than 15 years old ^{2}

___ Double glazed, less than 15 years old ^{3}

___ Triple glazed^{4}

36 How much of your property has double or triple glazing?

___ None^{1}

___ up to 25%^{2}

___ 26%- 50%^{3}

___ 51%-75%^{4}

___ 76%- 100%^{5}

37 What is your main roof type?

___ Pitched roof with no access to loft^{1}

___ Pitched roof with no insulation^{2}

___ Pitched roof insulated along the slope of the roof^{3}

___ Pitched roof with unknown insulation^{4}

___ Flat roof with no insulation added since it was built^{5}

___ Flat roof with additional insulation added^{6}

___ Others. Please specify:_______________________________

Heating Information

38 What is the fuel type used for space heating?

___ Oil ^{1}

___ Wood/Biomass ^{2}

___ Electricity ^{3}

___ House Coal ^{4}

____ Bulk LPG ^{5}

_____ Bottled gas ^{6}

_____ Anthracite eggs ^{7}

_____ Peat ^{8}

39 If the fuel is not electricity, how much fuel do you use annually for space heating and cooking?

39.1 LPG____ Kg

39.2 LPG____ small cylinder

39.3 LPG____ large cylinder

39.4 Oil__________ Litre

39.5 Biomass/Wood __________ ton/kg/m^3/______

___ Others (please specify______________________)

40 What is the main type of heating system? (only one answer possible)

___ Boiler with radiators [1] (go to question 41)

___Boiler with underfloor heating [2](go to question 41)

___ Storage heaters [3](go to question 44)

___ Air source heat pump [4](go to question 48)

___ Ground source heat pump with radiators [5] (go to question 48)

___ Ground source heat pump with underfloor heating [6] (go to question 48)

___ Rayburn or similar [7] (go to question 48)

___ Room heaters [8](go to question 48)

___ Open fire [9]

___ Open fire with radiators [10]

___ Wood burning stove [11]

___ Wood burning stove with radiators [12]

___ *No clear distinction between main and secondary heating system. Please select any of your heating system.*

If your main heating system is a boiler

41 What type of boiler do you have? (more than one answer possible)

____ Normal (with hot water cylinder) [1]

____ Combination boiler (no cylinder) [2]

____ Condensing boiler (with hot water cylinder) [3]

____ Condensing combination boiler (no cylinder) [4]

____ Back boiler (behind the fire place) [5]

____ Rayburn or similar [6]

42 What is the age of your boiler? ______ years

43 What heating controls do you have?

___ None[1]

___ Room thermostat only [2]

___ Programmer and room thermostat [3]

___ Programmer, TRVs (TRV = control on the radiator) [4]

___ Programmer and at least two thermostats [5]

(go to question 49)

If your main heating system is storage heaters

44 What type of heater does your property have?

___ Old (large volume heaters) [1]

___ Modern (slim line heaters) [2]

___ Integrated storage/ direct acting heating [3]

___ Fan assisted storage heaters [4]

45 How are they controlled?

___ Manual charge controls [1] ____ Automatic charge controls [2]

(go to question 49)

If your main heating system is room heaters

46 What type of heater does your property have?

___ Oil room heater [1]

___ Open fire with solid fuel [2]

___ Electric heaters [3]

47 How are they controlled?

___ No thermostatic control of room temperature [1]

___ Appliance thermostat [2]

___ Programmer and appliance thermostat [3]

(go to question 49)

If your main heating system is heat pump/warm air

48 What heating controls do you have?

___ None ^{1}

___ Room thermostat only ^{2}

___ Programmer and room thermostat ^{3}

___ Programmer only (heat pumps only) ^{4}

___ Programmer, TRVs and Bypass (Heat pumps only) ^{5}

For all heating types

49 What secondary heating system do you have?

___ No secondary heating^{1}(Go to question 51)

___ Oil room heater ^{2}

___ Wood burning stove ^{3}

___ Open fire with solid fuel ^{4}

___ Electric heaters ^{5}

___ Others, please specify ____________________________

50 What is your secondary heating fuel?

___ Oil ^{1}

___ Wood/Biomass ^{2}

___ Electricity ^{3}

___ House Coal ^{4}

____ Bulk LPG ^{5}

_____ Smokeless fuel ^{6}

_____ Bottled gas ^{7}

_____ Anthracite ^{8}

51 How is your hot water usually heated?

___ From the main heating system ^{1}

___ Electric immersion heaters ^{2}

___ Instant electric water heater ^{3}

___ From the secondary heating system ^{4}

___ Others. Please specify: ________________________

51.1 If your water heating systems includes a boiler. What is the age of the boiler? _______

52 What size is your hot water cylinder?

___ No cylinder [1] (go to question 55)

___ Don’t know/ No access to cylinder [2]

___ Normal (up to 90 cm/ 36” tall) [3]

___ Medium (Between 90/36” and 135 cm/54” tall) [4]

___ Large (Over 135 cm/54” tall) [5]

53 What hot water cylinder insulation do you have?

___ None [1]

___ Thin jacket – up to 100 mm or 4” [2]

___ Thick jacket – over 100 mm or 4” [3]

___ Thin spray foam – up to 38 mm or 1.5” [4]

___ Thick spray foam – over 38 mm or 1.5” [5]

54 Is there a thermostat on the hot water cylinder?

____ Yes [1] ___ No [2]

55 If the fuel is not electricity, how much fuel do you use annually for water heating?

55.1 Oil_________ Liters

55.2 Biomass/Wood _________ ton/kg/m3/______

55.3 Coal _______ kg

55.4 LPG________ m^3

55.5 ___ I don’t know as my water heating system is integrated in the space heating system

SECTION 2: ASSESSMENT OF RENEWABLE ENERGY

56 Solar Thermal systems

56.1 Do you have a solar thermal system installed in your house?

___Yes [1] (Proceed to question 61)

____No [2]

56.2 Are you interested in installing a Solar Thermal System?

___Yes [1]

____No [2]

56.3 Reason: _________________________________

57 Do you have a solar photovoltaic panel installed in your house?

___Yes [1]

____No [2]

57.1 If you have solar photovoltaic panels, what percentage of your roof is covered with panels? ______ %

58 Are you interested in installing a solar photovoltaic panel?

___Yes [1]

____No [2]

58.1 Reason:_________________________________

59 Do you have a micro wind turbine installed in your house?

___Yes [1]

____No [2]

60 Are you interested in installing a Micro wind turbine?

___Yes [1]

____No [2]

60.1 Reason: ________________________________

SECTION 3: TRANSPORTATION QUESTIONNAIRE

61 Please complete the table below indicating the means of transport you own.

Please use one row for each vehicle you own

Type of vehicle *Car(1), truck(2), bicycles (3), motorbikes(4), boat(5)*	**Type of fuel**	**Fuel Consumption (Miles/litre) (Miles/gallon)**	**Miles/year travelled**	**Age (years)**
61.1	67.1.1	67.1.2	67.1.3	67.1.4
61.2	67.2.1	67.2.2	67.2.3	67.2.4
61.3	67.3.1	67.3.2	67.3.3	67.3.4
61.4	67.4.1	67.4.2	67.4.3	67.4.4
61.5	67.5.1	67.5.2	67.5.3	67.5.4

62 If you do not own a bike, would you like to own one? ____Yes 1 ____No 2 ___N/A 3

63 Please complete the table below indicating your primary means of transport when accessing your 5 most common destinations.

(For "means of transport" please use the types of vehicles you provided above)

Destination	**Purpose** work1; shopping2, school3, GP (doctor)4, leisure5, Others: please indicate	**Distance** (miles)	**Means of Transport** Car (1), truck (2), bicycles (3), motorbikes (4), boat (5), public bus6, train7	**Number of trips per month**	**Preferred Weekday of travel**(only for non routine travels) Monday 1, Tuesday2, Wednesday3, Thursday4, Friday5, Saturday6, Sunday7
63.1	67.1.1	67.1.2	67.1.3	67.1.4	67.1.5
63.2	67.2.1	67.2.2	67.2.3	67.2.4	67.2.5
63.3	67.3.1	67.3.2	67.3.3	67.3.4	67.3.5
63.4	67.4.1	67.4.2	67.4.3	67.4.4	67.4.5

63.5	67.5.1	67.5.2	67.5.3	67.5.4	67.5.5

64 What amount of your annual income is spent on private and public transportation?

64.1 Private Transportation ______ £/year

64.2 Public Transportation_____ £/year

65 What is your perception about the cost of public transportation in Applecross?

__Very expensive [1]

___Expensive [2]

__ Moderate [3]

___ Cheap [4]

____Very cheap [5]

____ N/A[6] (free)

66 Are you satisfied with the frequency of public bus services linking Applecross and other towns?

___Yes [1] ____No [2],

66.1 If you answered “no” please briefly describe why

____

67 If you answered ‘No’ to question 66, please specify which destination and frequency you suggest the bus service in the week?

Destination (Round trip)	Mo.	Tue.	Wed.	Thu.	Fr.	Sa.	Su.
67.1	67.1.1	67.1.2	67.1.3	67.1.4	67.1.5	67.1.6	67.1.7
67.2	67.2.1	67.2.2	67.2.3	67.2.4	67.2.5	67.2.6	67.2.7
67.3	67.3.1	67.3.2	67.3.3	67.3.4	67.3.5	67.3.6	67.3.7
67.4	67.4.1	67.4.2	67.4.3	67.4.4	67.4.5	67.4.6	67.4.7
67.5	67.5.1	67.5.2	67.5.3	67.5.4	67.5.5	67.5.6	67.5.7

68 Are there any suggestions you have regarding improvements in public transportation system of the community?

____

69 Please let us know your degree of agreement or disagreement to the following statements where 1 means that you strongly agree and 4 means that you strongly disagree:

		I strongly agree (1)	**I agree** (2)	**I disagree** (3)	**I strongly disagree** (4)	Comments
69.5	The roads in Applecross are in good condition					
69.6	There is enough infrastructure to support cycling					
69.7	I am interested to purchase an electric car in the future					
69.8	Public transportation is important for my daily activities					

70 If you believe there are not suitable conditions for cycling please describe what is missing:

____

____

71 Are you aware of the community car scheme in Applecross? (volunteers driving passengers in their own cars)

___Yes 1 ____No 2 (If no proceed to 75)

72 How many times do you use the scheme in a year? _____

73 If you have ever used the scheme, were you satisfied?

___Yes 1 ____No 2

74 If you answer “No” to question 73, please describe briefly what problems you have with the scheme.

____

____

75 If you had the option to travel by passenger ferry from Applecross what would be your top destinations (in terms of priority), frequency and the reason of your travel:

Destination	**Frequency (times a week)**	**Purpose of traveling May be the day is more important than the purpose**
75.5	75.5.1	75.5.2
75.6	75.6.1	75.6.2
75.7	75.7.1	75.7.2
75.8	75.8.1	75.8.2
75.9	75.9.1	75.9.2

76 *To assess the potential for domestic renewables in Applecross we need some information on roof sizes, inclination, compass direction etc. of the buildings in Applecross. Do you allow us to take some measurement of your building from outside?*

___Yes[1] *___No*[2]

Do you agree that this information can be passed on to Applecross Energy Efficiency (AEE) to fill out a home energy check form?

AEE will let you see this form before sending it to the Energy Saving Trust. This will encourage the Energy Saving Trust to focus more on Applecross energy needs.

Place, date signature of respondent

Additional Information

77 Date of birth of eldest householder ___DD/___MM/___YY

78 Is a member of your household in receipt of benefits?

____ Yes [1] ___ No [2]

How else can I save energy?

79 Would you like to reduce your car fuel costs?

____ Yes [1] ___ No [2]

80 Would you be interested in advice on using the car less or using sustainable transport to save money and energy?

____ Yes [1] ___ No [2]

81 Are you interested in any of the following technologies to generate your own energy and income?

___ General information[1]

___ Solar electricity[2]

___ Heat Pumps[3]

___ Wind[4]

___ Hydro power[5]

___ Solar hot water heating[6]

___ Feed in Tariffs/ renewable heat incentive[7]

82 Reducing hot water use in your home could save you money. Would you like to know more?

____ Yes [1] ___ No [2]

83 Would you be interested in advice or information on any of the following?

___ Recycling[1]

___ Home composting[2]

___ Reducing food waste[3]

___ Maximising income[4]

___ Fuel cost reduction[5]

___ Interest free energy loans[6]

84 Good time to call?

___ Daytime[1] ___ Evening[2]

85 Preferred method of contact?

___ Telephone[1]

___ Email[2]

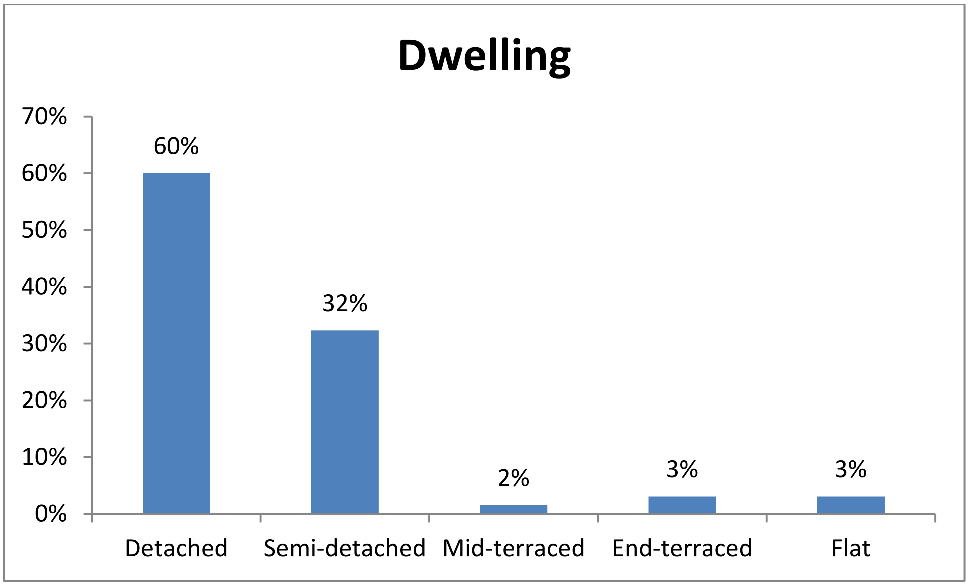
___ Post[3]

___ Any[4]

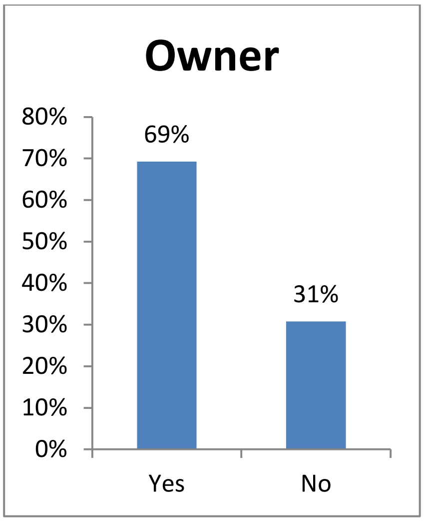
ANNEX B SURVEY RESULTS

6. Age of respondent
    a. Average: 56
    b. Median: 58
    c. Mode: 46
    d. Min: 21
    e. Max: 88

7. Type of dwelling

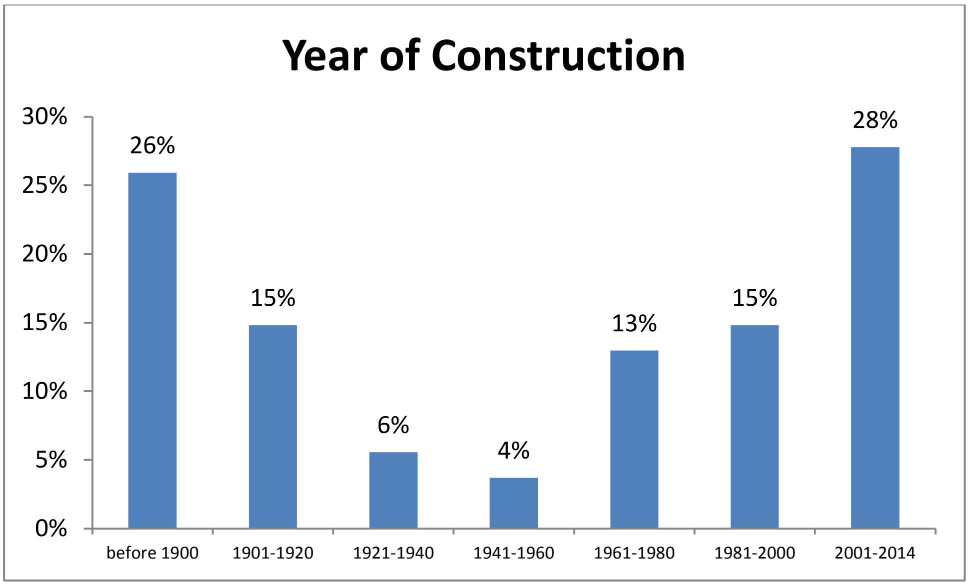


8. Own the house

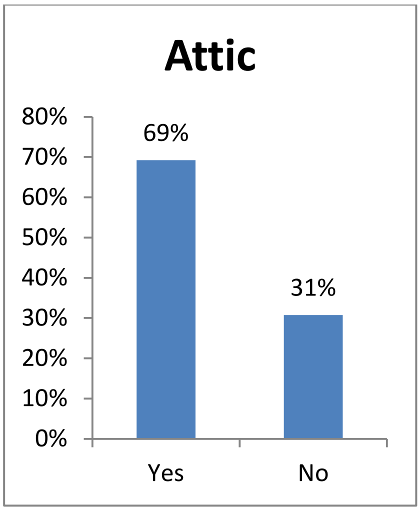


9. Year of Construction

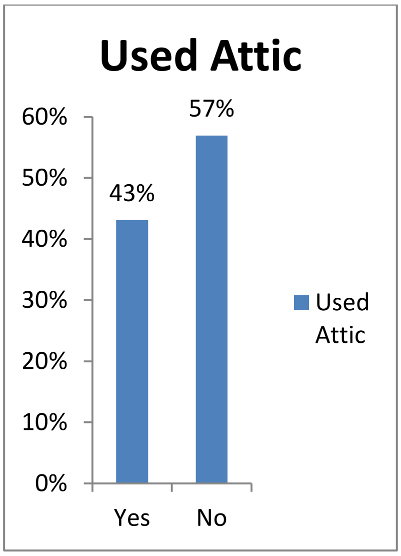
From 65 respondents, 54 answered this questions, 11 indicated that they didn’t know the year of construction



10. Have an attic

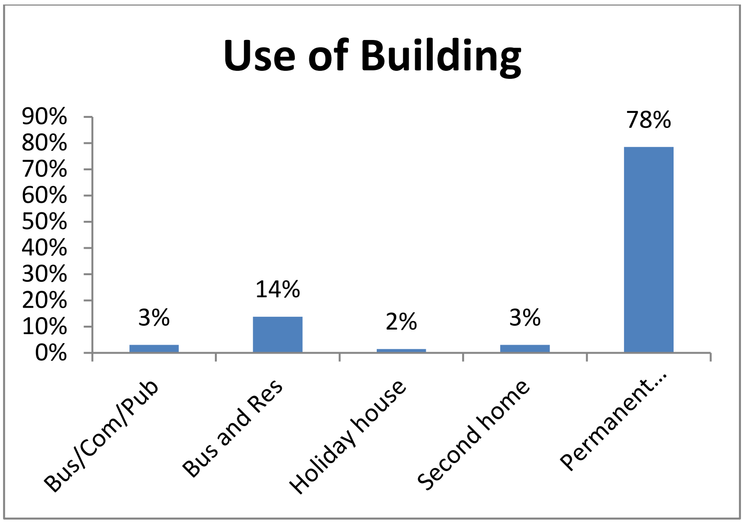


11. Use attic

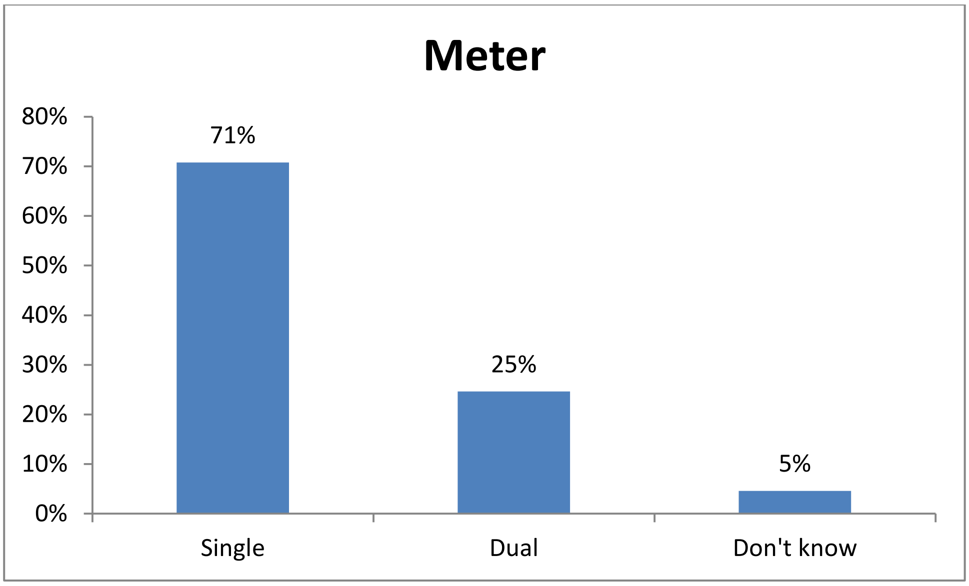


12. Average fireplaces: 1

13. Size
    a. Average of rooms: 8
    b. Average size of dwelling: 115 m^2
    c. Average storeys: 2
14. Use of building



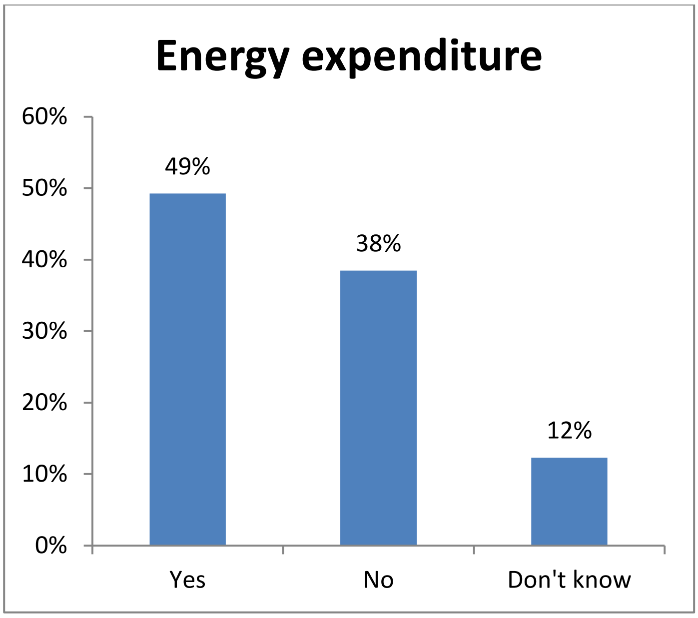
15. From business/commercial/public : 1 shop, 1 hotel, 1 ice cream factory
16. From business/residence: 3 bed and breakfast, 2 offices, 1 shop
17. Total bednights:
    a. Off-season: 27
    b. On-season: 144
18. Week per season (holiday houses): 1 week
19. Full time residents
    a. Average adults: 1.8 = 2
    b. Average children: 0.3
20. Type of electricity meter



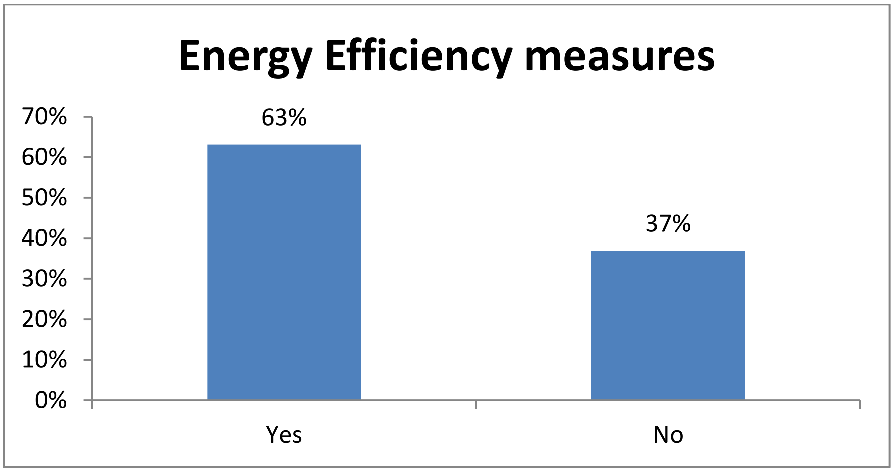
21. Electricity consumption

	£/year	kWh/year
Standard meter (54 respondents)	Average: 1185 Median: 775 Mode: 600 Min: 232 Max: 10,108	Average: 5253 Median: 3693 Min: 785 Max: 15084
White meter (2 respondents)	Average: 786 Median: 786 Min: 400 Max: 1172	Average: 2893 Median: 1510 Min: 400 Max: 6772

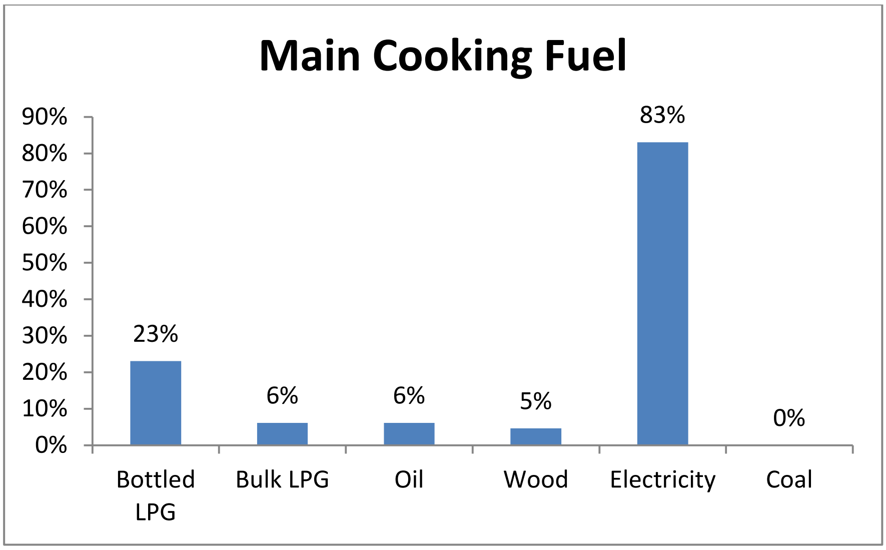
22. Fuel Poverty



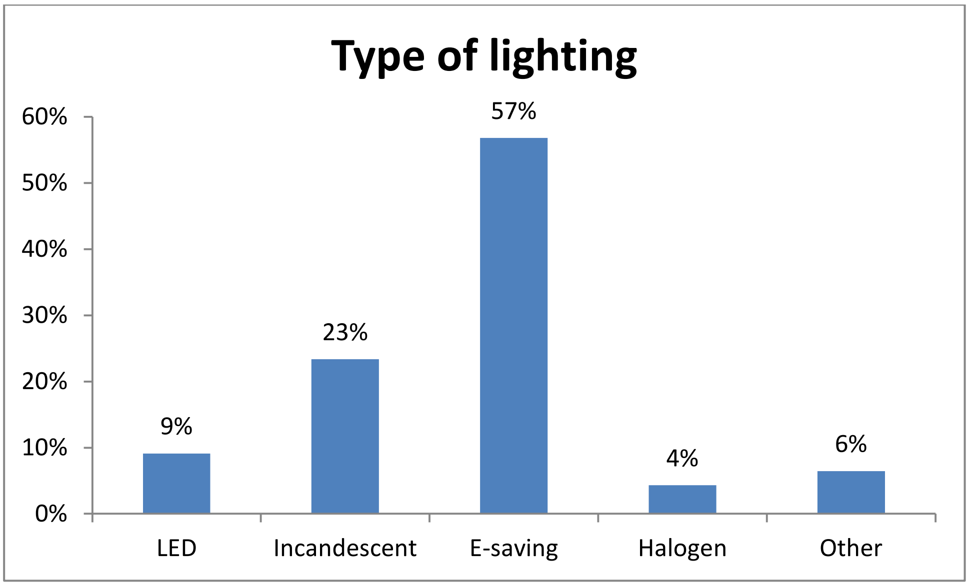
23. Carried energy efficiency in the past



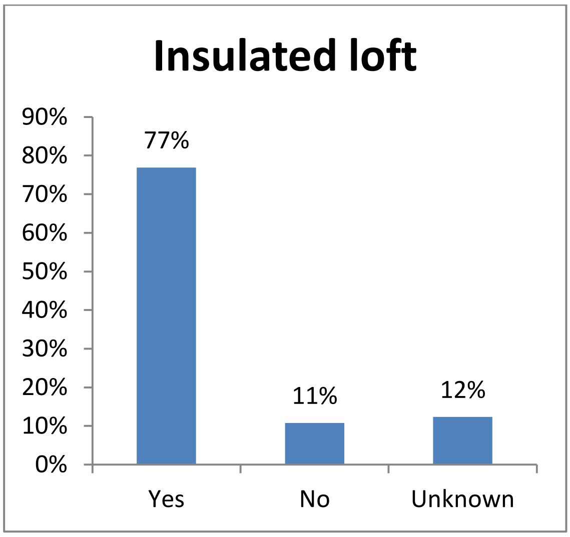
24. Energy performance certificate: 12% of households interviewed
25. Energy audit conducted before: 18%
26. Access to report: 2%
27. Interested in EE group energy audit: 75%
28. Main fuel for cooking



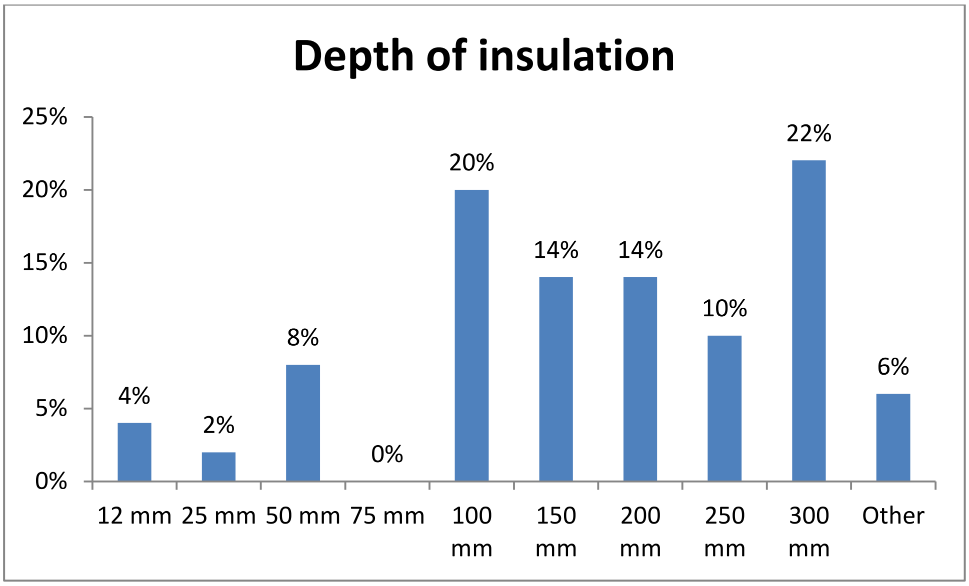
29. Other high consuming appliances: 43%
30. Type of lighting



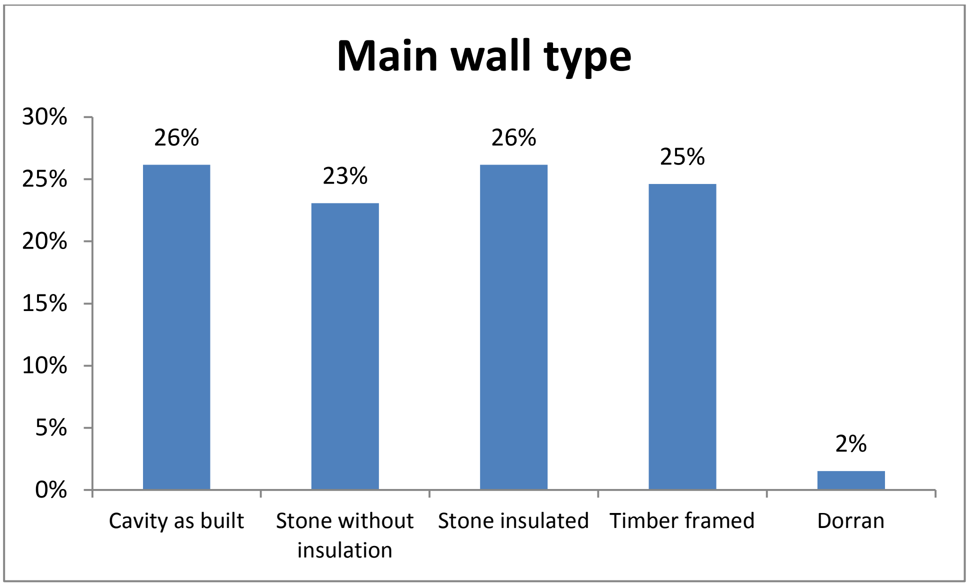
31. Is your loft insulated



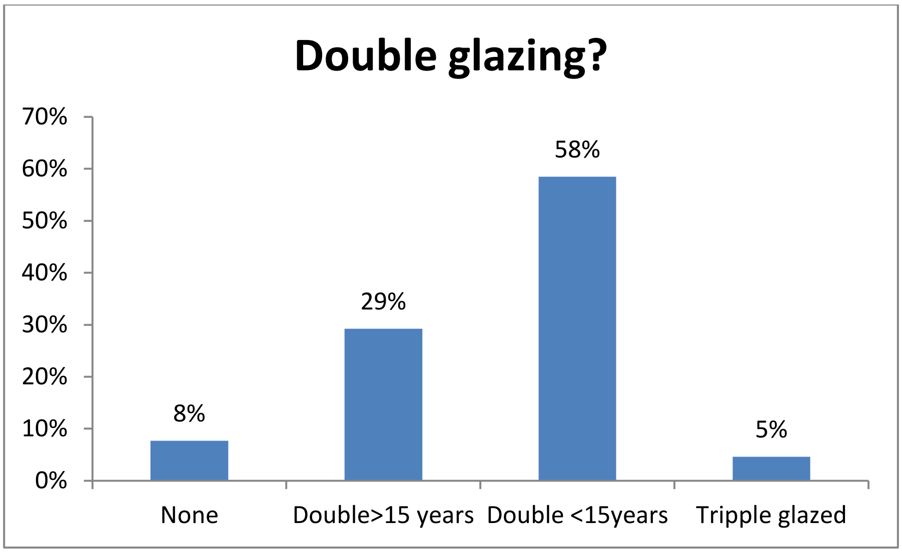
32. Type of insulation



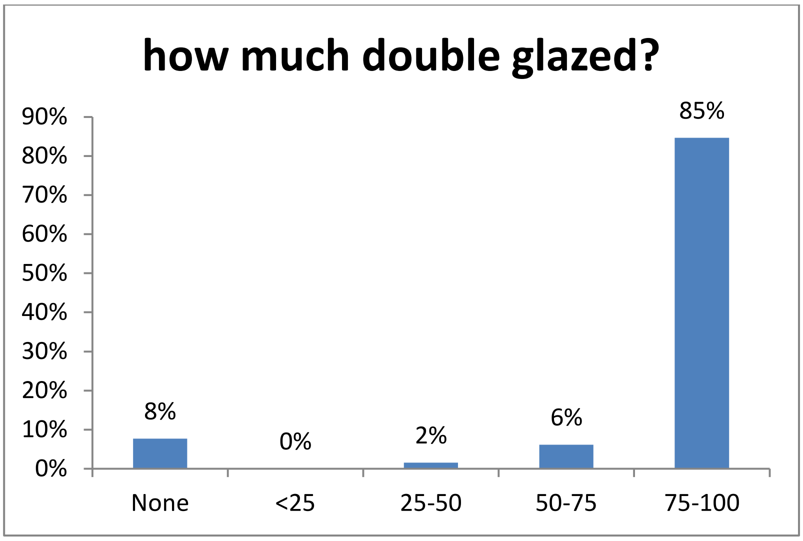
33. Wall type



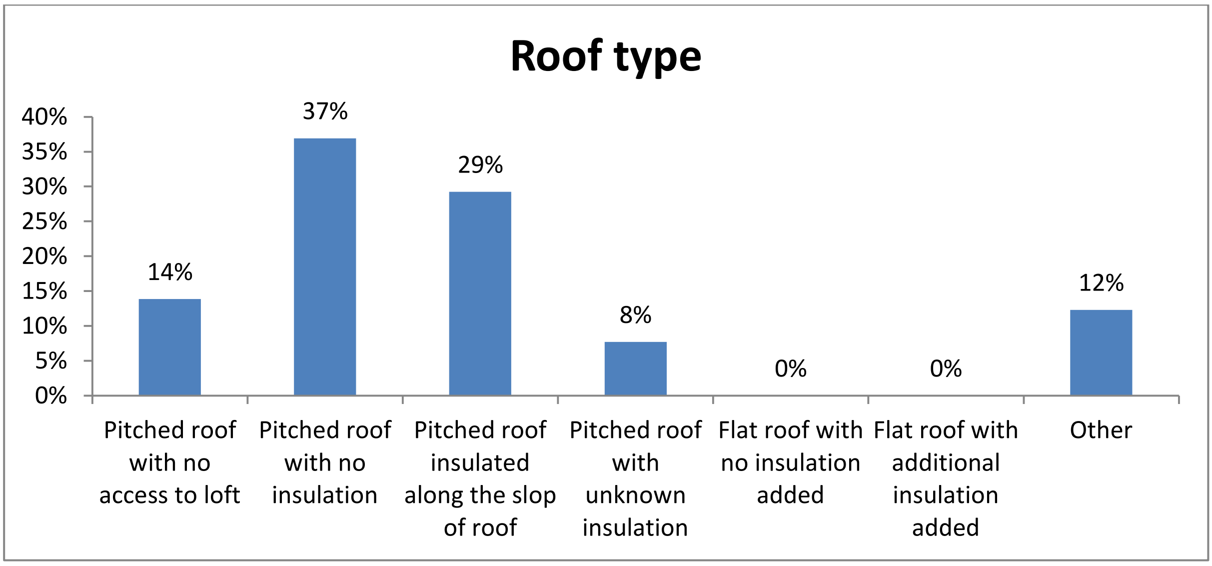
34. Is the cavity insulated:
    a. 53% of the cavities are insulated
    b. Materials: Polyestirene, fiberglass, foam, rook wool
35. Double glazing?


Double glazing?
70%
60%
50%
40%
30%
20%
10%
0%
8%
29%
58%
5%
None
Double>15 years
Double <15years
Tripple glazed

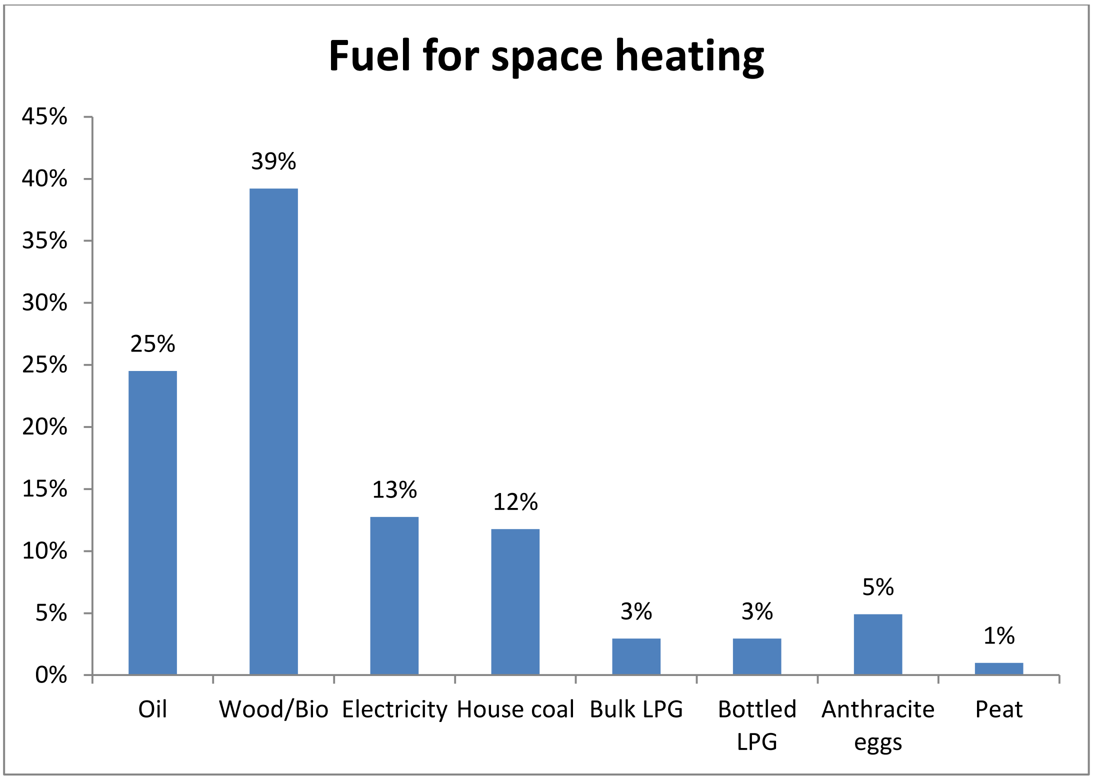
36. How much of your property is double or triple glazing?



37. Type of roof



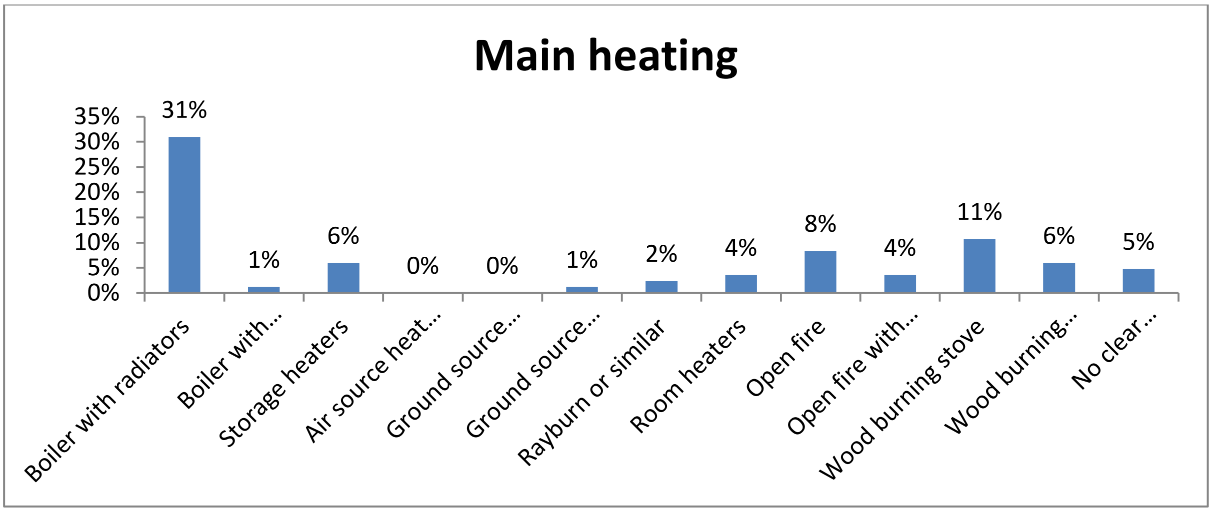
38. Fuel for space heating



39. How much is used?

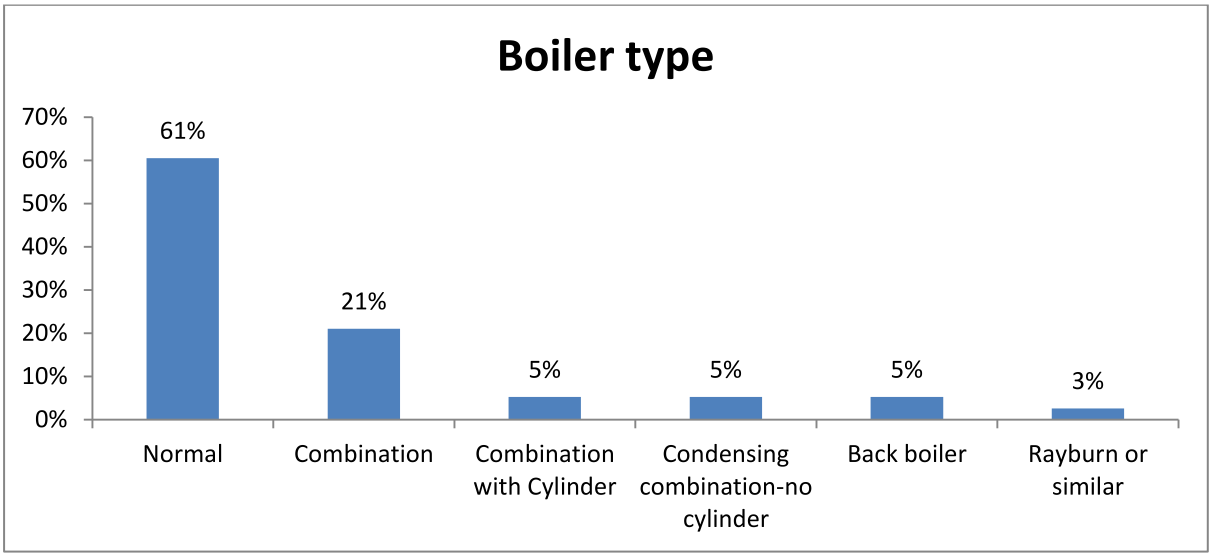
LPG kg	LPG small cylinder	LPG large cylinder	Oil litre	Wood kg
Average: 388 Median: 388 Min: 7 Max: 768	Average: 2 Median: 2 Min: 2 Max: 2	Average: 1 Median: 1 Mode: 1 Min: 1 Max: 1	Average: 1625 Median: 1825 Mode: 2000 Min: 350 Max: 4000	Average: 4468 Median: 3000 Mode: 5000 Min: 500 Max: 15000

40. Main heating system

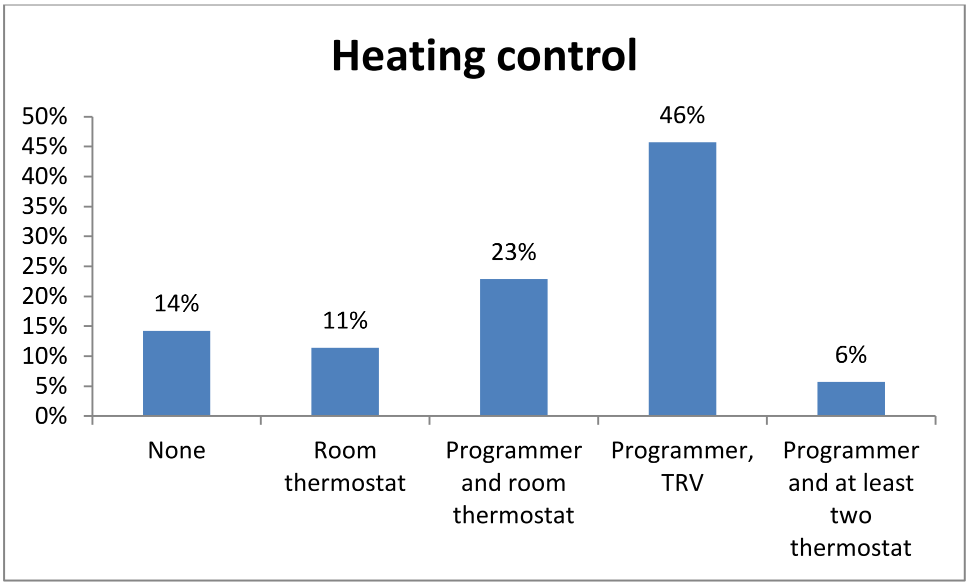


If your main heating system is a boiler

41. Type of boiler



42. Age of boiler:
    a. Average: 10 years
    b. Median: 10
    c. Mode: 1
    d. Min: 0.3
    e. Max: 30
43. Heating controls



If your heating system is storage heaters

44. Type of storage heaters
    - a. 80% old
    - b. 20% modern
45. 100% controlled manually

If your main heating system is room heaters

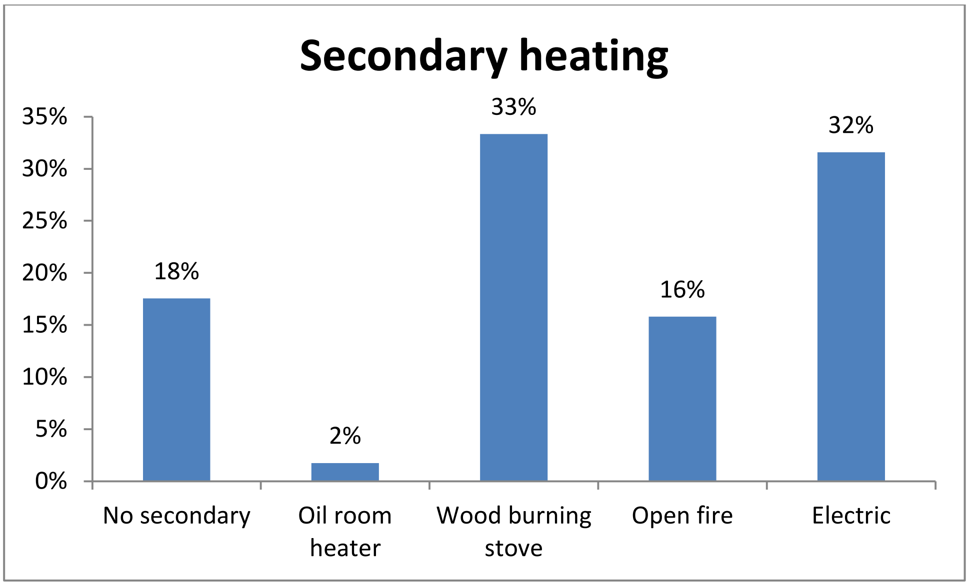
46. Type of heaters: 100% electric heaters
47. How are they controlled:
    - a. 67% don’t have thermostatic room temperature
    - b. 33% appliance thermostat

If your main heating system is heat pump air

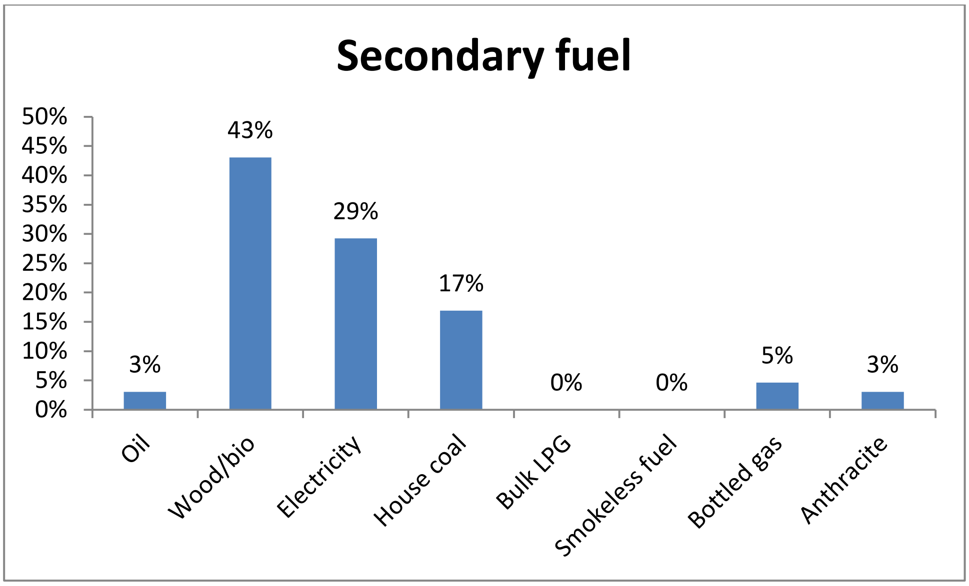
48. Heating controls:
    - a. 50% room thermostat
    - b. 25% Programmer and room thermostat
    - c. 25% Programmer only

For all heating types

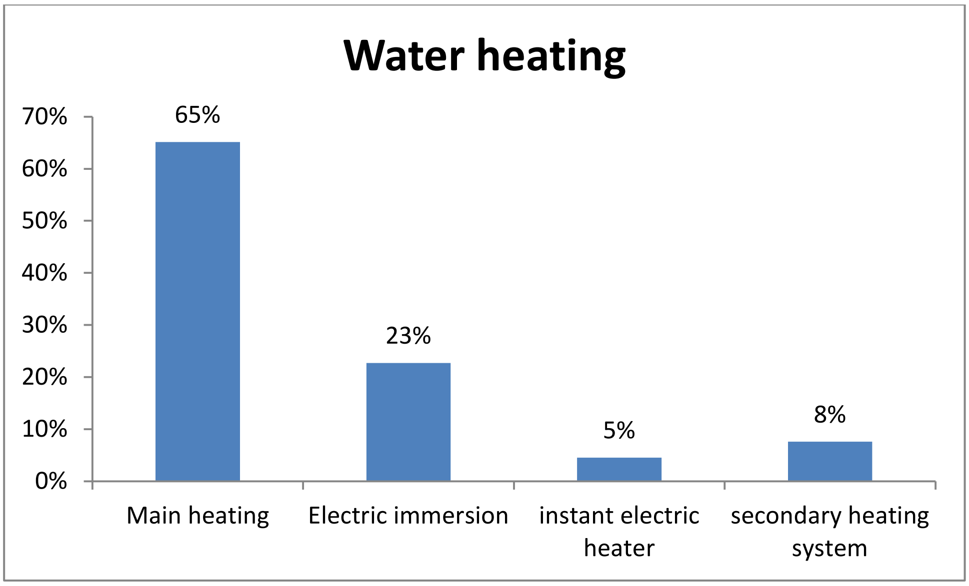
49. Secondary heating system



50. Secondary fuel



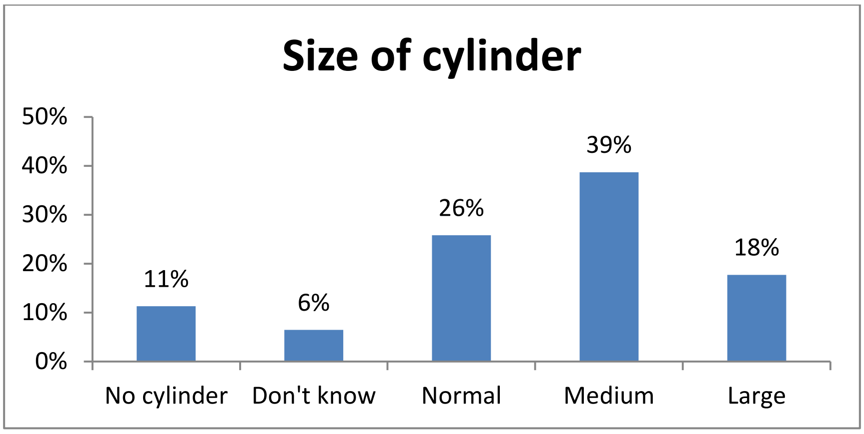
51. How is your water heated



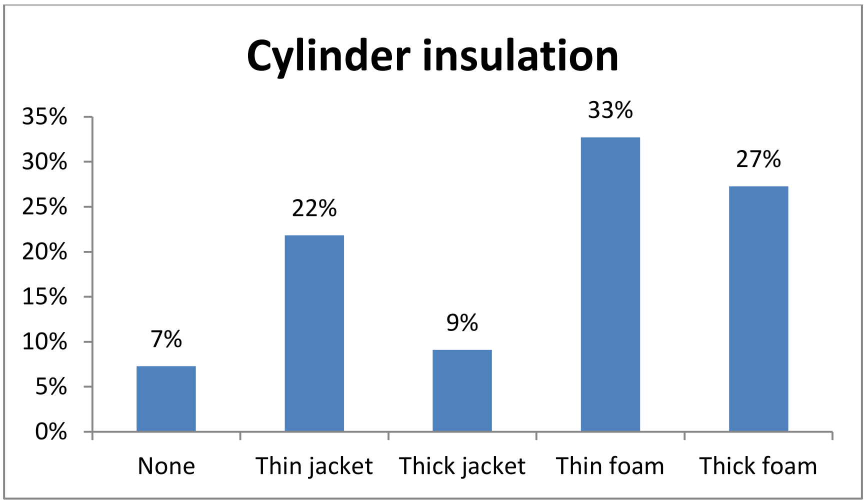
Age of the Boiler

a. Average: 17
b. Median: 11
c. Min: 10
d. Max: 30

52. Size of hot water cylinder



53. Insulation of the boiler



54. Thermostat
    a. 80% have
    b. 20% don’t have
55. Fuel for water heating

Oil (lit)	Wood (kg)	Coal (kg)	LPG m3
Average: 1450 Median: 1350 Mode: 800 Min: 350 Max: 2500	Average: 5500 Median: 4500 Min: 1000 Max: 1000	Average: 1090 Median: 1090 Min: 500 Max: 1680	None

56. Have a solar thermal system installed: 100% No
57. Interested on installing a solar thermal: 49% Yes
58. Have a solar photovoltaic system installed: 2% Yes
59. Interested on installing a solar photovoltaic system: 39% Yes
60. Have a wind turbine installed: 5% Yes
61. Interested on installing a micro-wind turbine: 42% Yes

ANNEX C HYDROPOWER TABLES

1. Camusterrach

p%	flow from reference river a1	flow (a2/a1)	abstracted flow	generation flow	design power
5	0.166	0.097921	0.092921	0.051	49.2305
10	0.129	0.076096	0.071096	0.051	49.2305
20	0.092	0.05427	0.04927	0.04927	47.5602
30	0.071	0.041882	0.036882	0.036882	35.60236
40	0.051	0.030084	0.025084	0.025084	24.21395
50	0.038	0.022416	0.017416	0.017416	16.81147
60	0.028	0.016517	0.011517	0.011517	11.11727
70	0.02	0.011798	0.006798	0.006798	6.561898
80	0.014	0.008258	0.003258	0.003258	3.145373
90	0.01	0.005899	0.000899	0.000899	0.867689
95	0.008	0.004719	-0.00028	0	0
99	0.006	0.003539	-0.00146	0	0

2. Estate					
p%	**flow from reference river a1**	**flow (a2/a1)**	**abstracted flow**	**generation flow**	**design power**
5	5	0.057	0.056	21.22484	9.1
10	10	0.042	0.041	15.53962	9.1
20	20	0.026	0.025	9.475375	9.1
30	30	0.018	0.017	6.443255	6.443255
40	40	0.012	0.011	4.169165	4.169165
50	50	0.009	0.008	3.03212	3.03212
60	60	0.006	0.005	1.895075	1.895075
70	70	0.004	0.003	1.137045	1.137045
80	80	0.003	0.002	0.75803	0.75803
90	90	0.002	0.001	0.379015	0.379015
95	95	0.001	0	0	0
99	99	0.001	0	0	0

ANNEX D ENERGY EFFICIENCY MEASURES TABLES

TABLE 9-1REGULATED U-VALUES PER YEAR IN UK

Year	**U Values (W/m^{2}K)**			
	Wall	*Roof*	*Floor*	*Windows*
1965	1.7	1.42	-	5.7
1974	1.0	0.60	-	5.7
1981	0.6	0.35	-	5.7
1990	0.45	0.25	0.45	5.7
1995	0.45	0.25	0.45	3.3
2002	0.35	0.16	0.25	2.0

- SOURCE: (KING 2007)

ANNEX E BIOMASS SECTION

Forest Sampling in Smiddy Woods

Area of Smiddy Woods: 25 hectare

Plot Size: 10 m X 10 m

TABLE 9-2: GIRTH SAMPLING AND MOISTURE CONTENT SAMPLING

Sample no	Girth (cm)
1	75
2	97
3	62
4	52
5	62
6	60
7	78
8	58
9	96
10	145
11	70
12	50
13	95
14	66
15	50
16	74
17	56
18	79
19	70
20	72
Avg	**73.35**

Moisture content sampling	
Sample	Felled tree
1	14.1
2	14.3
3	14.2
Avg. MC	**14.2**

TABLE 9-3TREE VOLUME CALCULATION

Calculation of the volume of the woodland (Smiddy Woods)			
		Unit	**Comment**
Avg Height	15	m	assumed for the whole forest based on the measurement of the felled trees
Diameter	0.23	m^2	Diameter = Girth/π
Basal area	0.04	m^2	Basal area = π X $(\text{Diameter})^2$ /4
Volume of 1 tree	0.21	m^3	Volume = Basal Area X Avgerage Height
Tree spacing	4	m^2	2m x 2m spacing
Number of trees	62500		
Total Forest Volume	12830.63	m^3	
	7698.38	tons	
Volume Density	513.23	m^3/ha	
	307.94	ton/ha	

Source: http://forestry.oxfordjournals.org/content/85/2/237/T2.expansion.html

TABLE 9-4 FELLING PLAN OF APPLECROSS ESTATE FOREST (TAYLOR 2010/11)

Compartment	Area	P-Year	Felling Period	Volume Estimate
3	5.33	1968	2012-2016	650
4	27.75	1968	2012-2016	4,400
5	20.72	1972	2012-2016	2,100
6	2.87	1972	2012-2016	300
8	77.97	1972	2012-2016	11,000
Arina	33.02	1975	2017-2021	6,000
Coire nan Arr	5.37	1972	2012-2016	0
17	17.34	1972	2017-2021	6,600
20	14.56	1972	2017-2021	7,650

TABLE9-5 RESTRUCTURING PLAN OF APPLECROSS ESTATE FOREST(TAYLOR 2010/11)

Compartment	Area (ha)	RP Year
3	5.33	2018
6	2.87	2016
8	48.51	2014
Arina	42.54 + 9.51	2019
Total	**108.76**	

TABLE9-6 NEW PLANTING PLAN OF APPLECROSS ESTATE FOREST (TAYLOR 2010/11)

Compartment	Area (ha)	RP Year
Fireach Garbh	17.19	2018
Hartfield	7.23	2016
Allt Mor	31.48	2016
Allt Beag	31.15	2015
Compt 8-13	5.92	2014
Upper compt 17	1.6	2019
Total	**94.57**	

TABLE 9-7 CUSTOMER PROFILE OF LOCAL FUEL WOOD SUPPLIER (SOURCE: INTERVIEW WITH IANGILLIES, 2014)

Township	Type of wood product (m^3)			Total (m^3)
	Logs	**Round**	**Split Load**	
Ardubh	18	11	2	31
Arrina	4	7	3	14
Burnside	-	-	5	5
Callacille	8	-	3	11
Camusterrach	10	-	46	56
Camustiel	-	-	13	13
Culduie	5	19	7	31
Estate	6	-	14	20
Farm	-	-	13	13
Kenmore	5	-	-	5
Milltown	-	7	4	11
North Coast	12	-	-	12
Shieldaig	4	-	-	4
Toscaig	28	-	8	36
The Shore Street	-	-	24	24
Upper Toscaig	-	8	-	8
Total: 12	**100**	**52**	**142**	**294**

TABLE 9-8 FOREST VOLUME BY AGE PER HECTARE FOR SITKA SPRUCE (EUROPEAN FOREST INSTITUTE, 2014)

	Forestry Commission			
	no site class (ALL)	**Sitka spruce+Norway spruce**		
Age min	Age max	Area (ha)	Volume (m3/ha)	Increment (m3/ha/year)
0	10	16655	0	0
11	20	51631	23	4.95
21	30	93376	104	16.21
31	40	65152	173	17.76
41	50	36876	242	16.05
51	60	12585	294	11.94
61	70	4174	359	7.69
71	80	1866	393	6.83
81	90	5	427	6.04
91	100	0	479	5.12
101	130	30	479	4.95
131	150	0	445	4.91

TABLE 9-9 CROFTING LAND IN NORTH APPLECROSS (SOURCE: MR. DONALD ARCHIE MACLELLAN, 2014)

Crofting Township	Approximate Area (ha.)
Lobain	480
Callacille	1150
Cuaig	1050
Fearnmore	550
Fearnabeag & Arrina	650
Kenmore	950
Ardheslaig	1300
Total: 7	**6130**

TABLE 9-10 CROFTING LAND IN SOUTH APPLECROSS (SOURCE: MR. DONALD ARCHIE MACLELLAN, 2014)

Crofting Township	Approximate Area (ha.)
Milltown	230
Camusteel	50
Camusterrach	410
Culdie	300
Ard Dubh	125
Coillieghillie	50
Uags	630
Toscaig	1030
Crowlin	290
Total: 10	**3115**

ANNEX F BIOMASS BASED HEATING SYSTEM CALCULATIONS

TABLE 9-11 BOILER SIZING AND WOOD VOLUME CALCULATION FOR CAMUSTERRACH BIOMASS BASED DHS

Household/ Demand Options	Total Annual heating Energy per HH (kWh/yr)	Total Annual Heating Energy for 5 HH	Boiler size	Volume of wood log (m^3)
Current Demand	33120	165600	61	130
Option 1- Demand less than 10%	29808	149040	55	117
Option 2- Demand less than 20%	26496	132480	49	104
Option 3- Demand less than 30%	23184	115920	43	91
Option 4- Demand less than 40%	19872	99360	37	77
Option 5- Demand less than 50%	16560	82800	30	64
Option 6- Demand more than 50%	49680	248400	91	195
Option 7- Demand more than 40%	46368	231840	85	182
Option 8- Demand more than 30%	43056	215280	79	156
Option 9- Demand more than 20%	39744	198720	73	143
Option 10- Demand more than 10%	36432	182160	67	90

ANNEX G COMBINATION OF MICRO-HYDROPOWER AND BIOMASS BASED DHS

The average heating demand per household in Applecross is 22996.29 kWh. The replacement and conversion of existing systems in Applecross to 100% biomass based heating system is based on this average heating demand value.

Total number of Households in Applecross that are fully occupied is 114 with 46 households with oil boiler and 14 households with electric heaters as their main heating system as per the household survey conducted.

TABLE 9-12 DETAILS OF PRIMARY FUELS AS PER 2014

	Amount equivalent to heating demand	Cost	CO_2 emission (kg/kWh)
Oil	28475 Liter	0.6426 £/Lt	0.265
Electricity	22996.29 kWh	0.1785 £/kWh	0.47
Wood	22.5 m^3	35 £/m^3	0.025

- 1 liter of oil equivalents to 10 kWh
- Boiler Efficiency = 80%
- Wood stove with back boiler efficiency = 80%
- 1m^3 fuel wood = 304 kg of fuel wood
- Calorific value of fuel wood (Sitka Spruce at 15% Moisture Content) = 4.2 kWh/kg

Hydropower Investment Cost

TABLE 9-13 INVESTMENT COST OF ALLTNACHRICHE MICRO-HYDROPOWER (49.18 KW) (WALLACE 2009)

Particulars	Cost (£)
Turbine, generator and controller	32,587
Earth excavation	41,200
Intake	10,300
Pipe	19,267
Turbine foundation/enclosure	5150
Electrical cable/ connection	42,357
Total	**150,861**

TABLE 9-14 HYDROPOWER AND BIOMASS BASED DHS COMBINATION DETAILS (SOURCE: AUTHORS)

				Current Demand Scenario									
				Demand					Supply				
				Camusterrach Place			Burnside	Combined	Camusterrach Place			Burnside	
Month starting	HDD		monthly kwh generation	Camusterrach Place Demand (kWh)	Heat loss for DHS	Output from storage tank (kWh)	Burnside Demand	Combined demand	Biomass DHS (kWh)	Hydro kWh output	Hydro input supply (kWh)	Hydropower supply (kWh)	Main Grid supply (kWh)
January	329	0.129172	20844.06	14260.54	0.20	17112.65	22514.61	36775.15	14260.54	0.00	0.00	20844.06	1670.55
February	321	0.126031	18158.44	13913.78	0.20	16696.54	21967.14	35880.92	13913.78	0.00	0.00	18158.44	3808.70
March	370	0.145269	20042.76	16037.69	0.20	19245.23	25320.38	41358.07	16037.69	0.00	0.00	20042.76	5277.61
April	296	0.116215	10608.24	12830.15	0.20	15396.18	20256.30	33086.45	12830.15	0.00	0.00	10608.24	9648.06
May	206	0.080879	5759.38	8929.09	0.20	10714.91	14097.29	23026.38	8929.09	0.00	0.00	5759.38	8337.91
June	104	0.040832	5506.86	4507.89	0.20	5409.47	7117.08	11624.97	4507.89	0.00	0.00	5506.86	1610.22
July	46	0.01806	12651.78	1993.88	0.20	2392.65	3147.94	5141.81	0.00	1993.88	2392.65	3147.94	0
August	66	0.025913	10795.27	2860.78	0.20	3432.93	4516.61	7377.39	0.00	2860.78	3432.93	4516.61	0
September	109	0.042795	15746.10	4724.62	0.20	5669.54	7459.25	12183.86	0.00	4724.62	5669.54	7459.25	0
October	159	0.062426	20293.87	6891.87	0.20	8270.25	10880.92	17772.79	0.00	6891.87	8270.25	10880.92	0
November	274	0.107578	18981.90	11876.56	0.20	14251.87	18750.77	30627.33	11691.65	184.91	231.13	18750.77	0
December	267	0.104829	18959.73	11573.14	0.20	13887.77	18271.73	29844.88	11022.74	550.40	688.00	18271.73	0
Total	2547	1	178348.40	110400.00		132480.00	174300	284700.00	93193.55	17206.45	20684.51	143946.96	30353.04

				Efficiency Scenario									
				Demand					Supply				
				Camusterrach			Burnside		Camusterrach Place			Burnside	
Month starting	HDD		monthly kwh generation	Biomass DHS (kWh)	Heat loss for DHS	Output demand from storage tank	Demand for Burnside	Combined demand	Biomass DHS kWh output	Hydro output kWh	Hydropower input kWh	Hydro kWh input	Main Grid
January	329	0.129172	20844.06	11408.43	0.20	13690.12	18011.68	29420.12	9142.54	2265.90	2832.37	18011.68	0
February	321	0.126031	18158.44	11131.02	0.20	13357.23	17573.71	28704.73	10663.24	467.78	584.73	17573.71	0
March	370	0.145269	20042.76	12830.15	0.20	15396.18	20256.30	33086.45	12830.15	0.00	0.00	20042.76	213.54
April	296	0.116215	10608.24	10264.12	0.20	12316.95	16205.04	26469.16	10264.12	0.00	0.00	10608.24	5596.80
May	206	0.080879	5759.38	7143.27	0.20	8571.93	11277.83	18421.11	7143.27	0.00	0.00	5759.38	5518.45
June	104	0.040832	5506.86	3606.31	0.20	4327.58	5693.66	9299.98	3606.31	0.00	0.00	5506.86	186.80
July	46	0.01806	12651.78	1595.10	0.20	1914.12	2518.35	4113.45	0.00	1595.10	1914.12	2518.35	0
August	66	0.025913	10795.27	2288.62	0.20	2746.35	3613.29	5901.91	0.00	2288.62	2746.35	3613.29	0
September	109	0.042795	15746.10	3779.69	0.20	4535.63	5967.40	9747.09	0.00	3779.69	4535.63	5967.40	0
October	159	0.062426	20293.87	5513.50	0.20	6616.20	8704.73	14218.23	0.00	5513.50	6616.20	8704.73	0
November	274	0.107578	18981.90	9501.25	0.20	11401.50	15000.61	24501.86	6316.22	3185.03	3981.29	15000.61	0
December	267	0.104829	18959.73	9258.52	0.20	11110.22	14617.39	23875.90	5784.64	3473.88	4342.35	14617.39	0
Total	2547	1	178348.40	88320.00		105984	139440.00	227760.00	65750.50	22569.50	27553.03	127924.42	11515.58

TABLE 9-15 MONTHLY POWER PRODUCTION FROM ALLTNACHRICHE MICRO-HYDROPOWER (49.18 KW), SOURCE: AUTHORS

January

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.219	0.129	0.078	0.051	49.180	1829.508
10	0.171	0.101	0.050	0.051	49.180	1829.508
20	0.127	0.075	0.024	0.051	49.180	3659.016
30	0.1	0.059	0.008	0.051	49.180	3659.016
40	0.084	0.050	0.005	0.045	42.961	3196.298
50	0.068	0.040	0.005	0.035	33.860	2519.151
60	0.051	0.030	0.005	0.025	24.189	1799.681
70	0.038	0.022	0.005	0.017	16.794	1249.499
80	0.026	0.015	0.005	0.010	9.968	741.638
90	0.017	0.010	0.005	0.005	4.849	360.742
95	0.013	0.008				
99	0.008	0.005				
						20844.056

February

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.195	0.115	0.064	0.051	49.180	1829.508
10	0.153	0.090	0.039	0.051	49.180	1829.508
20	0.112	0.066	0.015	0.051	49.180	3659.016
30	0.088	0.052	0.005	0.047	45.236	3365.585
40	0.072	0.042	0.005	0.037	36.135	2688.437
50	0.055	0.032	0.005	0.027	26.465	1968.968
60	0.042	0.025	0.005	0.020	19.070	1418.786
70	0.03	0.018	0.005	0.013	12.244	910.925
80	0.02	0.012	0.005	0.007	6.555	487.708
90	0.014	0.008				
95	0.011	0.006				
99	0.008	0.005				
						18158.440

March

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.197	0.116	0.065	0.051	49.180	1829.508
10	0.15	0.088	0.037	0.051	49.180	1829.508
20	0.107	0.063	0.012	0.051	49.180	3659.016
30	0.087	0.051	0.005	0.046	44.668	3323.263
40	0.075	0.044	0.005	0.039	37.841	2815.403
50	0.061	0.036	0.005	0.031	29.878	2222.898
60	0.048	0.028	0.005	0.023	22.483	1672.716
70	0.039	0.023	0.005	0.018	17.363	1291.820
80	0.03	0.018	0.005	0.013	12.244	910.925
90	0.02	0.012	0.005	0.007	6.555	487.708
95	0.015	0.009				
99	0.011	0.006				
						20042.765

April

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.114	0.067	0.016	0.051	49.180	1829.508
10	0.088	0.052	0.005	0.047	45.236	1682.793
20	0.062	0.037	0.005	0.032	30.447	2265.220
30	0.044	0.026	0.005	0.021	20.207	1503.429
40	0.035	0.021	0.005	0.016	15.088	1122.533
50	0.028	0.017	0.005	0.012	11.106	826.281
60	0.023	0.014	0.005	0.009	8.262	614.673
70	0.019	0.011	0.005	0.006	5.986	445.386
80	0.016	0.009	0.005	0.004	4.280	318.421
90	0.012	0.007				
95	0.01	0.006				
99	0.007	0.004				
						10608.244

May

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.093	0.055	0.004	0.051	49.180	1829.508
10	0.066	0.039	0.005	0.034	32.722	1217.254
20	0.037	0.022	0.005	0.017	16.225	1207.177
30	0.026	0.015	0.005	0.010	9.968	741.638
40	0.019	0.011	0.005	0.006	5.986	445.386
50	0.016	0.009	0.005	0.004	4.280	318.421
60	0.013	0.008				
70	0.011	0.006				
80	0.009	0.005				
90	0.007	0.004				
95	0.006	0.004				
99	0.006	0.004				
						5759.383

June

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.081	0.048	0.005	0.043	41.254	1534.667
10	0.06	0.035	0.005	0.030	29.309	1090.288
20	0.039	0.023	0.005	0.018	17.363	1291.820
30	0.027	0.016	0.005	0.011	10.537	783.960
40	0.02	0.012	0.005	0.007	6.555	487.708
50	0.016	0.009	0.005	0.004	4.280	318.421
60	0.013	0.008				
70	0.01	0.006				
80	0.008	0.005				
90	0.007	0.004				
95	0.006	0.004				
99	0.006	0.004				
						5506.863

July

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.1	0.059	0.008	0.051	49.180	1829.508
10	0.079	0.047	0.005	0.051	49.180	1829.508
20	0.052	0.031	0.005	0.051	49.180	3659.016
30	0.037	0.022	0.005	0.051	49.180	3659.016
40	0.028	0.017	0.005	0.012	11.106	826.281
50	0.021	0.012	0.005	0.007	7.124	530.029
60	0.016	0.009	0.005	0.004	4.280	318.421
70	0.012	0.007				
80	0.01	0.006				
90	0.007	0.004				
95	0.007	0.004				
99	0.006	0.004				
						12651.779

August

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.143	0.084	0.033	0.051	49.180	1829.508
10	0.104	0.061	0.010	0.051	49.180	1829.508
20	0.075	0.044	0.005	0.039	37.841	2815.403
30	0.052	0.031	0.005	0.026	24.758	1842.003
40	0.038	0.022	0.005	0.017	16.794	1249.499
50	0.027	0.016	0.005	0.011	10.537	783.960
60	0.019	0.011	0.005	0.006	5.986	445.386
70	0.014	0.008				
80	0.011	0.006				
90	0.008	0.005				
95	0.006	0.004				
99	0.006	0.004				
						10795.266

September

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.169	0.100	0.049	0.051	49.180	1829.508
10	0.138	0.081	0.030	0.051	49.180	1829.508
20	0.097	0.057	0.006	0.051	49.180	3659.016
30	0.078	0.046	0.005	0.041	39.548	2942.368
40	0.058	0.034	0.005	0.029	28.171	2095.933
50	0.043	0.025	0.005	0.020	19.639	1461.107
60	0.032	0.019	0.005	0.014	13.381	995.568
70	0.023	0.014	0.005	0.009	8.262	614.673
80	0.016	0.009	0.005	0.004	4.280	318.421
90	0.011	0.006				
95	0.009	0.005				
99	0.007	0.004				
						15746.102

October

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.203	0.120	0.069	0.051	49.180	1829.508
10	0.16	0.094	0.043	0.051	49.180	1829.508
20	0.12	0.071	0.020	0.051	49.180	3659.016
30	0.097	0.057	0.006	0.051	49.180	3659.016
40	0.079	0.047	0.005	0.042	40.117	2984.690
50	0.064	0.038	0.005	0.033	31.584	2349.864
60	0.049	0.029	0.005	0.024	23.052	1715.038
70	0.037	0.022	0.005	0.017	16.225	1207.177
80	0.026	0.015	0.005	0.010	9.968	741.638
90	0.016	0.009	0.005	0.004	4.280	318.421
95	0.012	0.007				
99	0.008	0.005				
						20293.874

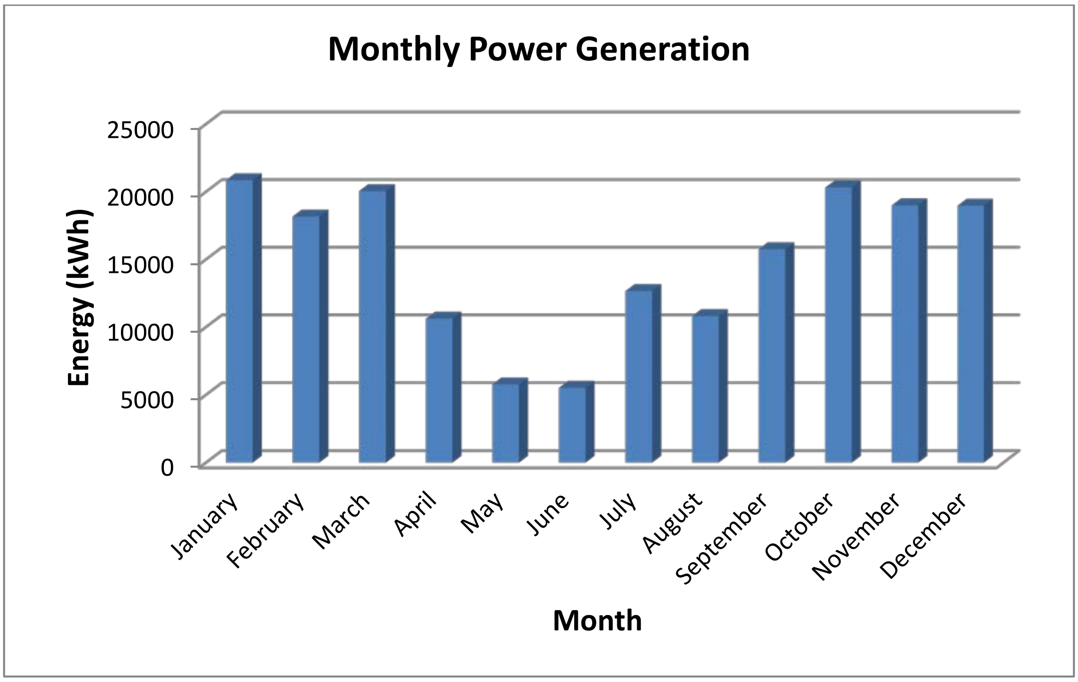
November

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.193	0.114	0.063	0.051	49.180	1829.508
10	0.152	0.090	0.039	0.051	49.180	1829.508
20	0.112	0.066	0.015	0.051	49.180	3659.016
30	0.09	0.053	0.002	0.051	49.180	3659.016
40	0.071	0.042	0.005	0.037	35.566	2646.116
50	0.054	0.032	0.005	0.027	25.896	1926.646
60	0.042	0.025	0.005	0.020	19.070	1418.786
70	0.032	0.019	0.005	0.014	13.381	995.568
80	0.024	0.014	0.005	0.009	8.831	656.994
90	0.017	0.010	0.005	0.005	4.849	360.742
95	0.014	0.008				
99	0.009	0.005				
						18981.900

December

Reference river		Combined				
P (%)	Q (m^3/s)	Q (m^3/s)	ER	Total DD	Power (kW)	kWh
5	0.22	0.130	0.079	0.051	49.180	1829.508
10	0.17	0.100	0.049	0.051	49.180	1829.508
20	0.127	0.075	0.024	0.051	49.180	3659.016
30	0.097	0.057	0.006	0.051	49.180	3659.016
40	0.079	0.047	0.005	0.042	40.117	2984.690
50	0.058	0.034	0.005	0.029	28.171	2095.933
60	0.042	0.025	0.005	0.020	19.070	1418.786
70	0.031	0.018	0.005	0.013	12.812	953.247
80	0.021	0.012	0.005	0.007	7.124	530.029
90	0.013	0.008				
95	0.01	0.006				
99	0.008	0.005				
						18959.732

FIGURE 9-1 MONTHLY POWER GENERATION FROM ALLT NA CHRICHE (49.18KW)



SOUTCE: AUTHORS