THE TRANSPORT SECTOR IN ROUSAY AND EDAY: ENERGY, COST AND EMISSIONS COMPARED TO KIRKWALL

International Class 2010

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EXECUTIVE SUMMARY

For the last eight years the University of Flensburg has being working in close collaboration with Community Energy Scotland (CES) regarding environmental and energy issues on rural and island communities of Scotland. In February and March 2010 eleven students of the 18 months Energy and Environmental Management Master of Engineering course of the University of Flensburg/Germany, conducted a study in the Islands of Rousay, Eday and the town of Kirkwall, capital of the Orkney Islands within the International Class 2010.

The field research study aims to determine the difference of the direct and embedded transport energy consumption, CO_2 emissions as well as costs between Rousay and Eday and compare this with Kirkwall. In addition a transport poverty indicator was developed, which is used to assess the transport poverty in the three places. The study focused on the behaviour of transport related activities in three main sectors: households, agriculture and small businesses.

Field surveys were carried out to collect data from the three locations on the three focus areas. Primary data were collected through face to face interviews and distributed questionnaires using a standardized instrument. In addition interviews with experts were conducted on specific aspects and questions. Secondary data were mainly obtained from the following documents: DEFRA report, Scottish Transport Statistics, reports and statistics of the Orkney Council, Orkney Ferries as well as Rousay and Eday development plans.

The study was conducted by taking random samples of 2% of the households in Kirkwall, and around 60% on the two islands. The samples have a 95% confidence level under the established confidence intervals.

CO_2 calculations for all the sectors were based on the fuel consumption of the vehicles and the emission factors of the various fuels. For the calculation of the CO_2 emissions of the ferries, the total emissions per trip between the mainland and the islands were figured out using the fuel consumption of each ferry and the required time for the trips.

The average transport energy demand of households in Rousay (excluding the ferry transport) is about 25% higher than the one in Eday. However, when the ferry transport is included in the household sector the difference increases to almost 50%.

In Eday the transport energy demand in the household sector excluding the ferry transport is less than that of Kirkwall and Rousay. When the ferry transport is included the consumption in Eday increases by 30% and becomes higher than that of Kirkwall but lower than that of Rousay. Hence, the transport energy demand from the ferry transport in Rousay is much higher than that of Eday. The most important findings of the study are shown in the tables below.

Average annual transport energy demand (MWh / year)

	HH including ferry transport	HH excluding ferry transport	Businesses excluding ferry transport	Farms excluding ferry transport
Rousay	12	8.02	7.85	8.52
Eday	8.37	6.44	5.66	15.94
Kirkwall	---	7.51	---	---

Including the expenditure on ferry transport, HHs in Eday and Rousay pay 34% and 75% more for transport than HHs in Kirkwall respectively. The expenditure on ferry transport represents 49% in Eday and 59% of the total expenditure in Rousay.

Average annual expenditure on transport (£ / year)

	HH including ferry transport	HH excluding ferry transport	Business excluding ferry transport	Farm excluding ferry transport
Rousay	1,655.28	1,042.92	932.50	725.57
Eday	1,267.76	860.28	724.00	1,383.35
Kirkwall	---	945.21	---	---

The carbon dioxide emissions from all the sectors considered in this study are directly related to the consumption of fossil fuel. For both Rousay and Eday households, CO_2 emissions

associated with the use of ferry is quite significant. The figures show that, 36% and 25% of the CO_2 emissions of the Rousay and Eday households respectively are due to the ferry transport.

Average annual CO_2 emission (t CO_2 / year)

	HH including ferry transport	HH excluding ferry transport	Business excluding ferry transport	Farm excluding ferry transport
Rousay	3.27	2.11	2.09	2.24
Eday	2.26	1.69	1.57	4.91
Kirkwall	---	1.97	---	---

To estimate the impact of the embedded transport cost on Eday and Rousay households were compared with households in Kirkwall, the IC 2010 researchers compared the living cost of a typical household in these three locations. From the survey data it is seen that due to the difference in food prices and observed transport expenditures, the household in Rousay would spend £1,284 more per year than in Kirkwall. For Eday, the household would spend £ 1,214 per year more than the household in Kirkwall.

The study from the given sample shows that, households in Eday and Rousay with an income below the poverty line are more likely to be under transport poverty than the same household in Kirkwall. Households who spend more than 8.3% of their income on transport are prone to transport poverty. 25.0% of the HH in Eday fall under transport poverty compared to 22.2% in Rousay and 11.4% in Kirkwall. Thus Eday has the highest percentage of transport poor households.

The researchers studied possible future transport options for Eday and Rousay and had a closer look to the idea of building a bridge between the mainland and Rousay. With the high investment it would take a very long time (in the best case nearly 192 years) until it pays back. On the other hand the disadvantage of constructing a bridge is the negative environmental impact. Therefore, the bridge option for Rousay was neglected. In the case of Eday this options was not considered because the island is far away (about 16 miles) from mainland Kirkwall.

Reducing the number of trips between the islands and mainland

In case of Rousay, the introduction of a passenger ferry in combination with car ferry services by replacing the current ferry with a bigger one increases the total energy consumption by almost 2,000,000 kWh/y. The total CO_2 emissions for the ferry services between Tingwall and Rousay will also increase significantly. Therefore the IC 2010 research team did not consider this option as a feasible option. This option is not considered for Eday because the service is already limited to two round trips per day to Kirkwall and this route is combined with the services of the two more populated islands Stronsay and Sanday.

Replacing the existing ferries with new technologies

A new LNG (Liquefied Natural Gas) ferry technology will emit less CO_2 compared to the existing ferries. The study shows that, CO_2 emissions by the LNG ferries are smaller than with the marine diesel fueled ferry. Out of the presented scenarios the best option could be the replacement of the actual ferries for new ferries with a more efficient technology like the LNG ferries.

Public bus service on the islands

Using public busses with the same frequency of ferry departure and arrival times, so that more people would use public transport which helps to improve the mobility on the islands

The IC 2010 team considered that the implementation of public buses in the islands can be done in the short term, while the replacement of current ferries can be implemented once the current ferries have to be replaced.

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List of Abbreviations

BP	:	British Petroleum
ECE	:	Eday Community Enterprises
GHG	:	Green House Gas
CO_2	:	Carbon Dioxide
DEFRA	:	Department for Environment, Food and Rural Affairs
DERV	:	Diesel Engine Road Vehicle
ET	:	Expenditure on Transport
FES	:	Family Expenditure Survey
HH	:	Household
IPCC	:	Intergovernmental Panel on Climate Change
IC	:	International Class
ISMI	:	Income Support for Mortgage Interest
LHV	:	Lower Heating Value
LNG	:	Liquefied Natural Gas
MGO	:	Marine Gas Oil
SPSS	:	Statistical Package for the Social Sciences
UNFCCC	:	United Nations Framework Convention on Climate Change

List of Units

cc	:	Cubic Centimeter
kW	:	Kilowatt
MW	:	Megawatt
kWh	:	Kilowatt hour
MWh	:	Megawatt hour
g	:	Gram
Kg	:	Kilogram
KJ	:	Kilo Joule
MJ	:	Mega Joule
Km	:	Kilometre
l	:	Litre
m^2	:	Square meter
t	:	Tonne
kCO_2	:	Kilogram of Carbondioxide
tCO_2	:	Tonnes of Carbon Dioxide
gCO_2	:	Grams of Carbon Dioxide
y	:	year
£	:	Pound

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CHAPTER I: INTRODUCTION

1.1 Context of the study

The Islands of Orkney are a group of 70 islands and skerries 6.2 miles from the north-east tip of the Scottish Mainland. The total population is about 20,000. The largest island is known as 'Mainland' and the capital of Orkney is Kirkwall.[1] Given the open exposure to the Atlantic and North Seas, the most noticeable feature about Orkney weather is the wind.

Eday and Rousay, the main research areas of this study, are two small islands located north east of Orkney Mainland. (Figure 1). Rousay with a population of 220 is 3.6 miles away from the mainland and can be reached within 20 minutes via ferry connection from Tingwall. Eday with 151 inhabitants is located 15.8 miles away from Kirkwall and can be reached in 75 minutes by ferry connection from Kirkwall.

Between Rousay and the mainland, there is a regular ferry connection which operates six times a day and six days a week. But in Eday the ferry connection is only two times a day on average.

There is no public bus service in Eday. But in Rousay there is one public bus which operates only one day a week.

Figure 1. 1 Orkney Islands[1]

This research study is carried out in these two islands Rousay and Eday by a group of eleven international students from the University of Flensburg Germany, as an exercise of their 18-month energy and environmental management Masters Course.

[1] http://www.visitorkney.com/about_orkney.asp (10/03/2010)

1.2 Research problem and questions

Unlike people living on the mainland, people living on Rousay and Eday islands need to travel long distances to get access to the important products and services on the mainland. This study is therefore aimed at finding out in how far people living on small islands are affected by the cost of higher energy consumption for transport, how the higher transport demand increases their carbon footprint and how both, the cost and the carbon footprint could be reduced.

According to information from Orkney Ferries, the vessels connecting the islands to the mainland carried 44,905 passengers and 9,257 vehicles between Rousay and Tingwall in the fiscal year of April 2008 to March 2009. In the same year the ferry service between Eday and Kirkwall carried 9,826 passengers and 2,198 vehicles.[2]

Most people on the islands need to travel to the mainland for various reasons, which include buying products for their daily living, getting goods for the shop, buying and selling of agricultural inputs and products, purchasing supply for small business activities etc. As a result of this, people living in the islands say that they pay a substantially higher amount for the products which have been transported to the islands. This might be due to the additional cost of transport which has been included in the cost of the products. This extra cost is known as embedded transport cost.

Based on the description of these problems the research questions for this study are:

- What is the direct as well as embedded transport energy demand in the two islands?
- What are the direct as well as embedded transport related carbon dioxide emissions?
- What is the direct as well as embedded transport cost for households, businesses and farms on the isles as compared to Kirkwall?
- What percentage of the population is under ‘transport poverty’ according to the ‘transport fuel poverty indicator’ developed in this study?

[2]Marine Services, Orkney Islands Council. Information from | Head of Marine Services Support

- What are possible sustainable alternative transport scenarios which would reduce the direct and embedded transport cost and CO_2 emissions from transport for the isles?

1.3 Objective and Relevance of the study

The main objective of this study is to determine the difference of the direct and embedded transport energy consumption, CO_2 emissions and costs between Rousay and Eday and compare this with Kirkwall.

Another objective is to provide a transport poverty indicator for the two islands based on the data collected during the field research and estimate the share of households in transport poverty in Eday, Rousay and Kirkwall.

The topic of the study is of great relevance to many island communities because mobility is one of the most fundamental issues of concern to those living on islands as it impacts on every aspect of their lives. Affordable, frequent and safe transport services are therefore vital to island communities.

Island households and businesses consistently comment on the detrimental impact of transportation on their lives. High travel cost means that prosperity and growth is constrained by high operating and living cost due to their geographical settings which imposes limitations. As stated in the Orkney Islands local transport strategy 2007-2010,"Passenger and goods transport services are fundamental to the sustainability of Orkney. Transport plays a crucial role in the economic and social development of Orkney and its connectivity to mainland Scotland. For these simple reasons, the availability and affordability of transport services are of great importance to all who live in Orkney and visit or want to visit Orkney".[3]

The relevance and significance of this study stems from the above need and desire to overcome the transport challenges and disadvantages on these two isles. The developmental visions of both islands are similar in the sense that they seek to create an economically prosperous self-reliant community that is connected with the wider world and that remains a

[3] Orkney Islands local transport strategy 2007-2010. Page 3

safe environment, where people are proud to live, able to work, to bring up and educate their children and to fulfill their hopes and ambitions.

In both development plans one major factor that is identified as a key element in achieving this vision is regular, reliable, faster and affordable transport links with other islands and mainland Scotland. [4]

It is important also to state that, this study was identified explicitly in the Eday development plan 2008-2013 to measure the additional costs attached to island living. It is the aim of the IC 2010 team that this report provides useful information for the two communities.

1.4 Structure of the report

After these introductory notes in chapter 2 of this report the methodology of the study is presented and more detailed explanations about the type and approach used, the sampling and the limitations of the study are given.

Chapter 3 analyses the data that have been obtained from the field research and focuses on the direct and embedded transport cost and emissions from the various transport means used on the islands. A cost analysis of the life cycle of a standard household living on the two islands is also done to assess the cost of embedded and direct transport energy demand more in depth and see how different the cost of living on small islands are compared to life in Kirkwall.

In chapter 4 the concept, methodology and results of an exercise to develop a transport fuel poverty indicator based on the existing fuel poverty index is presented for the two islands.

In chapter 5 alternative scenarios have been developed to assess different options to reduce the direct and embedded costs and carbon emissions from transport on the islands.

The last chapter (6) gives the conclusions and recommendations of the study.

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[4] Eday development plan 2008-2013 p.10 & Draft Rousay development plan 2007 page 1

CHAPTER 2: METHODOLOGY

In this chapter, the methodology applied during this field research is presented together with its design, sources, techniques and data collecting instruments. The approaches, methods, tools and data analysis techniques used to interpret data are briefly explained.

2.1 Approach and type of the research study

We conducted the research by using three study approaches:

A quantitative or analytical approach was used to compare two or more groups, for example comparing findings of the small islands Eday and Rousay with Kirkwall on the mainland. The study was conducted by taking random samples in Kirkwall as well as around 60 percentage samples out of the total population, in the two islands Eday and Rousay.

A Descriptive study involves describing the characteristics of a particular situation, event or case. In this research project, the direct and embedded energy consumption, cost and CO2 emission for transport in Eday and Rousay, compared with Kirkwall are presented. In order to do that comparison, the island population was divided into three main sectors: households, agriculture and small business.

The purpose of an **exploratory study** is to familiarize the researcher with a relatively unknown phenomenon and allows obtaining information about the likelihood to conduct further research in that specific area.[5]

Although there are several studies on fuel poverty related to heating in Scotland, the International Class 2010 team didn't find any literature or previous studies about the fuel poverty concept applied to the transport sector. Hence, we developed a methodology, based on the existing heating fuel poverty indicator studies, to calculate a transport poverty indicator in Eday and Rousay.

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[5] Hernandez and Col, 2006

2.2 Defining the boundary

Any process involving the research of reality must be placed within a perspective in time and space[6], in that sense in the following lines the spatial and temporary boundaries of this research are established in these two dimensions:

Spatial boundary

This research project is limited to the transport sector of the households of Rousay, Eday and the city of Kirkwall, and the agriculture and small businesses were analyzed for Eday and Rousay only. As this is a comparative study between Kirkwall and the two islands, only transport in these locations and between Rousay, Eday and Kirkwall was considered.

Time boundary

For the present study, the year 2009 was used as reference year.

2.3 Operationalization of the variables

In the following section the main variables are defined and the indicators used for answering each research question are presented in table 2.1.

The variable "Energy demand" refers to annual transport energy demand for households, agriculture and small businesses of Eday, Rousay and Kirkwall.

The environmental variable refers to the CO_2 emissions linked to the transport energy demand for households, agriculture and small businesses of Eday, Rousay and Kirkwall.

The socio-economic variable refers to the expenditure linked to the transport energy demand for households, agriculture and small businesses of Eday, Rousay and Kirkwall.

The variable on behavior refers to the different attitudes and customs of the households that affect the transport energy demand for households, agriculture and small businesses of Eday and Rousay, as well as of households in Kirkwall.

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[6] Mendez, 2006

Table 2. 1 Operationalization of the research questions

Research question	Variables	Indicators
What are the direct and embedded transport energy demand, CO_2 emissions and costs?	Energy demand	Transport energy consumption (MWh) per households (HH)
		Transport energy consumption (kWh) per kg transported by ferry per trip
		Transport energy consumption in MWh per kg of cattle and sheep meat
		Transport energy consumption MWh per business and farm
		Embedded transport energy demand per kg of food and drinks sold in the local store (kWh)
		Embedded transport energy demand for a wood house of 131 square meters in each island (kWh)
	Environment	Transport CO_2 emissions per HH (t/year)
		Transport CO_2 emissions (g) per kg transported by ferry per trip
		Transport CO_2 emissions (kg) per kg of cattle and sheep meat
		Transport CO_2 emissions per business and farms (t/year)
		Embedded transport CO_2 emissions per kg of food and drinks sold in the local store (kg)
		Embedded transport CO_2 emissions for wood house of 131 square meters in each island (kg)
	Socio economic	Average transport expenditure per HH for the sample

Research question	Variables	Indicators
		Cost per liter of each type of transport fuel
		Cost of reference food and drink basket in islands and Kirkwall
	Behavior	Ferry trips per HH per year
		Transport means used to go to work
		Percentage of fuel purchased in Kirkwall per HH
Transport poverty index	Social	Percentage of HH under transport poverty index per site
Alternative transport scenarios	Energy	kWh per trip
	Environment	CO_2 emissions per trip
	Socio economic	Cost per trip (in £)

2.4 Data collection techniques

2.4.1 Primary data

- ***Face to face interview:*** The main method of data collection in Rousay, Eday and Kirkwall was the face to face interview with a standardized questionnaire. In the case of Eday and Rousay, the IC 2010 group members visited households, farms and small business firms. In Kirkwall, most of the interviews were conducted on Saturdays with residents of Kirkwall in different public areas of the city, 10.5% (6 questionnaires out of 57 in total) of the questionnaires were filled in by staff members of the Orkney council.

- ***Written questionnaire survey:*** In some of the households, farms and businesses in Rousay and Eday, depending on the availability of the respondent, the same standardized questionnaires as in the interview were filled in by the respondents

themselves. This was also the case for the survey at Orkney Energy Agency and Orkney Council, as well as Kirkwall Police office.

- ***Interview with experts:*** In order to get specific information about the transport, energy and environmental sector in Eday, Rousay and Kirkwall, the students had meetings with representatives and experts from the following institutions:

- Community Energy Scotland (national and local experts)
- Orkney Energy Agency
- Orkney Island Council
- Orkney Ferries
- International Centre for Island Technology
- Rousay Development Trust and Eday Partnership
- Local transport service providers in Eday and Rousay

2.4.2 Secondary data

The literature review involved screening of reports, technical research papers, local site maps and other relevant documents by internet search during the preparation seminar of the International Class at the University of Flensburg as well as on the site. Ordinance survey maps provided by Rousay and Eday community partner organizations were used to locate households, agriculture and business organizations on the islands.

2.5 Sampling description

The Table below shows the sample size of the study and the total population.

Table 2.2 Summary of the sampling of *the field* survey in the research sites

Location	**Sectors**	**Total (number)**	**Surveyed (number)**	**Proportion**
Rousay	Households	105	60	57%
	Agriculture	16	12	75%
	Small businesses	15	12	80%
Eday	Households	73	47	64%
	Agriculture	14	12	86%
	Small businesses	7	5	71%
Kirkwall	Households	3,120	56	2%

2.6 Analysis of technical data

In order to retrieve the data from the questionnaire survey, compilation sheets were designed. SPSS and MS Excel 2007 were used as statistical software to analyze the surveyed data. The answers from respondents were coded to convert them into quantitative data.

A sector wise analysis of the surveyed data was done for households, agriculture, and small businesses to allow comparisons between the islands. The comparison was done considering the variables and indicators mentioned in table 2.1.

CO_2 calculation method: CO_2 calculations for all the sectors were based on the fuel consumption of the vehicles and the emission factors for different types of fuels. For the ferries' CO_2 emission calculation, the total emissions per trip between Kirkwall and Eday, as well as Tingwall and Rousay were calculated, using the fuel consumption of each ferry and the required time for each trip.

The embedded CO_2 emissions were calculated for some specific examples: building a house, food supplied through the local shops and transport of fuel to the islands.

2.7 Limitations

A limitation faced while carrying out the field research was the fact that the answers from the interviews on how many miles does each vehicle run per year was could not be used for CO_2 emissions calculations, because they were not consistent with the fuel expenditures of the same period. This quality problem limited the CO_2 calculation to one method (fuel consumption from fuel expenditure).

CHAPTER 3: FINDINGS FROM THE FIELD RESEARCH

3.1 Emissions and Costs of Direct and Embedded Transport

3.1.1 Fuel consumption, energy demand and CO_2 emissions of vehicles, bus and ferry transport

3.1.1.1 Carriage of vehicles and passengers by the ferries

In Orkney, ferries are vital links between the outer islands and Orkney mainland. Three ferries, Earl Thorfinn, Earl Sigurd and the Varagen, are currently operated for the routes from Kirkwall to the outer north isles of Westray, Papa Westray, Stronsay, Sanday, Eday and North Ronaldsay. There is a regular ferry service from Tingwall to the inner north isles of Rousay, Egilsay and Wyre with one ferry - Eynhallow[7]. For the purpose of our study only the routes of Rousay-Tingwall and Eday-Kirkwall are considered. However, for the calculation of CO_2 emissions all passengers on the ferries are considered, no matter whether they go from/to Rousay/Eday or just pass by these islands.

Table 3. 1 Passenger and vehicle numbers 04.2008-03.2009[8]

	Rousay-Tingwall	**Eday-Kirkwall**
Total number of passengers	50,215	33,149
Number of cars	9,257	7,233
Number of commercial vehicle	4,748	3,901
Number of round trips	1,988	709

The total expenditure of Orkney ferries on fuel, marine gas oil for all routes operated, was £1,327,000 in 2008.

For the route of Tingwall-Rousay/Egilsay/Wyre, the total income in 2008 was £265,000. 26% of this income was spent on fuel (£67,600). For the route Kirkwall-Sanday/Stronsay/Eday

[7] Orkney Island Council - http://www.orkneyharbours.com/ferry_services.asp

[8] Marine Services, Orkney Islands Council; SESAM-IC2010

76.2% (£875,800) of the income was spent on fuel.[9] The high expenditure on fuel for the Kirkwall-Sanday/Stronsay/Eday route is mainly caused by the longer distance between Kirkwall and Sanday/Stronsay/Eday.

3.1.1.2 Energy consumption and CO_2 emission of ferries

The total fuel consumption and CO_2 emissions of the ferries have been calculated with information from the timetable and the specific fuel consumption of each ferry. Marine gas oil is used by all ferries of "Orkney Ferries". The specific fuel consumption of the ferry for Rousay-Tingwall is 70 liter/hour and for Eday-Kirkwall is 250 liter/hour. The CO_2 emission factor of marine gas oil (MGO) is 3 kgCO_2/liter and the specific heating value of MGO is 38.0 MJ/liter[10].

Table 3.2 below shows the specific fuel consumption and CO_2 emissions per kg weight of freight, resp.passengers[11]

Table 3. 2 Energy consumption and CO_2 emission of the ferries

	Unit	**Rousay-Tingwall**	**Eday-Kirkwall**
Total fuel consumption	liter/year	162,353	547,229
	kWh/year	1,713,730	5,776,308
Total freight & passengers	kg/year	33,361,375	26,353,381
Energy demand by weight	kWh/kg/trip	0.051	0.219
Total CO_2 emission	tCO_2/year	503	1,696
CO_2 emission by weight	gCO_2/kg/trip	15	64
Fuel consumption by weight	liter/kg/trip	0.005	0.021

[9] Ibid 2

[10] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol.2, chapter 3 & BP Specification for MGO

[11] *Total fuel consumption (Liter) = Total engine operating hour (hour) x Specific fuel consumption (liter/hour)*

Total energy demand (kWh) = Total fuel consumption (liter) x Fuel heating value (kWh/liter)

Total CO2 emission (tCO_2) = Total fuel consumption (liter) x CO_2 emission factor (tCO2/liter)

Total weight transported =Total weight of passengers (adults + children) + Total weight of vehicle (vehicle + freight)

Energy demand by weight (kWh/k/trip)= Total energy demand (kWh)/Total weight (kg)

CO_2 emission by weight (g/kg/-trip)= Total CO_2 emission (gCO2)/Total weight (kg)

These figures are used to calculate CO_2 emission and energy demand from ferry transport for all sectors, such as household, agriculture, business.

3.1.1.3 Capacity factors of Rousay and Eday ferries

Due to maintenance and real demand of ferry transport, the capacities of ferries depend on the seasons. The table below presents passengers and cars transported by seasons and the respective capacity factors for both routes Tingwall-Rousay and Kirkwall-Eday.

Table 3. 3 Passenger and car transported by ferry and ferry capacity factors in 2008[12]

		Passenger transported	Capacity for Passenger	Passenger capacity factor	Cars transported	Capacity for Car	Car capacity factor
Tingwall - Rousay/Egilsay /Wyre	Summer	27,003	170,240	16%	6,779	17,920	38%
	Winter	23,212	109,200	21%	7,226	21,840	33%
Kirkwall-Sanday/Stronsay/Eday	Summer	30,115	111,860	27%	9,226	15,792	58%
	Winter	26,356	68,310	39%	9,460	18,216	52%

During the year, capacity factors of both passenger and vehicles are quite low with factors for Tingwall-Rousay/Egilsay/Wyre lower than 50%. The factors of the route Tingwall-Rousay/Egilsay/Wyre are lower than those of the route Kirkwall-Sanday/Stronsay/Eday, where three ferries are used. This is due to the large number of passengers and vehicles from/to Sanday/Stronsay.

3.1.1.4 Cost and Emissions from Private Vehicles

Private vehicles are very important for mobility on remote islands such as Rousay and Eday. In Rousay, there is only one public bus which operates once a week on Thursday, but in Eday

[12] David Sawkins – Marine Services, Orkney Islands Council; SESAM-IC2010

there is no public bus. Therefore car ownership is often seen as a necessity for access to different services and activities on the islands.

In this study, primary data about monthly household expenditure on fuel, brand, model and age of their vehicle and the annual mileage has been gathered through questionnaire and interview. Based on these data the annual transport energy demand and the carbon dioxide emission from the sample vehicles have been calculated. The expenditure on fuel stated by the respondents was used to do these calculations.

The expenditures on the different fuels were converted to the quantities consumed using the average price of 2009 which is the reference year of the study. People living in the two islands purchase fuel either in fuel stations or in bulk from fuel suppliers. Three types of fuel are used in the island. These are petrol or gasoline, white diesel (DERV) and red diesel. The average price of fuel is taken from the fuel stations in Eday, Rousay and Kirkwall. In addition to that, the average price of red diesel is taken from Scottish Fuel when it is supplied in bulk.

Table 3. 4 Fuel cost in Eday, Rousay and Kirkwall[13]

Fuel Type	**Kirkwall (£/liter)**	**Eday (£/liter)**	**Rousay (£/liter)**
Petrol	1.11	1.30	1.29
DERV (White Diesel)	1.14	1.27	1.30
Red Diesel	0.45	0.64	0.58

Detailed results of calculation of transport energy demand and the CO_2 emissions of private vehicles can be found in the following chapters.

Basic assumptions for the calculation are as follows:

	Diesel	Petrol	Unit
LHV[14]	10.00	8.80	kWh/Liter
CO_2 emission factor[15]	2.63	2.30	kg CO_2/Liter

[13] Interviews with Eday and Rousay fuel stations conducted between 16-Feb-2010 and 09-03-2010, (of the price of red diesel is taken from an interview with Scottish Fuel, The fuel price in Kirkwall is the wholesale price)

[14] www.h2data.de (16.03.10)

3.1.1.5 Cost and Emissions from Public Bus

Regular public buses are only available in Kirkwall. People in Rousay need to continue their travel from Tingwall to Kirkwall either by public bus, by taxi or by private car. People living in Eday have the advantage to arrive directly in Kirkwall.

Primary data on monthly expenditure of each household for using public buses have been gathered through questionnaires and interviews. As many residents of the islands use the buses free of charge or at reduced tariffs these data do not reflect the real use of public buses in the three studied sites.

Therefore to calculate the energy demand and the carbon dioxide emissions from the use of buses we took the CO_2 emission factor from DEFRA which is 140gCO_2/miles/passenger [16]. Based on this figure we calculated the energy demand of the public bus per mile and passenger.

3.1.1.6 Transport-related energy demand, CO_2 emission and expenditure on trips between the mainland and the islands

On the average, people from Rousay travel to the mainland by ferry three times as often as those from Eday (5.7 compared to 2 trips per month). This is mainly because of the short connection to Mainland from Rousay and the cheaper ferry fee.

The journey from Rousay to Kirkwall is divided into 3 parts: (1) from the house to the pier on the island, (2) from the pier on the island to the pier on the mainland and (3) from the pier on the mainland to the final destination. Depending on which type of transport mean the passengers use, expenditures, fuel consumption, energy demand and CO_2 emissions for each part of the journey are calculated separately.

Route 1: The passengers can either walk or drive by car from their house to the pier on the island.

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[15] DEFRA, 2007 (16.03.10)

[16] DEFRA (2007) page 21

Route 2: On the ferry, the passengers can travel with or without their car

Route 3: On the mainland the passengers can drive their car (either they bring it from the island or they have a car parked at the pier in Mainland), walk or take a bus from the pier to the final destination.

To calculate the transport related expenditures, fuel consumption, energy demand and CO_2 emissions for a typical household, 4 different scenarios have been developed for travelling from Rousay to Kirkwall and two scenarios for travelling from Eday to Kirkwall. The basic assumptions and inputs were as follows:

General assumptions

- A medium sized car is used with a fuel consumption of 6.9 miles/liter
- Average maintenance cost of the car is 60% of the fuel cost per mile.[17]
- Specific expenditures, fuel consumption, energy demand and CO_2 emissions of the ferry are taken from part 3.1.1.2, those of cars and busses are taken from part 3.1.1.4 and 3.1.1.5

Specific assumptions for Rousay:

- Average distance from house to ferry terminal : 3.6 miles
- Distance from Tingwall to Kirkwall : 15 miles
- Full price of ferry ticket for passenger and car: £ 3.5 and £ 11.15 respectively
- Price of a trip with the '10 trips ferry ticket' for passenger and car is £ 2.62 and £ 8.36 respectively
- Price of a trip with the '20 trips ferry ticket' for passenger and car is £ 2.45 and £ 7.8 respectively
- Price of a trip with the '50 trips ferry ticket' for passenger and car is £ 1.75 and £ 5.57 respectively

[17] Automobile association, 2010 http://www.theaa.com/allaboutcars/advice/advice_rcosts_petrol_table.jsp

Table 3. 5 Different journey options from Rousay to Kirkwall

	Rousay								
	CO_2 (kg/trip)				***Energy (kWh/trip)***				***Cost (£/trip) Full and reduced ferry fares***
	Island	*Ferry*	*Mainland*	*Total*	*Island*	*Ferry*	*Mainland*	*Total*	
Car-Car on Ferry-Car	1.48	19.13	7.36	27.96	6.01	65.03	29.80	100.84	18.45
									14.79
									14.05
									11.12
Walk-Passenger on Ferry-Car	-	1.13	7.36	8.48	-	3.83	29.80	33.63	6.66
									5.78
									5.61
									4.91
Walk-Passenger on Ferry-Bus	-	1.13	2.52	3.65	-	3.83	9.56	13.39	6.20
									5.33
									5.15
									4.45

For each different option, four prices were calculated, considering the different tariffs that Orkney Ferries offer to Eday and Rousay residents. The energy consumption and CO_2 emission that was assigned to a passenger on the ferry was only around 5% of the emissions which was assigned to a car on the ferry. Further reduction would be achievable if public transport is used to travel from Tingwall to Kirkwall centre.

For Eday, the basic assumptions were as follows:

- Average distance from house to ferry terminal: 4.1 miles
- Distance driven within Kirkwall is 2 miles
- Full price of ferry ticket for passenger and car: £ 6.8 and £ 16.25 respectively
- Price of a trip with the '10 trips ferry ticket' for passenger and car is £ 5.14 and £ 12.19 respectively
- Price of a trip with the '20 trips ferry ticket' for passenger and car is £ 4.8 and £ 11.375 respectively
- Price of a trip with the '50 trips ferry ticket' for passenger and car is £ 3.425 and £ 8.125 respectively

Table 3. 6 Different journey options from Eday to Kirkwall

	Eday								
	CO_2 (kg/trip)				***Energy (kWh/trip)***				***Cost (£/trip) Full and reduced ferry fares***
	Island	*Ferry*	*Mainland*	*Total*	*Island*	*Ferry*	*Mainland*	*Total*	
Car-Car on Ferry-Car	1.68	81.60	0.82	84.09	6.79	279.23	3.31	289.32	24.17 18.40 17.24 12.62
Walk-Passenger on Ferry-Walk	-	4.80	-	4.80	-	16.43	-	16.43	6.85 5.14 4.80 3.43

As in Rousay, four different prices were calculated for each option. The ferries which are used to serve Eday, Stronsay and Sanday are ferries with high diesel consumption, therefore, 263 kWh and 77 kg CO_2 per trip was assigned to a car traveling on the ferry.

3.1.2 Embedded transport energy, cost and emissions

The embedded transport energy is the amount of energy used in transport to produce, commercialize or buy a product or service in one specific location. For example, if a household in Rousay buy their groceries in the local shop every kilogram of product bought has an embedded transport energy consumption, emissions and cost which are incurred during the transportation of the groceries from Kirkwall to the shop.

As the study focuses on the influence of transport on the living cost in Rousay and Eday, it is assumed that these embedded costs finally have to be borne by the households. In the case of agriculture and business it reduces the profit from business activities on the islands compared to Kirkwall. Embedded transport is related to almost all activities in our lives and for this research project the calculation focuses on the following activities:

- House construction
- Food supply through the island shops
- Transport of fuel to the islands

In general, the farms and the businesses buy the inputs for their activities directly in Kirkwall and not from suppliers on the islands. Therefore their transport demand is exclusively considered as direct transport.

3.1.2.1 House Construction

This exercise was done to estimate the transport energy consumption, cost and emissions associated with the construction of two identical 131 m^2 wood frame houses in Rousay and Eday. The required materials and quantities were obtained and calculated from drawings and specifications of an existing house in Rousay (See details in Annex 1). Based on the assumption that all the materials are purchased in Kirkwall, estimates of the transport costs from Kirkwall to the two islands were obtained from the local transport service providers. The results from the estimates of the quantities and their costs (Figure 3.1) shows that the total transport expenditure for building a house of 131 m^2 in Rousay is £ 2,400 and £ 2,514 in Eday.

The difference in the transportation cost is only 4.5% even though the difference in the ferry fees for a 7.5 m long lorry is 35.23%. This difference could be due to the fact that the ferry from Rousay arrives at Tingwall, whereas the Eday ferry goes directly to Kirkwall, hence making the total travel times from both islands to Kirkwall almost equal.

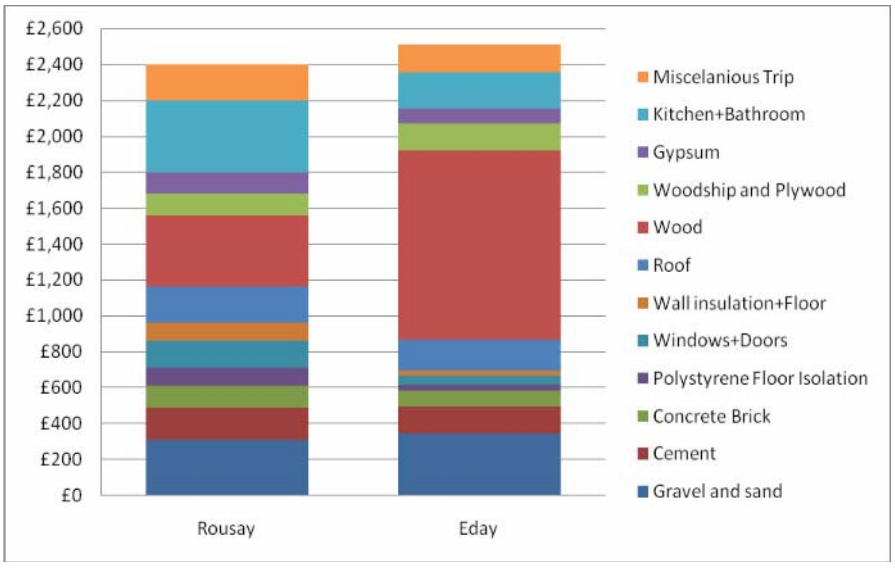


Figure 3. 1 Transport cost for a 131 m^2 wood frame house in Eday and Rousay

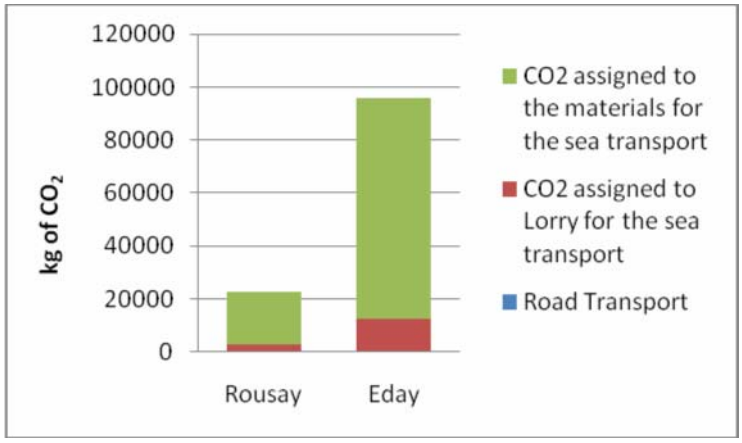


Figure 3. 2 CO_2 emissions assigned to the transport of materials for the reference house

For the CO_2 calculation the following values were used:

- The total estimated weight of the house material is 93 tones.
- The weight for an unloaded 7.5 meter long lorry is 7 tones[18]
- The distance between Tingwall ferry port and Kirkwall is 13.5 miles[19].
- The CO_2 emission per kg transported by the ferry between Tingwall and Rousay is 15 gCO_2 / kg of weight per ferry trip
- The CO_2 emission per kg transported by the ferry between Kirkwall and Eday is 64 gCO_2 / kg of weight per ferry trip
- The lorry CO_2 emission per mile is 0.47 kg/mile[20].

Assuming a total of 14 trips to transport all the building materials from Kirkwall to both Rousay and Eday, the total embedded CO_2 emissions is 23,213 kg per house in Rousay and 95,872 kg per house in Eday. In figure 3.2 the total emissions are presented for the two Islands. The higher CO_2 emissions for Eday, is basically due to the difference between the emission factors of the ferries from Eday and Rousay (Sea transport). The total emissions per kg transported in the Eday ferry is more than 3 times greater than in the case of Rousay and this is not only caused by the difference in distance but also by the difference between the emissions factors per kg of weight transported by ferry, which is 4.26 times bigger in Eday than in Rousay.

[18] Volvo FH 42T B3HC1, 2010. Model Ragnge. Available on http://www.volvotrucks.com/trucks/uk-market/en-gb/trucks/Volvo-FH/Pages/datasheets.aspx

[19] Google maps; Distance between Tingwall and Kirkwall. 09/03/10

[20] IPCC, 1996. Guidelines for National Greenhouse Gas Inventories. Volume 3: Reference Manual. Available on http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm.

For the calculation of the embedded transport energy consumption the following parameters are used:

- The total estimated weight of the house material is 93 tonnes.
- The weight of an unloaded 7.5 meter long lorry is 7 tonnes[21]
- The distance between Tingwall ferry terminal and Kirkwall is 13.5 miles.[22]
- The energy consumption per kg transported by the ferry between Tingwall and Rousay is 0.051 kWh/kg of weight per ferry trip.
- The energy consumption per kg transported by the ferry between Kirkwall and Eday 0.219 kWh/kg of weight per ferry trip.
- The lorry energy consumption is 0.56 miles/kWh[23]

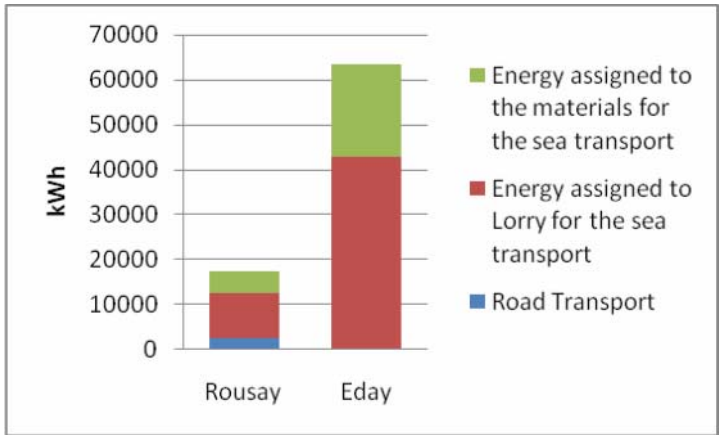


Figure 3. 4 Transport energy demand for the transport of materials of the reference house

Using the above data and the assumption of 14 trips to transport all the materials to the site, the embedded transport energy consumption for the house in Eday is 63,291 kWh and 17,439 kWh in Rousay.

In figure 3.3 the total transport energy consumption for transporting the house materials, are presented for the two Islands. Note that the result is consistent with the CO_2 emissions, because the biggest energy demand is caused by the sea transport and transport energy demand in the Eday case is bigger than in the case of Rousay.

3.1.2.2 Food supply through island shops

[21] Volvo FH 42T B3HC1, 2010. Model Ragnge. Available on http://www.volvotrucks.com/trucks/uk-market/en-gb/trucks/Volvo-FH/Pages/datasheets.aspx

[22] Google maps; Distance between Tingwall and Kirkwall.

[23] IPCC, 1996. Guidelines for National Greenhouse Gas Inventories. Volume 3: Reference Manual. Available on http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm.

For the calculation of the embedded transport costs and carbon emissions associated with the food supply, a basket of food and drink items for one month for a standard household of four persons was developed, based on the purchased quantities of household food and drinks for Scotland[24]. The detailed list, with items and quantities is shown in annex 1.

The prices for the items in the baskets in Rousay, Eday and Kirkwall were compared. In Eday and Rousay, the prices were obtained from the local shops. And the prices from Kirkwall were obtained from the supermarkets LIDL, TESCO and COOP.

The original basket items were selected from the shop in Rousay and based on this the baskets for Kirkwall and Eday were also made. For a fair comparison, items of the same brand were chosen, and in the case where this was not possible a product of similar quality was selected.

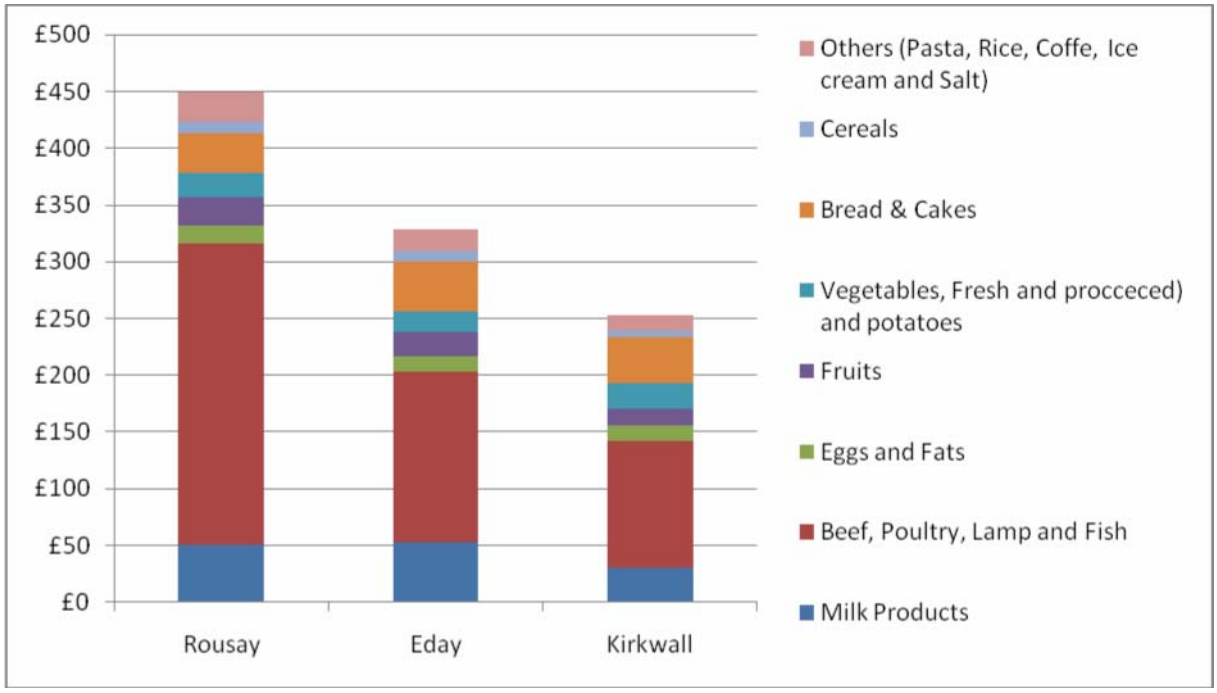


Figure 3. 5 Cost of Food and drinks in food baskets

The results of the comparison (figure 3.4) shows that a household buying in Rousay would spend £131/month more for the same basket of food and drinks than buying in Eday. When compared to buying in Kirkwall, the household would spend £196/month more in Rousay. The basket of goods from the Eday shop costs £ 76/month more than in Kirkwall.

[24] Office of national statistics-UK: Family spending 2009

Even though most of the items are cheaper in Kirkwall, the biggest difference between Kirkwall, Eday and Rousay is the price of the meat products. Of the total price difference between the basket in Kirkwall and Rousay, 78% is due to the meat price difference. For the basket price difference between Eday and Rousay more than 90% is due to the meat price difference.

In principle the total price difference cannot be explained only with the transports cost because there are other factors in the cost structure of each location, like size of the shop (the local shop in Rousay is smaller than the local shop in Eday), stock turnover, electricity, salaries, etc. Another indicator that the difference is not only due to transport cost is the fact that it is not evenly distributed among all the product groups.

Assuming a household in Rousay goes shopping in Kirkwall twice a month taking their own vehicle, then the total transport cost comprising of ferry fees plus 0.1755 £/mile[25] of fuel cost and maintenance would be £63.34 a month.

Considering this behavior, the total energy consumed per kilogram of food and drinks would be 3.18 kWh/kg and 0.88 kg of CO_2/kg would be produced. For the surveyed sample in Rousay, only 40% of the households shopping expenditure are spent in the local shop. The embedded transport energy and emissions per kilogram of food from the local Rousay shop is approximately 1.26 kWh/kg and 0.34 kg of CO_2/kg of food and drinks.

If a household do their entire grocery in Kirkwall instead of in the local Rousay shop, an amount of 138 £/month would be saved on the food and drinks expenditure but an extra transport energy of 219 kWh would be consumed and 61.52 kg more of CO_2 produced. As stated earlier, this total price difference is as a consequence of the high price difference in the meat products which can be explained with the absence of a slaughterhouse on the island and therefore farmers have to transport the living animals to the slaughter in Kirkwall and then transport the meat product back to the island which increases the price substantially.

[25] Automobile association, 2010 http://www.theaa.com/allaboutcars/advice/advice_rcosts_petrol_table.jsp

If the percentage of the household's shopping expenditure in Rousay is increased to 90%, the new embedded energy and emissions per kilogram of food and drinks in the local store would be 0.16 kg of CO_2/kg and 0.59 kWh/kg. This represents approximately a 53% reduction in the embedded energy and emissions per kilogram of food and drinks.

In the case of Eday a household would spend £ 92.4 for two round trips between Eday and Kirkwall per month for shopping if they go with their own car. For these 2 round trips they would consume 5.12 kWh/kg and produce 1.5 kg of CO_2/kg of food and drinks.

The household would expend £16 more for shopping in Kirkwall than for shopping in Eday and considering that for the surveyed sample where 73% of the household's shopping expenditure is done in Eday, the embedded energy and emissions per kilogram of food for the local Eday shop is approximately 3.57 kWh/kg and 1.04 kg of CO_2/kg of food and drinks. So if a household in Eday do all their shopping in the community store (according to the food basket developed), not only would they save £16 per month, but also would consume 177 kWh less transport energy and produce less CO_2 emissions per month (51.72 kg/CO_2) when compared to doing their monthly shopping in Kirkwall.

In figure 3.5 all the analyzed cases are compared; note that the embedded transport energy and emissions between the individual shopping in Rousay are almost the same as in the local shop of Eday, this example shows the social and environmental benefits of using the local shop as a main provider.

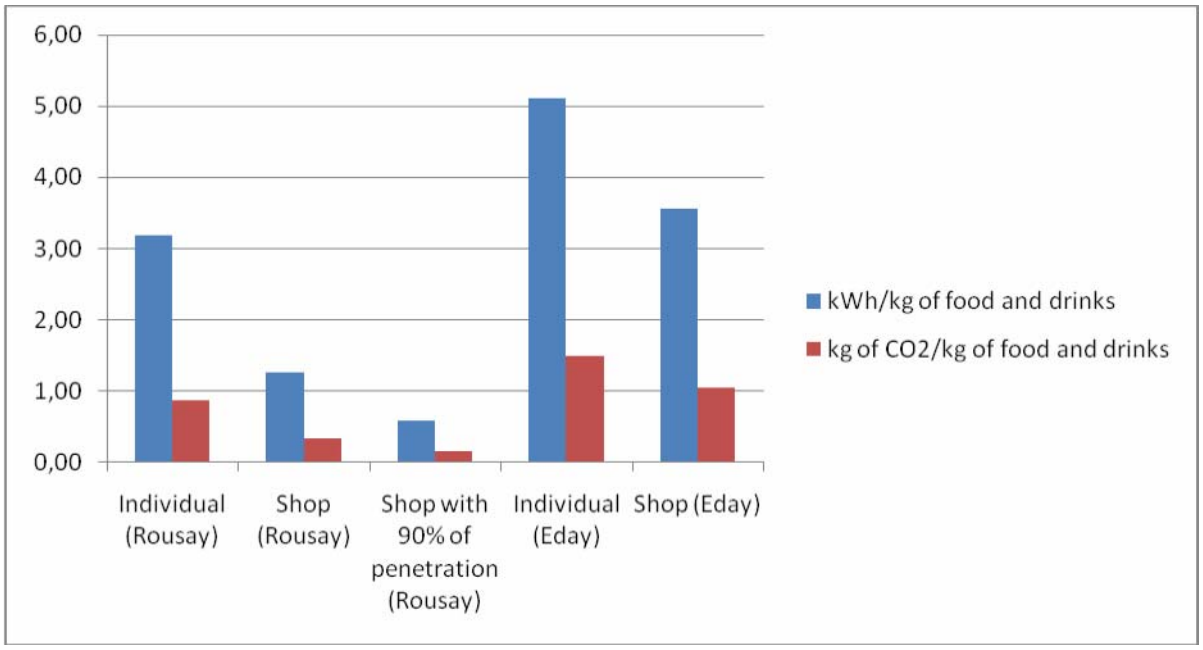


Figure 3. 6 Transport energy and emissions per kg of food and drinks for different scenarios

3.1.2.3 Transport fuel cost

The table 3.4 in chapter 3.1.1 shows the fuel prices in Eday, Rousay and Kirkwall; there is a difference of 17.11% for petrol, 11.4% for DERV and 42.22% for red diesel between Eday and Kirkwall. Between Rousay and Kirkwall there is a difference of 16.21% for petrol, 14.04% for DERV and 28.89% for red diesel. Even though Rousay is closer to Kirkwall than Eday the difference in cost of transport fuel, compared with Kirkwall is almost the same as in Eday.

From the available data it is not possible to determine the real value of the embedded transport cost in the presented fuel costs; however it can be said that in the case of Eday, the embedded transport costs are close to the difference between Kirkwall and Eday prices.

The difference in prices in food and fuel between Rousay and Eday, help to explain why from the studied sample, 23.3% refuel their vehicles in Rousay local fuel station, because once a household member is in Kirkwall, he can easily refuel the vehicle and save money not only on food but also on fuel.

In the case of Eday, although the difference to Kirkwall fuel prices is in the same order of magnitude as in Rousay, 69.5% of the studied sample refuel their vehicles in Eday, however,

as it was explained before, the difference in food prices between Eday and Kirkwall is smaller than in the case of Rousay, hence the total savings from buying the food and refueling the vehicles is smaller in Eday than in Rousay. This fact helps to understand the different behavior between the surveyed households in Eday and Rousay.

3.2 Transport Energy Consumption, CO_2 and Cost in Households

The direct transport energy consumption, emissions and costs for Rousay and Eday households were calculated and analyzed, comparing their behavior and transport sector performance with the Kirkwall households in Orkney mainland, based on the survey findings in each location. As far as the fuel consumption for heating purposes is concerned, the embedded transport energy demand to bring heating fuels to the islands was analyzed.

In this chapter the survey findings of the household sector for the three different analyzed sites will be presented and compared. For this matter the facts presented in the following table were considered.

Table 3. 7 Household survey sample

	Rousay	**Eday**	**Kirkwall**
Total Population	220	151	8,686
Total Households	105	73	3,120
Households Sample	60	46	57
Hosehold Sample (%)	57.1%	63.0%	1.8%
Population represented in sample	131	102	147
Population represented in sample (%)	59.5%	67.5%	1.7%

3.2.1 Transport Behavior

For the analysis of transport behavior per household it was relevant to know how many individuals work away from home and how they go to their jobs.

In both, Eday and Rousay, the percentage of the samples that do not work (including retired people) is about 35% while it is 24% in Kirkwall. The percentage of the samples that go to school in Eday, Rousay and Kirkwall are 7%, 15% and 24% respectively. In Eday 60% of the studied sample has at least one job, whereas in Kirkwall and Rousay these are 52% and 49%

respectively. Another finding is that in the three sites at least 50% of the sample is economically active. (For detailed information see Annex II Percentage of economically active and inactive population)

The findings also show that the number of people who work at home is higher in Rousay and Eday than in Kirkwall. In Eday approximately 51% of the economically active population work at home. In the case of Rousay this figure is nearly half, around 27% and in Kirkwall only 4% of the working population work at home. The remaining populations of the three sites work away from their residence. (Annex II Percentage of working population that works at home and away from home).

In Kirkwall 60%, in Rousay 59% and in Eday 68% of the people go to work by car. One interesting finding is that from the 68% of the people in Eday who use cars to go to work 61% use 4x4. This figure is 23% in Rousay and 10% in Kirkwall. That means that on the average people in Eday are using less efficient vehicles. This affects the specific transport energy demand per household. (Annex II People's preference to go to work)

Of the studied samples in Rousay 74% of the working population work inside the island. In Eday this group represents 95% and in Kirkwall 94% of the total working population work on the mainland. The higher percentage of people from Rousay working on the mainland (26%) compared to Eday (5%) can be explained with the fact that Rousay is closer to the mainland than Eday and has more frequent ferry connections. (Annex II Percentage of the people that work in Mainland).

Regarding the number of jobs per person the behavior is similar in the three analyzed sites. The most common situation is that the residents only have one job (Kirkwall 94%, Rousay 78%, and Eday 69%). Economically active people living in Eday and Rousay are more likely to have more than one job than people who live in Kirkwall. In Eday 26% of the working population has a second job, in Rousay 16% and in Kirkwall only 6%. In Rousay 6% and in Eday 5% of the economically active people have a third job. (Annex II Number of jobs per person -main job, second job, third job)

Both Rousay and Eday have a shop. However, Rousay households do 60% of their shopping on the mainland while in Eday only 27% of the shopping is done on the mainland.

In Eday there is no public transport whereas in Rousay there is a public bus that runs only once a week. This fact makes it indispensable to have a car in those islands. In Eday all households in the sample have at least one vehicle. In Rousay 10% of the households do not have a vehicle. In this island the highest populated area is around the pier. Furthermore, between Tingwall ferry station and Kirkwall there is a bus connection. These two facts make it possible for a certain percentage of the population to live without a vehicle. In Kirkwall there are different public bus lines which could be one of the reasons why approximately 8% of the interviewed households in Kirkwall have no vehicle. Most of the households in all three locations have only one vehicle per household. (Annex II, Number of vehicles per households)

In Rousay fewer households than in Eday have only one vehicle. 48% of the households in Rousay have two or more vehicles, 45% in Kirkwall and 42% in Eday. It was also found that 13% of the vehicles of Rousay residents are parked at the Tingwall ferry terminal. One of the reasons found through the interviews is the high ferry travel cost for vehicles. Especially resident who have to travel to the mainland frequently find it cheaper to have a second car in Tingwall than to take their car on the ferry.

The people from the sample in Rousay go to mainland on average 67.5 times per year and the people from Eday go to mainland 23.6 times per year. The Rousay residents go to the mainland on the average about 3 times more often than the people in Eday.

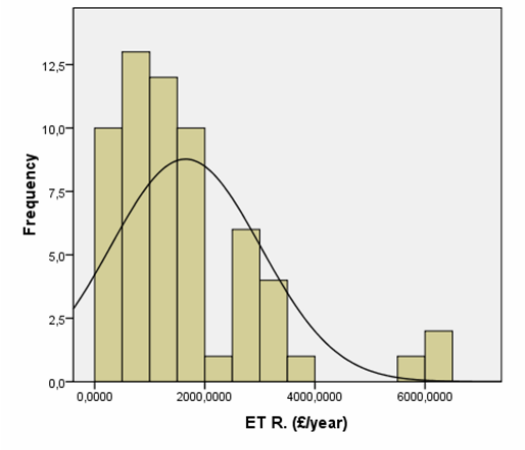
3.2.2 Expenditure on transport per household

The analysis of the expenditure on transport per household was based on the findings of the total expenditure on fuel for private vehicles, boats, ferry and public bus. The mean values of the samples were used for the comparison and histograms were used to illustrate the distribution of the total expenditure in a particular sample. The comparison of the results of the three samples was done using the statistic software SPSS.

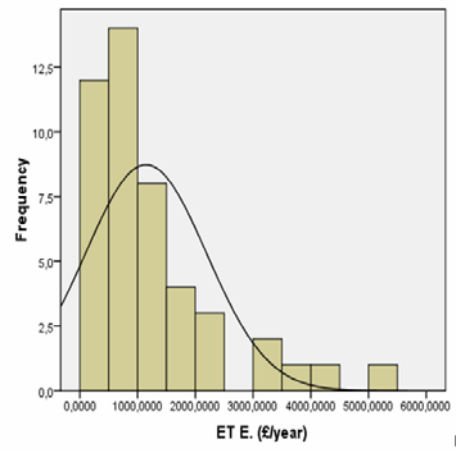
The results that are shown in figure 3.6 (histograms) demonstrate that the distribution of the values of Rousay, Eday and Kirkwall are skewed to the left. This indicates that the majority of the people of Rousay and Eday spend between 0 and 2000 £/year and in Kirkwall between 0

and 1000 £/year on transport. Moreover the histograms show us that the majority of the people of the sample from Rousay and Eday spend more in transport than the majority of the Kirkwall households.

Rousay Histogram



Eday Histogram



Kirkwall Histogram

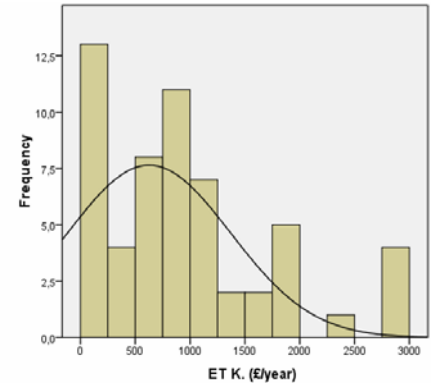


Figure 3. 7 Histograms – Expenditure on transport per household (ET) -Rousay, Eday and Kirkwall- (£/year)

According to the average values of the expenditure on transport per household the Eday households spend 17.6% more than the households in Kirkwall, whereas the households in Rousay spend around 44.9% more than the households in Kirkwall. The high value in Rousay can be due to the fact that the people there use the ferry more often than the people from Eday.

Table 3. 8 Household expenditure on transport per household (£/year)

	Kirkwall	Rousay	Eday
Mean annual transport expenditure	£1,712.62	£2,480.79	£2,014.63

3.2.3 Energy demand for transport per household

The values shown in the figure 3.7 represent the average transport energy demand per household of the samples. These values were calculated according to the fuel consumed by the household vehicles during one year (in the graphic HH Vehicle) and the energy used by the ferry between Rousay and Tingwall and Eday and Kirkwall (in the graphic HH Ferry).

The total energy demand for transport per household in Eday is 22.5% higher than Kirkwall. On the other hand the total energy demand in Rousay is 46% higher than in Kirkwall. The higher energy demand in Rousay can be explained with the number of travels to the mainland per year per household member. The residents of Rousay travel on average 44 times per year more to the mainland than the residents of Eday.

From the total energy demand for transport in Rousay 33% and in Eday 23% is related to the ferry. The remaining energy demand is caused by the vehicles. The total energy demand for transport is 43.3% higher in Rousay than in Eday. One interesting fact is that in Rousay the average energy consumption per household for ferry use is about double the one of Eday. This fact can be explained with the higher frequency of the ferry trips per day between Rousay and Tingwall than Eday to Kirkwall.

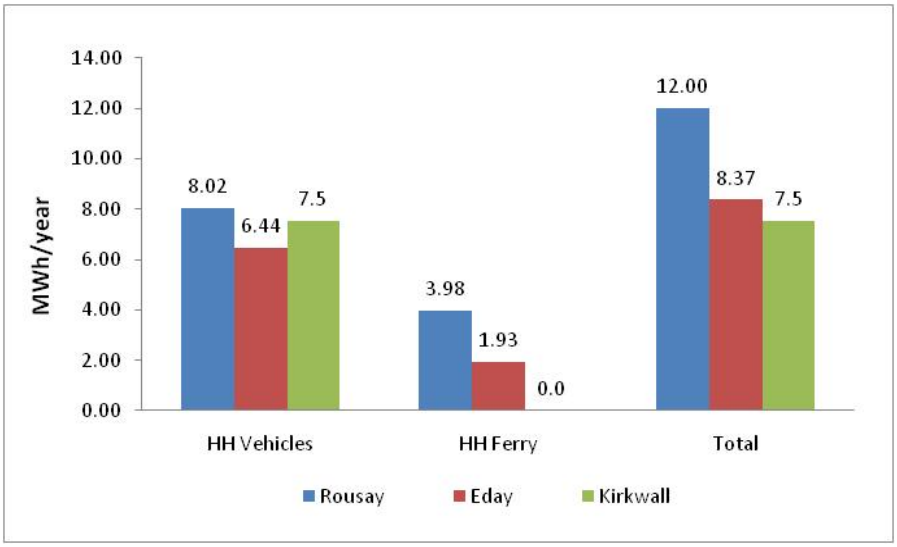


Figure 3. 8 Average household energy demand for transport (Mwh/year)

3.2.4 CO_2 emission for transport per household

The calculation of the CO_2 was based on the fuel consumption of the household vehicles and the use of the ferry to go to the mainland. The transport energy demand and the emissions were calculated on the same basis. In Rousay the CO_2 emissions related to transport on the island and between the island and Kirkwall are 66.3% higher than the local transport emissions in Kirkwall. In the case of Eday they are 14.6% higher than in Kirkwall. The emissions of the household vehicles in the sample of Rousay and Kirkwall are almost the same. Eday household vehicles produce around 0.3 tons CO_2 per year less than those in Kirkwall and Rousay. The frequency of the trips of the ferries are the main driver for the fuel consumption and therefore the emissions. See table 3.10 for more details.

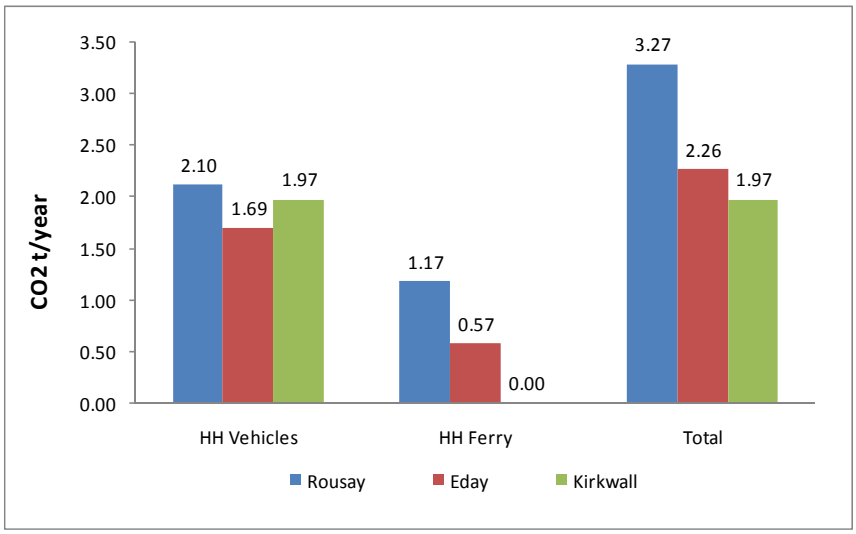


Figure 3. 9 Average CO_2 emission for transport per household (t/year)

The following table shows the CO_2 emissions per person in a national level according to the Scottish Transport Statistics (2008). In the case of Rousay, Eday and Kirkwall the emissions of the vehicles were calculated only with the local travels whilst the CO2 emission of the passenger cars of Scotland include all kind of travels. In spite of this fact in Rousay the total average household member emission for passenger car and navigation transport is higher than the national levels. The high frequency of the ferries between Tingwall and Rousay can be the explanation.

Table 3. 9 Average Emissions for passenger car per person in Scotland compared to Rousay, Eday and Kirkwall

	Scotland		
Total Population (2006)[26]	5,116,900		
Passenger cars Scotland plus national navigation CO_2 emission [27]	7,020,000.00		
CO_2 emission per person national level (t CO_2/year)	**1.37**		
	Rousay	**Eday**	**Kirkwall**
Total household members of the sample	131	102	147
HH total CO_2 Emission for transport (only vehicles and ferry Rousay-Tingwall, resp.Eday-Kirkwall, t CO_2/year)	196.40	103.80	112.20
CO_2 emission per household member	**1.50**	**1.02**	**0.76**

3.3 Transport energy demand, cost and CO_2 emissions in agriculture

Agriculture is one of the biggest economic activities in the two islands as it is in Orkney generally. Farmers who are living in these two isles are affected by a higher transport cost when they purchase agricultural supplies including feed for livestock, fertilizer, vets, fuel and others. On the other hand, most farmers sell their products in Orkney Auction Mart which again implies a higher transport energy demand.

3.3.1 Description of the sample

This study team interviewed 12 farmers on each island out of 14 and 16 farmers on Eday and Rousay respectively. Out of the samples taken in Rousay, 100% of the farmers are involved only in livestock whereas in Eday 10 of the 12 farmers are involved only in livestock.

Out of the sample taken 67% of the vehicles in Rousay and 58% of the vehicles in Eday which are involved in the agricultural sector are tractors. However, in this study tractors are not included in the transport sector. This is to keep consistency with the European

[26] General Register Office for Scotland, SCOTLAND'S POPULATION 2008

[27] Scottish Transport Statistics 2008 Edition, P, 138

Commission method of reporting Greenhouse Gas Inventory to the UNFCCC Secretariat as it is mentioned in the "Annual European Community Greenhouse Gas Inventory 1990–2007 and inventory report 2009".[28] According to the document, tractors are included under the category 1A4 which mainly includes emission from 'small scale fuel combustion' (Page 189). Tractors are accounted in the road transport sector only when they are used with road trailers but in the two isles transportation of inputs and outputs to and from Kirkwall is done mainly with haulage companies.

The majority of the interviewed farmers use the tax reduced red diesel. To keep the price even cheaper the majority of the farmers in both islands buy the red diesel in bulk from fuel suppliers such as Scottish Fuels and Highland Fuels.

3.3.2 Transport Energy Demand and CO_2 Emission

The following table presents the summary of the demand for different types of fuels and the associated carbon dioxide (CO_2) emission excluding the energy demand and emission from tractors.

Table 3. 10 Summary of the demand for different types of fuel and CO_2 emission by transport in the agricultural sector in Rousay

Fuel Type	Annual Fuel Consumption (liter)	Annual Transport Energy Demand (MWh)	Annual CO_2 emission of the sample (tons)
Petrol	1544.18	13.59	3.55
DERV	3563.24	35.63	9.37
Red Diesel	5297.94	52.98	13.93
Total		102.20	26.86

As shown in the table above, the road transport in Rousay represents an annual transport energy demand of 102.20 MWh and an associated emission of 26.86 tons of CO_2. This value

[28] Erasmia Kitou et al. (2009). Annual European Community greenhouse gas inventory 1990–2007 and inventory report 2009. Brussels. European Commission

is quite low as compared to the energy consumption and emission from the tractors which is 959.71 MWh and 252.35 tons of CO_2 respectively.

According to the survey in Rousay, 100% of the farmers get their agricultural input supply from the mainland. In most cases the farmer is responsible for transporting the supplies and also more than 65% of the farmers transport and sell their products on the mainland. Most of the farmers use haulage companies for these transport works.

In Eday the agricultural road transport of the sample represents an annual transport energy demand of 191.32 MWh and associated emission of 50.29 tons of CO_2, as it is shown in the table below. Again these figures are very low as compared to the energy demand and corresponding emission from the tractors in the farming sector which is 423.65 MWh and 111.42 tons of CO_2 respectively.

Table 3. 11 Summary of the demand for different types of fuel and CO2 emission by transport in the agricultural sector in Eday

Fuel Type	Annual Fuel Consumption (liter)	Annual Transport Energy Demand (MWh)	Annual CO_2 emission of the sample (tons)
Petrol	1721.54	15.15	3.96
DERV	9354.85	93.55	24.60
Red Diesel	8262.33	82.62	21.73
Total		191.32	50.29

The chart below shows the comparison of the average transport energy demand of the two islands. Even though an equal number of farmers were interviewed in both islands, the transport energy demand per farm on Eday is found to be more than 85% higher than the demand per farm on Rousay.

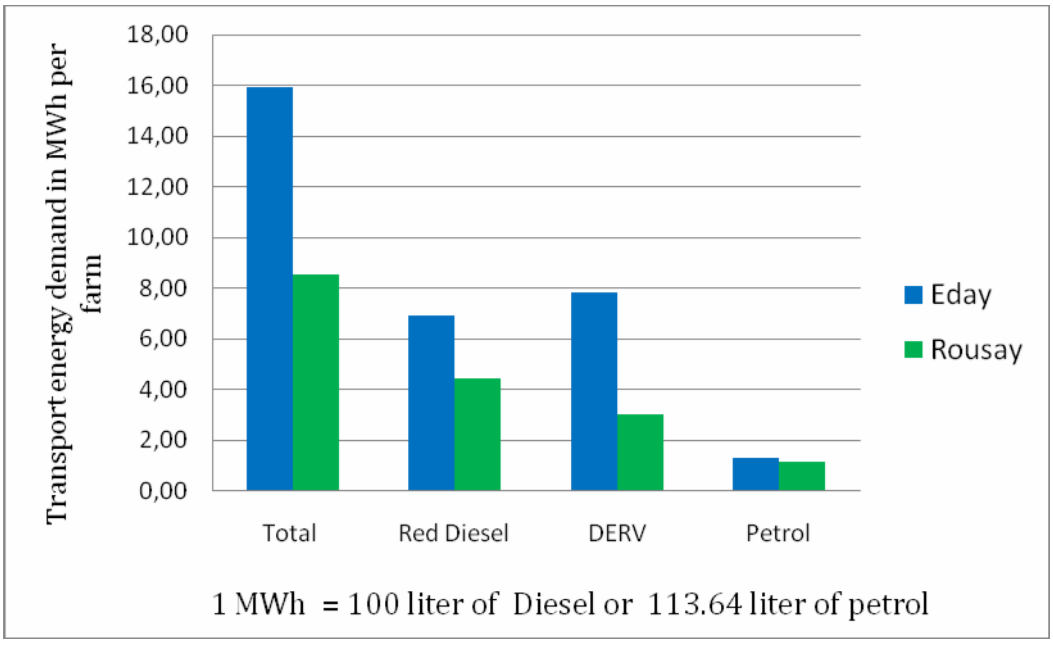


Figure 3. 10 Comparison between Eday and Rousay for annual transport energy demand per farm in the agricultural sector

3.3.3 Transport Expenditure

The average annual expenditure on fuel in the agriculture sector is £993.05 and £725.57 for Eday and Rousay respectively. The expenditure in Eday is still 37% higher than that of Rousay but this difference is not as big as in the case of transport energy demand (more than 85%), caused by the higher share of red Diesel on Eday

In addition to the apparent transport energy demand presented so far, we also need to take into account the transport energy demand of the agriculture sector through the haulage companies and from ferry transport. Most farmers in Eday get their agricultural supply from the mainland at least 3 times a month and sell their products to the mainland at least thrice a year. In Rousay most farmers get their agricultural supply from the mainland at least twice a month and sell their products to the mainland at least 2 times a year. The next section presents a case study to take into account the issues which have been presented in this section.

3.3.4 Life cycle transport assessment of agricultural products

In a broader sense, in the last few years there have been a number of discussions in UK about food production and supply chain. Food that has travelled long distances is perceived as

having a negative impact on the environment. The distance food travels from the farm to consumer is known as “food miles”.

The study team has made an analysis in the farm sector of these two islands and found some results regarding the transport energy demand and CO_2 emission in the life cycle of cattle and sheep production. For analysis purpose, a typical farmer who annually brings 100 cattle and 500 sheep to the Orkney Meat for slaughtering is assumed. The allocation of transport energy demand and CO_2 emission is done based on the weight of the animals regardless of the revenue generated by the farmer.

Some farmers in these islands bring fertilizer from the Mainland to grow feed for the cattle and some farmers directly buy the feed from the Mainland. For both cases, the chart below shows the transport related carbon dioxide emission associated with each kilogram of cattle and sheep meat.

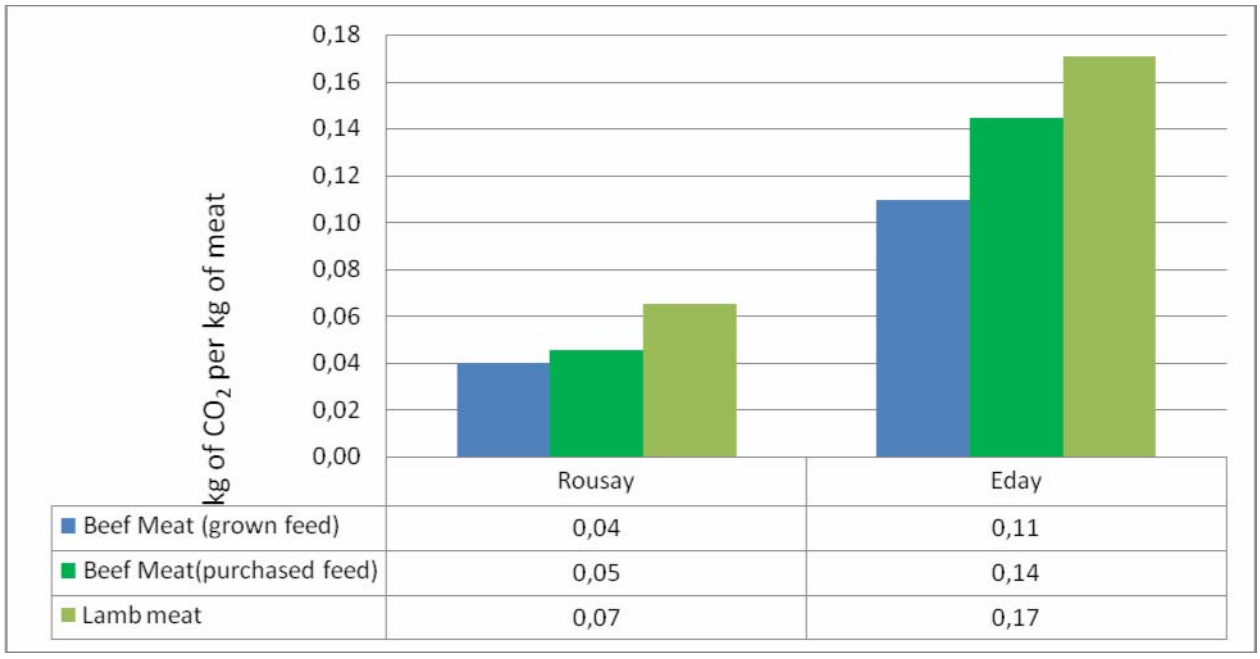


Figure 3. 11 Transport related CO_2 Emission in the whole life cycle of Meat Production

As shown in the chart above, the transport related CO_2 emission in these two islands is higher for a lamb meat. To produce one kg of lamb meat requires 0.56 and 0.15 kWh of transport energy in Eday and Rousay respectively. This is due lower total weight of the lambs carried per ferry trip. The transport energy demand of the beef meat when the feed is grown at the

farm is 0.36 and 0.1 KWh per each kg of meat produced in Eday and Rousay respectively. When feed is purchased from the mainland, the transport energy demand of the beef meat is 0.48 and 0.12 kWh per each kg of meat produced in Eday and Rousay respectively.

3.4 Transport energy consumption, CO_2 emission and cost in shops and businesses

In this chapter, a summary of main findings of transport-related energy consumption, CO_2 emissions as well as expenditures of shops and other small business in Rousay and Eday will be presented and analysed. Expenditures on embedded transportation and behaviours of people in Rousay and Eday in purchasing food and drinks are also calculated and shown in the second part of the chapter.

3.4.1 Small business

The number of business activities in Eday and Rousay is relatively low as compared to the number of farms. In Rousay, interviews were conducted with 12 out of 15 businesses including a privately owned shop and fuel station. Similarly in Eday, 5 out of 7 businesses have been interviewed including the Eday Community Enterprise. Some of the businesses in these two islands have no separate vehicle for their business activities, especially very small businesses like Bed and Breakfast. In these cases their transport activities have been considered as household activities.

In Rousay, only 46 % of the vehicles in the small business sector are fueled at the local fuel station. This is because the fuel price at the Rousay fuel station is higher than in Kirkwall. In Rousay, an annual transport energy demand of 56.32 MWh for the total surveyed 10 business firms represents total fuel expenditures of 6,480 pounds. The total associated emission from these firms is 14.81 tons of CO_2.

In Eday, the transport energy demand and the annual fuel expenditure of the surveyed 4 business firms are 16.86 MWh and 2,240 pounds consecutively. The emission from this energy consumption is 4.41 tons of CO_2.

The table below shows the comparison of the two islands for small business transport energy demand, expenditure and associated emission of CO_2. per firm per annum. The figures for Rousay are higher than for Eday. In Rousay 3 firms out of 10 firms have no vehicle exclusively for their business activities. On the other hand, in Eday 1 out of 4 interviewed firms has no car that is only used for business.

Table 3. 12 Comparison of the two islands for small business annual transport energy demand, expenditure and associated emission of CO_2 per firm

	Average annual fuel expenditure per firm(£)	Average annual energy demand per firm (MWh)	Average annual emission per firm (tCO_2)
Eday	746.67	5.62	1.47
Rousay	977.14	8.05	2.12

3.4.2 Transport-related energy demand, CO_2 emission, expenditure of shops

3.4.2.1 Transportation activities and expenditures of shops

In Rousay, there are two shops. Both of them belong to private owners. In Eday, there is only one shop that is owned by Eday Community Enterprises (ECE). In the table below, a summary of their purchasing and selling activities with a focus on transport is presented.

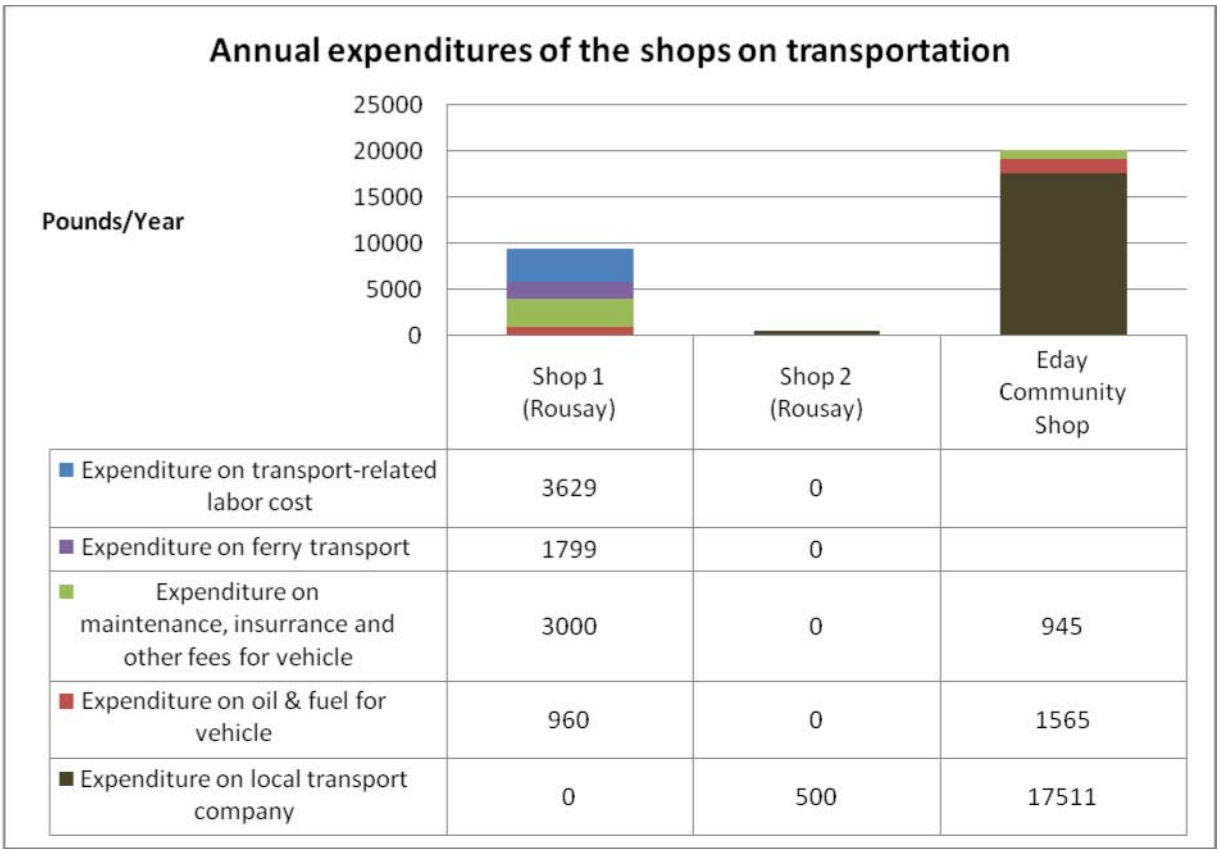
Table 3. 13 Transport activities and expenditures of shops

No	**Name of shop**	**Location of suppliers**	**Transporter**	**Frequency of supply**	**Expenditure of shop for transportation**
				times/month	***(£/year)***
1	Shop 1 (Rousay)	Kirkwall (main suppliers)	-Shop (van used)	12	9,388
		Rousay (farms)	Farms	8	0
2	Shop 2 (Rousay)	Kirkwall (main suppliers)	-Local transport company	8	500
		Rousay (farms)	Farms	8	0

3	ECE (Eday)	Kirkwall (main suppliers)	- Local transport company -Shop (car & truck used)	12	20,012
		Eday	-Farms	8	0

The transportation expenditure of shop 1 includes fuel and miscellaneous expense for vehicle, ferry transport expense and labour cost for purchasing products from Kirkwall. The Scottish minimum wage for an adult of £5.8/hour is considered in the calculation. Shop 2 does not use their own vehicle for their business, thus their transportation expenditure is only for the services of the local transport company.

The transportation expenditure of ECE includes fuel and miscellaneous expenditures for vehicles and for a local transport company. All local farms deliver their products to the shops without any additional transportation cost (for detailed calculations, please see annex III).



	Shop 1 (Rousay)	Shop 2 (Rousay)	Eday Community Shop
Expenditure on transport-related labor cost	3629	0	
Expenditure on ferry transport	1799	0	
Expenditure on maintenance, insurrance and other fees for vehicle	3000	0	945
Expenditure on oil & fuel for vehicle	960	0	1565
Expenditure on local transport company	0	500	17511

Figure 3. 12 Annual expenditures of the shops on transportation add Rousay in graph (transport related labor cost are opportunity cost based on the Scottish minimim wage)

The shops have to pay high amounts for ferry transport, either directly or indirectly for local transport companies.

3.4.2.2 Fuel consumption, energy demand and CO_2 emission of the shops

The ferry use contributes most to the transport energy demand and CO_2 emission of shops transport activities. Optimizing the ferry transport could reduce these figures drastically as shown in the table below.

Table 3. 14 Fuel consumption, energy demand and CO_2 emission of the shops in 2009

		Fuel consumption (liter)		**Energy demand (kWh)**			**CO_2 emission (tCO_2)**		
		Vehicle (diesel)	*Ferry use (MGO)*	*Vehicle (diesel)*	*Ferry use (MGO)*	*Total*	*Vehicle*	*Ferry use*	*Total*
Rousay	*Shop 1*	738.00	1,440.00	6,498.00	15,120.00	***21,618.00***	1,942.00	4,320.00	***6,262.00***
	Shop 2	0.00	30.00	0.00	315.00	***315.00***	0.00	0.09	***0.09***
Eday	*ECE*	1,301.00	6,048.00	11,448.00	63,504.00	***74,952.00***	3,422	18,144.00	***21,566.00***

In the table, calculations for vehicle and ferry use are done separately. For example, the fuel consumption of shop 1 for their own vehicle is 738 liters of diesel. From the annual weight of passengers, van and products transported by ferry for the shop and the specific fuel consumption of the ferry (liter MGO/kg-trip), the annual fuel consumption for ferry transport is calculated. 1,440 liters of Marine Gas Oil are assigned to the shop for ferry transport. (More detailed explanations about ferry transport related calculations are presented in 3.1).

3.4.2.3 Expenditures of households for embedded transportation

In general, the prices in small island shops are higher than in the supermarkets in Kirkwall. They pay higher wholesale prices and they have to cover their transport cost. Transportation costs are direct cost for the shops but for households, who buy products in the shops these are embedded cost they have to pay via higher prices of the goods.

As shown in table 3.14 the transport cost of the local shop in Rousay is £9,888/year while in Eday the transport cost is £20,021/year.

The average expenditure on embedded transportation per household by purchasing products in the local shops are therefore as follows:

- Rousay: £9,888/year/105households = **94.17** (£/household/year)
- Eday: £20,021/year/73 households = **274.27** (£/household/year)

The figure in Eday is about 3 times higher than the one in Rousay because the shop in Eday is much bigger than the two shops in Rousay.

3.6 Life cycle transport assessment of a reference household in Eday, Rousay and Kirkwall

To estimate the impact of the embedded transport cost on Eday and Rousay households compared with households in Kirkwall, the IC 2010 researchers compared the living cost of a typical household in these three locations. The reference household consists of two adults and two children. The comparison is done to show the cost difference between the individual islands and Kirkwall. The areas used for the case study are:

- Housing expenditure
- Food and drinks expenditures
- Transport expenditures

3.6.1 Housing expenditure

Table 3.16 shows the values that are used to estimate the cost associated with the construction of a 131m^2 house (please refer to section 3.1.2 for details) in Kirkwall, Rousay and Eday. For Kirkwall, a building plot of fully developed land (with access to all the services) was considered and the used land price reflects this availability of services. In Rousay and Eday the available land with building permission is not developed. Therefore the service connections and necessary constructions costs, such as connection to the electrical grid or borehole construction, were obtained through interviews with local contractors and/or experts from each island. The costs of transporting the materials to Rousay and Eday are the same as estimated in section 3.1.2 of this report

Table 3. 15 Estimated housing costs

	Kirkwall	***Rousay***	***Eday***
House material transport cost from Kirkwall	£0	£2,400	£2,513
Borehole construction	£0	£1,000	£0
Borehole pump cost	£0	£772	£0
Water connection to the local grid	£0	£0	£700
Electricity connection to the local grid	£0	£3,578	£6,000
Septic Tank (600 Gl)	£0	£567	£567
Cost of a land plot	£ 30,000[29]	£ 17,000[30]	£ 10,400
Total cost	£30,000	£25,317	£20,180
Savings on the islands compared to Kirkwall (Transport + Land Cost)	£0	£4,683	£9,820

The sample standard plot of land for a house in Kirkwall has an area of 364 m^2, whereas in Rousay and Eday it is approximately 2,000 m^2 (half of an acre). The information of the sizes and land prices in Rousay and Kirkwall were obtained from a local real estate company, whereas in the case of Eday they were obtained from interviews with local experts.

Even so the price per square meter of land in Kirkwall is 9.8 and 16 times more expensive than in Eday and Rousay, only the difference in price between lots was used for the calculation, this criteria is based on the fact that the reference household would have more land available to build his/her house in a rural area (Rousay and Eday) than in a urban area.

3.6.2 Food and drinks expenditures

The calculated monthly food expenditure estimated in chapter 3.1.2 is used for Kirkwall and Eday. For Rousay, an extra amount of 43£/month more than the expenditure in Kirkwall was used. This value was estimated assuming the household buy all their meat products from Kirkwall and all other products in Rousay.

[29] Lows Kirkwall, 2010, Land plot reference prices, available on http://www.lowsorkney.co.uk/search_results.asp?area=2&type=5&bedrooms=0&min_price=0&max_price=0&Submit=Search+Properties

[30] Lows Rousay, 2010, Land plot reference prices, available on http://www.lowsorkney.co.uk/property_detail.asp?pID=79

Table 3. 16 Considered Food and drinks expenditures

	Kirkwall	Rousay	Eday
Annual food expenditure compared with Kirkwall	£3,029	£3,546	£3.940

3.6.3 Transport expenditures

The mean annual transport expenditure of the reference household was taken from the mean annual transport expenditure of the studied sample. (See Table 3.17)

Table 3. 17 Annual transport expenditures

	Kirkwall	Rousay	Eday
Mean annual transport expenditure	£1,712.62	£2,480.79	£2,014.63

3.6.4 Results of the case study

In order to generate one indicator that allows weighing the differences in savings and extra expenditure of the household during a 20 year cycle, the IC 2010 team used the net present value (NPV) as an indicator. The NPV is today's value of expenditures or income in the future, considering a certain interest rate. An income in the future has a lower NPV as an income today as we can earn interest with today's income. The interest we can earn is the difference of the NPV of a present and a future income.

On one hand, in both islands the reference household would save money in the house investment due to the lower land price (See table 3.16). If this amount of money would be invested by the household at a fixed 3% annual rate of interest, the household in Rousay would receive 314.74 £/y and the household in Eday would receive 660 £/y.

On the other hand, due to the difference in food prices and observed transport expenditures, the household in Rousay would spend £1,284 more per year than in Kirkwall. For Eday, the household would spend £ 1,214 per year more than the household in Kirkwall. This means that in Rousay, the reference household would have a total expenditure of £ 969 per year more than the same reference household in Kirkwall. And the reference household in Eday would also have a total annual expenditure of £ 554 more when compared to the household in Kirkwall.

This means that over a period of 20 years the reference household in Rousay would spend £14,000 more than in Kirkwall and the Eday household would spend £ 8,000 more than the same household in Kirkwall as well, expressed in today's value of these expenditures.[31]

These values mean that the option for this reference household of living on Rousay for the next 20 years instead of Kirkwall will cost £ 14,000 in today's money. If the same household would make the decision of living in Eday instead of Kirkwall, this option would have a cost equal to £ 8,000 in present monetary terms. In table 3. 18 the results are presented.

Table 3. 18 Case study life cycle cost assessment of a reference household in Eday, Rousay and Kirkwall results

	Rousay	Eday
Land Costs minus the material transport and services connection costs	£4.682,54	£9.819,10
Annual Transport Cost difference between the island and Kirkwall	-£768,00	-£302,00
Annual Food Expenditure difference between the island and Kirkwall	-£516,00	-£912,00
Annual total difference between the Island and Kirkwall	-£969,26	-£554,00
Net present value of the difference	-£14000.13	-£8,002.09

These results considered only house construction, food and transport and that there might be other factors which contribute to higher expenditures or savings, for example services can be more expensive than in Kirkwall when commissioned from the mainland or cheaper than in Kirkwall when commissioned from the island.

[31] The net present value is therefore; -£ 14,000 for Rousay and -£ 8,000 for Eday, considering an interest rate of 3% for both, savings and loans (discount rate)

CHAPTER 4: TRANSPORT POVERTY INDICATOR

4.1 Concept of Fuel Poverty Indicator

The concept of fuel poverty has a long history in the UK. The result of the UK's 1988 Family Expenditure Survey showed that households in the three lower income deciles spent on an average, 10% of their income (excluding Housing Benefit or Income Support for Mortgage Interest-ISMI,) on fuel for all household uses. This was assumed to represent the maximum amount that low income households could reasonably be expected to spend on fuel.[32]

This definition has later been more restricted to heating, which for Scotland has been defined by the Scottish executive as: "A household is in fuel poverty if, in order to maintain a satisfactory heating regime, it would be required to spend more than 10% of its income (*including* Housing Benefit or ISMI) on all household fuel use". [33] For Scotland, a 'satisfactory heating regime' is defined as the level recommended by the World Health Organisation (WHO).

A household in Britain is 'poor' when it has both low standard of living and low income. For fuel poverty the standard of living is measured in terms of heating level since heating deprivation is often considered as an indicator of low standard of living. Fuel poverty is considered as potential cause of estimated 40,000 excess winter deaths per year in Britain. [33]

Not being able to heat a home to acceptable standards at reasonable costs is said to be caused by three main factors which are:[34]

- ***Income:*** The ability of households to afford the necessary fuel depends on the household income. Households with low income are likely to be fuel poor as they need to spend a high proportion of their income for heating to required standards.
- ***Fuel costs:*** Prices and availability of different types of fuels and heating systems affect the number of people suffering from fuel poverty in a particular area.

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[32] Gordon, David (2006), Predicting Fuel Poverty at Small Area Level, University of Bristol (pg. 2-3)

[33] Scottish Executive (August 2002), The Scottish Fuel Poverty of Statement (pg 4-7)

- **Energy efficiency:** Energy efficiency of houses is another important factor that can cause fuel poverty. The amount of energy needed to heat a home to acceptable standards depends on the thermal quality of the house and the effectiveness of the heating source. This factor helps determine the standard in terms of the ability of a household to maintain adequate warmth inside.

So far all the studies and research on fuel poverty have only focused on the purpose of heating but no studies have been identified which determined poverty related to transport. Scottish households especially those in rural areas and on small islands seem to spend a very large proportion of their income on transport. Hence, coming up with a concept to assess transport poverty might be very useful to plan and improve the transportation system to reduce the number of people falling below the acceptable transport poverty levels.

With this in mind, this study aims to develop a simple transport poverty indicator using a similar concept and factors as those used in developing the heating fuel poverty indicator.

4.2 Approach and Calculation of Transport Poverty Indicator

4.2.1 Approach

Transport provides mobility to the people to enhance accessibility to different services and goods for fulfilling their needs and comforts of life. Good and effective transportation provides an adequate standard of mobility at reasonable costs. Hence a household can be classified as transport fuel poor if the mode of transportation it uses is not effective and if the household spends a large share of its income on transport. To develop a transport poverty indicator based on mobility and costs, the three most relevant factors are:

- ***Income:*** Ability of a household to afford necessary mobility depends on the household income. Households with low income are likely to be transport poor as they will have to spend a high proportion of their income for transport to access the required services and goods.

- ***Transport costs:*** Prices and availability of different types of fuels and transport systems affect the number of people suffering from transport poverty in a particular area.

- **Mobility:** Mobility here means accessibility to daily basic services and goods. Hence mobility is the factor that helps determine the standard of living of the people/ households.

In cities of the UK, services and products to fulfil needs and comforts are available within the city itself. They can be accessed by reliable sources of public transport. However, the access to sufficient mobility by people living in rural communities and small islands is restricted to those who own private means of transport The lack of adequate public transport systems and the fact that people in rural communities have to travel to the nearest urban settlements for accessing the basic minimum services and goods, add up to the cost of mobility for people living in rural communities and islands.

Keeping these factors in mind, for the calculation of a transport energy poverty indicator, the city of Edinburgh was used as a reference because the city has an extensive bus network covering all parts of the city, its suburbs and the surrounding city-region. This means that a citizen of Edinburgh has a complete access to mobility using the bus system. The details of calculating a standard transport poverty indicator is explained in the following section.

4.2.2 Transport fuel poverty calculation

To develop a transport poverty indicator, a household of two adults and two children living in Edinburgh is considered. We assume that each of the two adults earn an income which is in the lowest income level in UK (£5.8 per hour) [34] and we also assume that all the four members of the household use only public buses for mobility. The local bus service provider (Lothian bus) [35] charges an annual fee of £540 per year per adult and £360 per child per year for the use of public buses in Edinburgh. Hence, taking the charges of Lothian bus, the total transport cost of the household is £1800 per year and the annual gross income is £24,127.2 per year (considering that both the adults work 40 hours per week).

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[34] Directgov, 2010, National minimum wage rates for workers in the UK, Available on http://www.direct.gov.uk/en/Employment/Employees/TheNationalMinimumWage/DG_10027201

[35] Lothian Buses, 2010, Buses fares 2010, available at http://lothianbuses.com/tickets.php

Deducting £6,035 (personal annual tax allowance) from the annual gross income of the household and applying a tax of 20% on the rest of their income (20% tax is applicable for any income between £0 and £34,800 in the UK)[36], the net annual income of the household works out to £21,717.6. Hence, the household spends 8.3% of its net annual income (£1800) for mobility at all times.

For this study we define, "A *household is in transport poverty, if it spends more than 8.3% of the household income (after taxes) on transport/mobility to access the minimum services and goods of daily life"*

4.2.3 Transport poverty in Rousay and Eday

The primary data obtained from field surveys in Rousay, Eday and Kirkwall has been used to calculate the transport cost and income of people living in these islands. The details of the calculation are explained below:

The most commonly used threshold of low income is 60% of median income[37]. Hence the low income level for Orkney has been set at 60% of the median gross weekly earnings of £434.2 for full-time employees in Orkney from the Scottish neighbourhood statistics, 2010. Again considering a tax personal annual allowance of £6,035 and applying a tax of 20%[7] on the rest of this gross low income in Orkney, the net average annual salary in Orkney for 2009 was £7,940. This value has been considered in this study as the net annual low income threshold of an adult in Orkney.

Once the two lines were set (Transport poverty indicator of 8.3% and low annual income line in Orkney of £7,940), the data available for from field survey were analyzed for Rousay, Eday and Kirkwall. The first step was to calculate the percentage of household in these islands over and below the set low income threshold of £7,940 per year (60% of the median gross annual income of Orkney). For the households falling below this low income threshold level, the percentage of the individual household income spent on transport was calculated and compared with the set transport poverty indicator of 8.3%. The total transport cost of

[36] HM Revenue and customs, 2010. Rates and allowances - Income Tax. Available on http://www.hmrc.gov.uk/rates/it.htm
[37] Joseph Rowntree Foundation, Choices of low-income threshold. Available on http://www.poverty.org.uk/summary/income%20intro.shtml

households here include the cost of fuelling vehicles, ferry charges, public bus charges and operation and maintenance cost of the vehicles. The operation and maintenance cost is taken as 60% of the individual household fuel cost based on information from UK Automobile Association.[38]

Further analysis of the field data show that some of the households falling below the low income threshold in Rousay and Eday take their car on ferries to the Mainland or own a second car on the Mainland. This is an extra cost which could be avoided if the people would go as pedestrians into the ferry and use public buses on the Mainland. Hence, the transport poverty indicator was recalculated for Rousay and Eday eliminating this extra cost of transportation and adding public bus fares for travelling from the Mainland ferry terminal to desired destinations. These recalculated figures show the true transport poverty situation in Rousay and Eday which is detailed in the section below.

4.3 Comparison of Transport Poverty in Rousay, Eday and Kirkwall

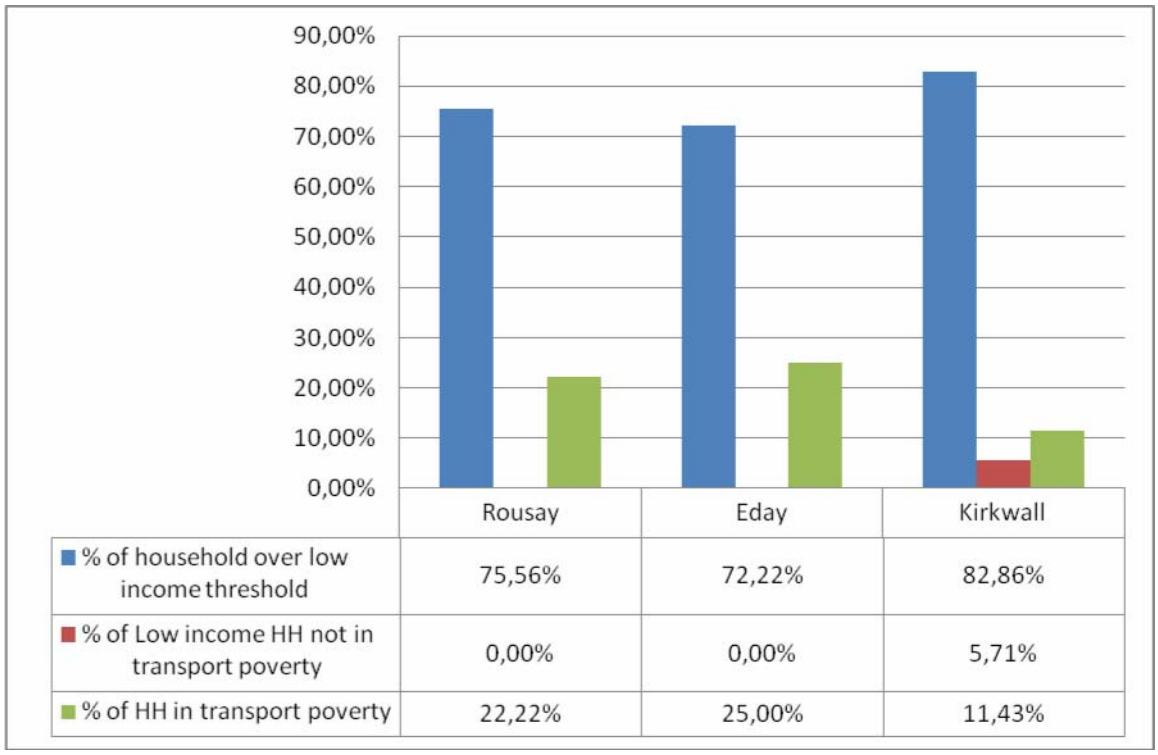
The sample size used for the calculation of transport poverty is different from the sample size presented in the methodology chapter. This is due to the fact that, during field surveys some households didn't provide all the information needed and hence it was not possible to calculate the transport poverty indicator for these households. The actual figure of the sample considered can be seen in table 4.1 below.

Table 4. 1 Income distribution

	Rousay	Eday	Kirkwall
Population Size	105	73	3120
Confidence level	95%	95%	95%
Sample size considered for calculating transport poverty	44	36	35
% of households with income above the Orkney low income threshold of £7,940	77.27%	72.22%	82.86%
% of households below the Orkney low income threshold of £7,940	22.73%	27.78%	17.14%

[38] Automobile association, 2010 http://www.theaa.com/allaboutcars/advice/advice_rcosts_petrol_table.jsp

From table 4.1, it can be seen that a larger proportion of the households in Rousay, Eday and Kirkwall have incomes higher than the low income threshold level in Orkney. From the three areas considered, Eday has the highest percentage of poor households followed by Rousay and Kirkwall. Figure 4.1 below shows the final results of transport poverty in the three areas.



	Rousay	Eday	Kirkwall
% of household over low income threshold	75,56%	72,22%	82,86%
% of Low income HH not in transport poverty	0,00%	0,00%	5,71%
% of HH in transport poverty	22,22%	25,00%	11,43%

Figure 4. 1 Transport poverty results

Figure 4.1 shows that in Eday there are 2.28% more households in transport poverty than in Rousay and 13.57% more than in Kirkwall. However, in Rousay double the households are in transport poverty than in Kirkwall. To summarize it, Eday has the highest percentage of its households in transport poverty followed by Rousay and then Kirkwall.

Another important finding that can be seen from figure 4.1 is that, a household in Eday and Rousay with an income below the poverty line, is more likely to be under transport poverty than the same household in Kirkwall, this behavior may be a consequence of the difference of access to buses between the two islands and Kirkwall and also due to the fact that in Kirkwall a household can have access to different services (like restaurants, city council, cinema, shopping centers, and so on) at a walking distance, whereas in Eday and Rousay the households are more dependent on vehicles to have access to the same services.

CHAPTER 5: FUTURE OPTIONS

From the study results, we can say that the ferry is the principal source of transport energy consumption and CO_2 emissions for both of the studied islands. In order to reduce the ferries energy consumption, CO_2 emissions and cost, there are three options available:

- Building a bridge.
- Reducing the number of trips between the islands and mainland.
- Replace the existing ferries with new technologies ferries.

Figure 5. 1 Bridge option location in Rousay.

In the case of Eday the first two options were not considered because, firstly the island is too far away from mainland (approximately 15.8 miles) and secondly because the service is already limited to two round trips per day (to and from Eday) and this route is combined with the services of two more populated islands Stronsay and Sanday.

In the case of Rousay, the possibility of a bridge was considered. The shortest distance connecting the mainland and Rousay is around 2.5 km from Stenso (mainland) to Frotoft (Rousay) and for the analysis we considered the construction of a 3 km long bridge.

Considering the total amount invested for the construction of the Skye Bridge in west Scotland, the number of vehicles transported in 2008 between Rousay-Tingwall-Rousay and a toll fee of 10£/vehicle, the number of years required for the return of the investment is as high as 192 years. Based on this figure the bridge option for Rousay was neglected by the IC 2010 team as a feasible option for Rousay.

In the case of reducing the number of trips to mainland from Rousay, we considered the introduction of a passenger ferry in combination with car ferry services. Replacing the current ferry with a bigger one that can carry 16 cars would reduce the number of car ferry trips from

6 to just 1 round trip per day. The remaining 5 return trips could be served by a passenger ferry. However, the proposed bigger car ferry plus the energy required to operate the passenger ferry (50 l/h) would increase the total transport energy consumption by almost 2,000,000 kWh/y. Hence the total CO_2 emissions for the ferry services between Tingwall and Rousay will also increase significantly. Because of this the IC 2010 researchers did not consider the reduction of trips for Rousay as a feasible option.

The third considered option for both islands was to replace the ferries by more efficient ferries, for this case we propose the use of LNG fueled ferries. Such a ferry will be more economical and environmentally friendly as compared to the present ferries operating with marine diesel. Studies in Norway show that the implementation of LNG ferry can reduce CO_2 emission by 20%.[39]

5.1 Results for the LNG ferries option

In table 5.1 the emission factors for the marine diesel and LNG ferries are presented. Based on these the emissions for different cases were calculated and the results are presented in table 5.3 for Rousay and in table 5.4 for Eday.

Note that the CO_2 emissions and energy consumption in the Rousay route, for each case are smaller with the LNG Ferry than with the marine diesel fueled ferry.

Table 5. 1 Ferries emissions factors per kg and trip

Fuel	Rousay	Eday
	gCO_2/kg/trip	gCO_2/kg/trip
Marine Diesel Ferry	15.00	64.00
LNG Ferries	12.00	51.20

For the Rousay ferry, the CO_2 emissions per trip, are reduced by approximately 14% in the case of ‘Car-Car on Ferry- Car’. They are reduced by 3% and 6% in the ‘Walk-Passenger on the ferry-Car’ and ‘Walk-Passenger on the ferry-Bus’ cases respectively. This difference is due to the fact that the emissions assigned to each case on the ferry, depend directly on the

[39] Strait Crossings 2009 page 9

weight of the load transported on the ferry and the location of the ferry terminal in mainland (Tingwall).

Table 5. 2 CO_2 emissions and transport energy consumption per trip for the analyzed cases in Rousay

Marine Diesel Ferry option				
Cases	CO_2 kg/trip			
	Rousay	Ferry	Mainland	Total
Car-Car on Ferry- Car	1.48	19.13	7.36	27.96
Walk-passenger on Ferry - Car	0.00	1.13	7.36	8.48
Walk-passenger on Ferry - Bus	0.00	1.13	2.52	3.65
LNG Ferry option				
Cases	CO_2 kg/trip			
Car-Car on Ferry- Car	1.48	15.30	7.36	24.14
Walk-passenger on Ferry - Car	0.00	0.90	7.36	8.26
Walk-passenger on Ferry - Walk	0.00	0.90	2.52	3.42

In the case of Eday only two cases were considered, because the ferry arrives directly to Kirkwall, hence the case 'Walk-passenger on Ferry – Bus' doesn't apply. For the CO_2 emissions per trip, there is a reduction of slightly more than 19% for the 'Car-Car on Ferry-Car' case while the reduction is 20% for the 'Walk-passenger on Ferry – Walk' case. This relatively higher reduction in Eday, compared with the same results in Rousay, is a direct consequence of the location of the Ferry terminal in mainland (Tingwall for Rousay and Kirkwall for Eday).

Table 5. 3 CO_2 emissions and transport energy consumption per trip for the analyzed cases in Eday

Marine Diesel Ferry option				
Cases	CO_2 kg/trip			
	Eday	Ferry	Mainland	Total
Car-Car on Ferry- Car	1.68	81.60	0.82	84.09
Walk-passenger on Ferry - Walk	0.00	4.80	0.00	4.80
LNG Ferry option				
Cases	CO_2 kg/trip			
Car-Car on Ferry- Car	1.68	65.28	0.82	67.77
Walk-passenger on Ferry - Walk	0.00	3.84	0.00	3.84

In absolutes terms per trip, the CO_2 emissions reduction for the 'Car-Car on Ferry-Car' case in Rousay is 4 kg of CO_2/trip. This saving would be in Eday 16 kg of CO_2/trip. This difference in absolutes terms is a consequence of two variables: the size of the ferries (it is

bigger in Eday than in Rousay) and the duration of the trip (the trip from mainland to Eday is three times longer than the trip between mainland and Rousay).

As a partial conclusion, it can be said that the best option to reduce the total transport CO_2 emission in Rousay and Eday is to replace the actual ferries with new ferries more efficient technology like the LNG option.

5.2 Option of public bus service on the islands

From chapter 3, it can be said that in the studied sample, the majority of Rousay and Eday residents depend on private vehicles, especially cars for transport within the island. In this option, the use of public buses inside the islands is considered, to reduce the use of own vehicles and improve the access to mobility on the island.

For this option analysis, the regular ferry schedule is assumed to be the same as the present pattern i.e.6 return trips a day to and from Rousay and 2 return trips to and from Eday, and the island bus schedule was planned to correspond with the departure and arrival scheduled of the ferries.

In both islands a 9 seater public bus is proposed. A typical van like Ford Transit or VW Transporter with transport energy consumption of 0.58 miles/kWh [40] and a CO_2 emissions factor of 0.45 kg of CO_2/mile was considered.

For Eday a 12 miles route for the bus was used, while in Rousay the used bus route was 13 miles. All the calculations were based on an average of 5 persons using the bus per trip and none of the persons used to take their car on the ferry to mainland. In table 5.4 the results for Rousay and Eday are presented, for the marine diesel and LNG ferries options.

[40] IPCC, 1996. Guidelines for National Greenhouse Gas Inventories. Volume 3: Reference Manual. Available on http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm. [accessed 13.03.10.].

Table 5. 4 Public bus service on the island results

Rousay cases	CO_2 kg/trip				kWh /trip			
	Rousay	Ferry	Mainland	Total	Rousay	Ferry	Mainland	Total
Bus--passenger on Ferry – Bus (Marine diesel ferry)	1.18	1.13	2.52	4.82	4.47	3.83	9.56	17.86
Bus--passenger on Ferry – Bus (LNG ferry)	1.18	0.90	2.52	4.60				
Eday cases	Eday	Ferry	Mainland	Total	Eday	Ferry	Mainland	Total
Bus--passenger on Ferry – Walking (Marine diesel ferry)	1.09	4.80	0.00	5.89	4.13	16.43	0.00	20.55
Bus--passenger on Ferry – Walking (LNG ferry)	1.09	3.84	0.00	4.93				

Even though the total emissions and energy consumption are increased due to the fact the island bus is introduced and all other parameters remain the same, better access to mobility is given to the islands. For comparison purposes the penetration level of the bus in the island was changed, and for the new calculation 7 persons on average will be using the bus per trip and two of the persons used to take their car on the ferry to mainland.

Based on this assumption the emissions and energy consumption factor per ferry trip was recalculated. The results are presented in table 5.5. In table 5.6 the results for the case bus-passenger on ferry-walking, for both islands and the two ferries options studied are presented.

Table 5. 5 Marine diesel ferries energy and marine diesel and LNG ferries emissions factor with 7 persons per trip using the island bus

Fuel	Rousay		Eday	
	kWh/kg/trip	gCO_2/kg/trip	kWh/kg/trip	gCO_2/kg/trip
Marine Diesel Ferry	0.06	17.43	0.23	66.24
LNG Ferries		13.94		52.99

Table 5. 6 Public bus service on the island results for 7 persons using the bus on average

Rousay Cases	CO_2 kg/trip				kWh /trip			
	Rousay	Ferry	Mainland	Total	Rousay	Ferry	Mainland	Total
Bus--passenger on Ferry – Bus (Marine diesel ferry)	0.84	1.31	2.06	4.21	3.19	4.45	7.82	15.47
Bus--passenger on Ferry – Bus (LNG ferry)	0.84	1.05	2.06	3.95				
Eday Cases	Eday	Ferry	Mainland	Total	Eday	Ferry	Mainland	Total
Bus--passenger on Ferry – Walking (Marine diesel ferry)	0.78	4.97	0.00	5.75	2.95	13.14	0.00	16.09
Bus--passenger on Ferry – Walking (LNG ferry)	0.78	3.97	0.00	4.75				

Note that even though the total emissions and energy consumption is almost the same, regardless the passenger on the bus (only the car emissions and energy inside the island are saved for the two new passengers per car), the emissions per trip are reduced in all cases. This reduction is because the emissions per passenger in the island bus are divided by 7 passengers instead of 5; hence the calculated emissions per trip are smaller.

The internal bus option can be attractive for the island inhabitants only if the price of each bus trip is not more than 0.50 £/trip. This means that the Orkney Council would have to subsidize the buses, however the island bus implementation is in line with the Orkney Island Council transportation strategy vision to "improve journey times and connections, reduce emissions and improve quality, accessibility and affordability of transportation on Orkney"[41].

5.3 Management measurements options

The current scheme by the Orkney Ferries of selling ferry tickets in bulk of 10, 20 and 50 trips can be very useful for Rousay and Eday residents because this can reduce the price of the ferry fee by 25%, 30% and 50% respectively. These savings reduce the percentage of the

[41] Orkney Islands Council Local Transport Strategy 2007-2010

household income spent on ferry substantially. In table 5.7 the ferry ticket price per person and per vehicle are presented for each location.

Table 5. 7 Ferry prices for Rousay and Eday

Rousay	
Ferry ticket price per person	£/trip
Normal price	3.50
10 Trips	2.63
20 Trips	2.45
50 Trips	1.75
Ferry ticket price per car	£/trip
Normal price	11.15
10 Trips	8.37
20 Trips	7.81
50 Trips	5.58
Eday	
Ferry ticket price per person	£/trip
Normal price	6.85
10 Trips	5.14
20 Trips	4.80
50 Trips	3.43
Ferry ticket price per car	£/trip
Normal price	16.25
10 Trips	12.19
20 Trips	11.38
50 Trips	8.13

In table 5.8 the impact on the cost per trip of each ticket price option is presented. Note that the impact is different per case and location, for example for the case 'Car-Car on the Ferry-Car' in Rousay the difference between the normal price and the 50 trips price is 40 %, while in Eday for the same case the difference is around 47%, this difference in the cost per trip is a direct consequence of the location of the ferry terminal in Mainland.

In order to estimate the total cost per trip presented in table 5.8, the following parameters were used:

- Fuel and maintenance cost per mile for the vehicles
- The bus tariff inside the island and in mainland
- The ferry fee for the vehicle (if applicable) and for one person.
- The fees for the LNG ferries are exactly the same as the one established for the marine diesel ferry

Table 5. 8 Cost per trip for all analyzed cases

Description		Rousay (£/trip)	Eday (£/trip)
Car-Car on the ferry-Car	Normal price	18.45	24.17
	10 Ticket price	14.79	18.40
	20 Ticket price	14.05	17.24
	50 Ticket price	11.12	12.62
Walk-passenger on the Ferry-Car	Normal price	6.66	Not applicable
	10 Ticket price	5.78	Not applicable
	20 Ticket price	5.61	Not applicable
	50 Ticket price	4.91	Not applicable
Walk- passenger on the Ferry –Bus in Rousay and walk in Eday	Normal price	6.20	6.85
	10 Ticket price	5.33	5.14
	20 Ticket price	5.15	4.80
	50 Ticket price	4.45	3.43
Bus- passenger on the Ferry –Bus in Rousay and walk in Eday	Normal price	6.70	7.35
	10 Ticket price	5.83	5.64
	20 Ticket price	5.65	5.30
	50 Ticket price	4.95	3.93
Car-car on the Ferry LNG-Car	Normal price	18.45	24.17
	10 Ticket price	14.79	18.40
	20 Ticket price	14.05	17.24
	50 Ticket price	11.12	12.62
Bus-passenger on the Ferry LNG- Bus in Rousay and walk in Eday	Normal price	6.70	7.35
	10 Ticket price	5.83	5.64
	20 Ticket price	5.65	5.30
	50 Ticket price	4.95	3.93

The IC 2010 team considered that the implementation of public buses on the islands can be done in the short term, while the replacement of current ferries can be implemented at end of the life cycle of the current ferries.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

The main objective of this study was to make a comparison of the direct and embedded transport energy consumption, CO_2 emissions and costs between Kirkwall, Rousay and Eday. The study also aimed to generate a transport poverty indicator in order to assess the poverty level due to transport in these areas.

Referring to the initial research questions (see page 2) the main conclusions are:

The average annual transport energy demand, CO_2 emissions and expenditure per household including ferry is much higher in Rousay than in Eday and lowest in Kirkwall. This can be explained mainly because the people of Rousay travel more to Mainland than the people of Eday. Also most of the people in Rousay use a car for travelling to mainland owing to the distance of road travel from Tingwall ferry terminal to Kirkwall.

In the agricultural sector of Eday, the annual average transport costs, emissions and energy demand excluding the ferry is much higher than that in Rousay. This might be due to the large farm sizes in Eday.

Transport energy demand for lamb production is as high as 5 times more than that demanded for beef production in Eday; in Rousay the equivalent transport energy demand is 1.5 times as high. This higher transport energy demand for lamb production is because, using the same medium of transport (car and ferry), more kilograms of live cattle can be transported, as compared to the weight of live sheep.

The annual average costs, emission and energy demand from transport for local shops is higher in Eday than in Rousay. This might be caused by the larger size of the shop in Eday and higher transportation cost there from the deployment of local transporters. Further, the higher emission in Eday is due to the larger size of the ferry to Eday.

The embedded transport energy demand and emissions per kilogram of food and drinks is higher for the shop at Eday than at Rousay. This is most probably because of the high charges

and long distance of transporting the goods in the ferry from Kirkwall to Eday as compared to the distance from Tingwall to Rousay.

Households who spend more than 8.3% of their income on transport are prone to transport poverty. 25.0% of the HH in Eday fall under transport poverty compared to 22.2% in Rousay and 11.4% in Kirkwall. Thus Eday has the highest percentage of transport poor households. This is because, many households in Eday have low incomes and they spend a higher portion of the income on ferry transport. Further, households with low incomes in Rousay and Eday are more likely to be in transport poverty than the households with low incomes in Kirkwall. (Low income household is the one with an income less than £7,940)

Of the 4 alternatives considered, the following conclusions were made:

- The building of a bridge between Rousay and mainland implies high investments with a 192 years back payment, therefore this option was neglected by the research team. In the case of Eday this options was not considered because the island is far away (about 16 miles) from mainland.
- The introduction of a passenger ferry between Tingwall and Rousay in combination with car ferry services by replacing the current ferry with a bigger one increases the total energy consumption and CO_2 emissions significantly.
- CO_2 emissions of LNG ferries are smaller than the marine diesel fueled ferry, which make these vessels recommended to be used between the mainland and the islands as the best scenario.
- The introduction of public bus service synchronized with the ferry schedules on the islands is an option that would improve the access to mobility on the islands.

From these conclusions made, we propose the following recommendations for improving the current transport patterns to reduce costs, emissions and enhance sustainability:

Especially in Eday awareness should be raised that people use smaller cars instead of high fuel consuming four wheelers with much higher CO_2 emissions. Also proper maintenance – especially with older cars could help reduce fuel consumption and the related CO_2 emissions.

To reduce the number of people prone to transport poverty it is recommended to make public buses operational in Rousay and Eday and more reliable in Kirkwall. Encourage more people to use public buses instead of personal vehicles. It is also recommended that the bus schedules in Kirkwall, should match with the ferry frequencies.

The embedded transport cost and emissions of the shop and households can be reduced if more people buy from the local shop (especially in Rousay). Also the shops of Rousay and Eday should promote and sell local products to reduce the expenditure, energy demand and CO_2 emission on transportation from mainland. This could help to promote the local economy and enhance the self-sufficiency on the islands.

In the case of Rousay the shop should try to reduce the prices of food and drinks, especially in the meat products group, to encourage the people to buy in the local shop. This could be achieved by making the shop bigger and more equipped.

It is highly recommended to consider LNG ferries as a replacement of the existing ones at the end of their lifecycle. LNG ferries consume less energy and emit less CO_2 compared to the existing ferries. It is also recommended the introduction of public bus service on the islands synchronized with the ferry schedules because this alternative will improve the access to mobility for the island inhabitants.

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We hope that the information, results and recommendations presented in this report would be useful for decision making further planning and the development of the transportation system of the communities of Rousay and Eday. We wish that they help to raise awareness among the people of Rousay and Eday about impacts of their existing transportation pattern and alternatives.

The IC 2010 team suggests that the same methodology could be applied for other islands in Orkney, so the results can be compared. In the case of the transport poverty index, it could be interesting to reproduce the study in different locations in Orkney and Scotland

Finally we like to encourage the local organisations and communities to use the results of this report as a basis for further research to achieve suitable transport systems for the islands.

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Annexes:

Annex I Embedded transport Cost (Reference list of materials, and food and drinks)

Table I.1: List of materials for a Wooden house of 131 m^2

Description	Quantity		length		thickness		width		volume		Mass	
Gravel and sand	39	Tonnes									39	t
Cement	517	sack									13	t
Concrete Brick	438	Brick									8	t
Polystyrene Floor Isolation	46	Board	2.4	m	0.05	m	1.2	m	6.58	m^3	0.33	t
Exterior Door	2	Doors	2.09	m	0.15	m	0.9	m	0.56	m^3		
Big windows	2	Windows	2.65	m	0.15	m	2.1	m	1.67	m^3		
Medium windows	5	Windows	1.81	m	0.15	m	1.54	m	2.09	m^3		
Small windows	4	Windows	1.81	m	0.15	m	1.03	m	1.12	m^3		
Garage door	1	Door	3.49	m	0.3	m	2.14	m	2.24	m^3		
Polystyrene wall Isolation	43	Board	2.4	m	0.05	m	1.2	m	6.26	m^3		
Floor	52	Board	1.38	m	0.006	m	0.19	m	0.08	m^3		
Slate (fibrecement) (Roof)	2,706	tiles	418	mm	334	mm		mm	0	m^3	13.81	T
Wood			672	m	45	mm	195	mm	5.90	m^3	2.95	T
Wood			144	m	45	mm	145	mm	0.94	m^3	0.47	T
Wood			884	m	45	mm	95	mm	3.78	m^3	1.89	T
Wood			408	m	45	mm	70	mm	1.29	m^3	0.64	T
Wood			100	m	45	mm	45	mm	0.20	m^3	0.10	T
Wood			800	m	25	mm	50	mm	1	m^3	0.5	T
Wood			340	m	10	mm	38	mm	0.13	m^3	0.065	T
Wood			54	m	21	mm	195	mm	0.22	m^3	0.11	T
Wood			90	m	21	mm	95	mm	0.18	m^3	0.09	T
Wood			90	m	12	mm	70	mm	0.08	m^3	0.04	T
Wood			180	m	12	mm	95	mm	0.21	m^3	0.10	T

Wood			125	m	16	mm	137	mm	0.27	m³	0.14	T
OSB(woodchip)	44	boards	2,400	mm	1,200	mm	11	mm	1.40	m³	1.12	T
OSB(woodchip)	62	boards	2,400	mm	1,200	mm	9	mm	1.61	m³	1.29	T
Plywood	14	boards	2,440	mm	1,220	mm	12	mm	0.50	m³	0.40	T
Plywood	10	boards	2,440	mm	1,220	mm	9	mm	0.27	m³	0.21	T
Laminate (woodchip)	2	boards	2,440	mm	1,220	mm	18	mm	0.18	m³	0.09	T
Gypsum	8	boards	2,400	mm	1,200	mm	12.5	mm	0.29	m³	0.29	T
Gypsum	110	boards	2,400	mm	1,200	mm	12.5	mm	3.96	m³	3.96	T
Gypsum	90	boards	2,400	mm	1,200	mm	12.5	mm	3.24	m³	3.24	T
Kitchen+Bathroom												
Miscelanious Trip												

Table I.2 List of Product per month for a standard family*	Average quantity		Used quantities	
Liquid whole milk	7.135	ml	7	Lts
Fully skimmed milk	2.527	ml	3	Lts
Semi-skimmed milk	18.379	ml	18	Lts
Yoghurt	3.505	ml	3,5	Lts
Cheese	1.945	g	2	Kg
Beef	5.080	g	5	Kg
Pork	794	g	0,8	Kg
Bacon and ham, uncooked	1.116	g	1,25	Kg
Cooked poultry not purchased in cans	891	g	1	Kg
Cooked or canned meat products	853	g	1	Kg
Chicken, uncooked - whole chicken or chicken pieces	2.750	g	2,75	Kg
Turkey, uncooked - whole turkey or turkey pieces	505	g	0,5	Kg
Sausages, uncooked – pork	783	g	1	Kg
Fish	2.539	g	2,5	Kg
Eggs	28	Units	30	Units
Butter	776	g	0,75	Kg
Margarine	329	g	0,25	Kg
Vegetable and salad oils	785	g	1	Lts

Fresh oranges	836	g	0,8	kg
Lemon	1.405	g	1,5	Kg
Fresh apples	2.550	g	2,5	Kg
Fresh pears	656	g	0,6	Kg
Fresh bananas	3.950	g	4	Kg
Pure fruit juices	5.468	g	6	Lts
Fresh cabbages	419	g	0,4	Kg
Leafy salads fresh	734	g	1	Piece
Fresh carrots	1.887	g	2	Kg
Fresh onions, leeks and shallots	1.975	g	2	Kg
Fresh cucumbers	389	g	1	Piece
Fresh mushrooms	464	g	0,5	Kg
Fresh tomatoes	1.417	g	1,5	Kg
Tomatoes, canned or bottled	425	g	0,5	Kg
Peas, canned	500	g	0,5	Kg
Potatos	13.097	g	13	Kg
White bread	5.030	g	5	Kg
Brown and wholemeal bread	3.124	g	3	Kg
Rolls - white, brown or wholemeal	1.899	g	2	Kg
Flour	905	g	1	Kg
Cakes, buns and pastries	2.642	g	2,5	Kg
Biscuits and crispbreads	3.323	g	3,25	Kg
Oatmeal and oat products	556	g	0,5	Kg
High fibre breakfast cereals	795	g	0,5	Kg
Sweetened breakfast cereals	580	g	0,75	Kg
Other breakfast cereals	497	g	0,375	Kg
Rice	1.140	g	1	Kg
Pasta	1.987	g	2	Kg
Coffe	294	g	0,3	Kg
Ice cream	3.124	ml	3	Lts
Salt	230	g	0,25	Kg

Annex II: Household detailed results

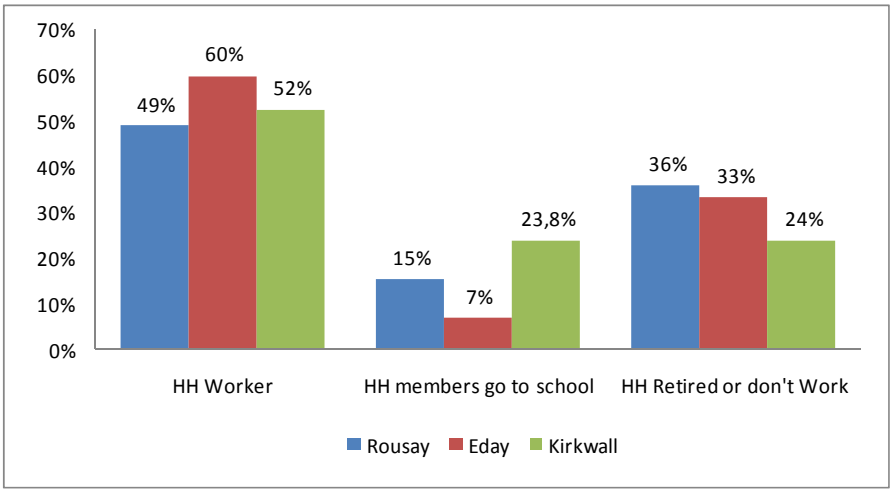


Figure II.1: Percentage of economically active and inactive population

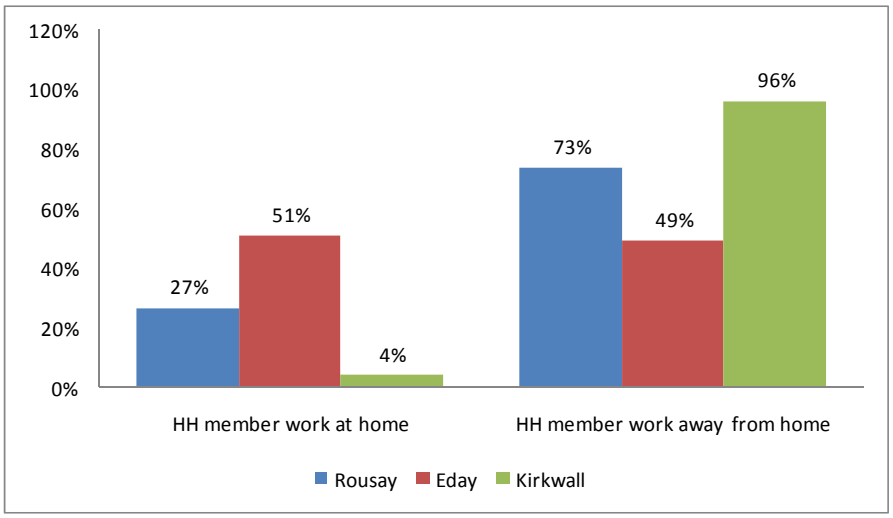


Figure II.2: Percentage of working population that works at home and away from home

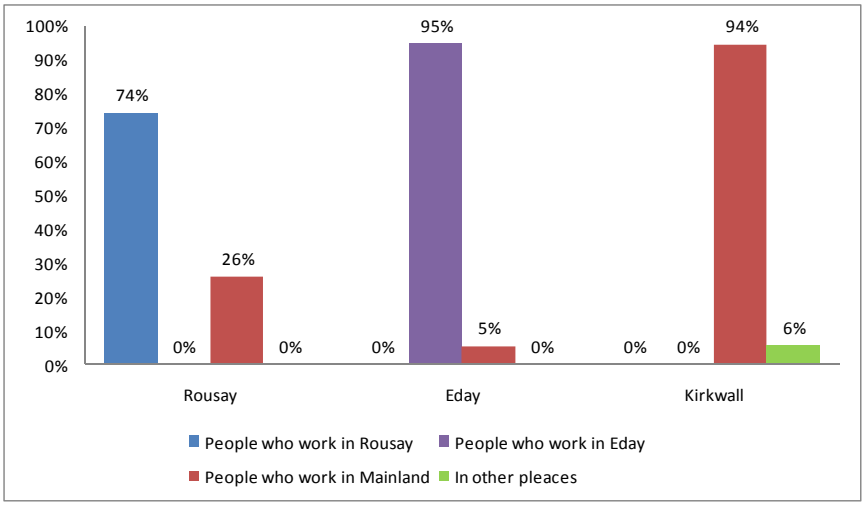


Figure II.3: Percentage of the people that work in Mainland

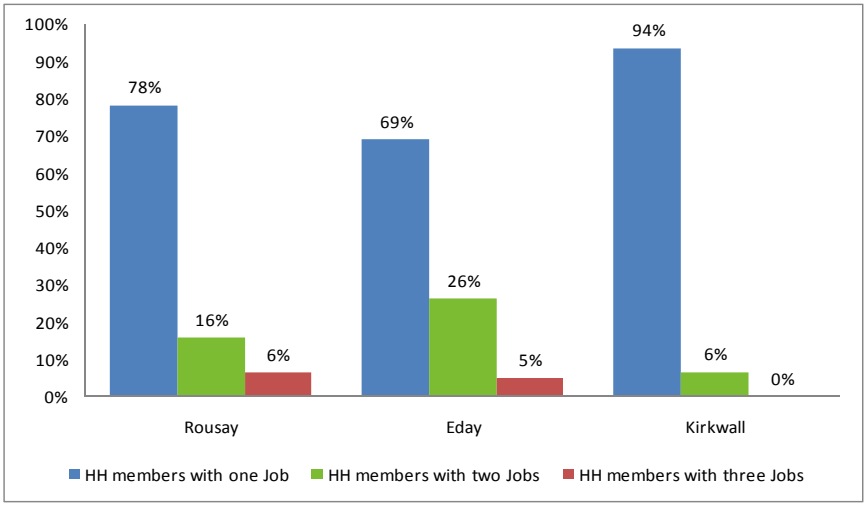
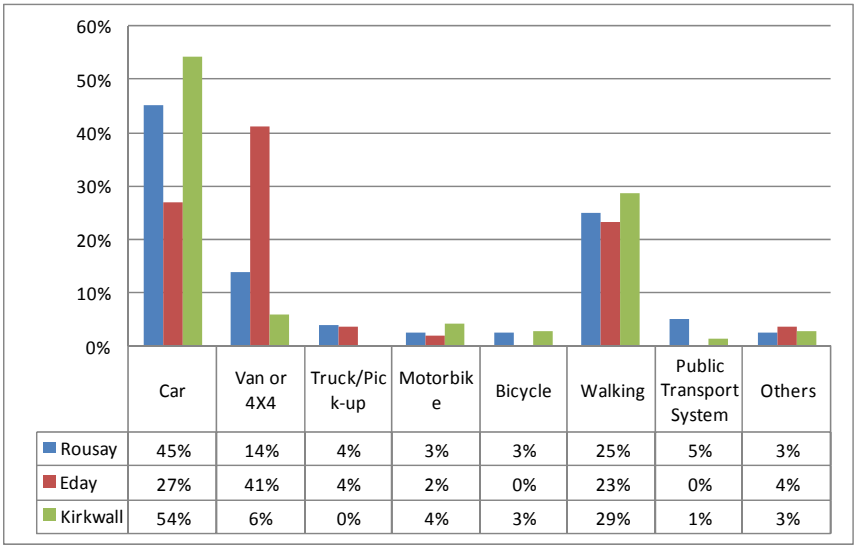


Figure II.4 Number of jobs per person -main job, second job, third job-



	Car	Van or 4X4	Truck/Pick-up	Motorbike	Bicycle	Walking	Public Transport System	Others
Rousay	45%	14%	4%	3%	3%	25%	5%	3%
Eday	27%	41%	4%	2%	0%	23%	0%	4%
Kirkwall	54%	6%	0%	4%	3%	29%	1%	3%

Figure II.5: People's preference to go to work

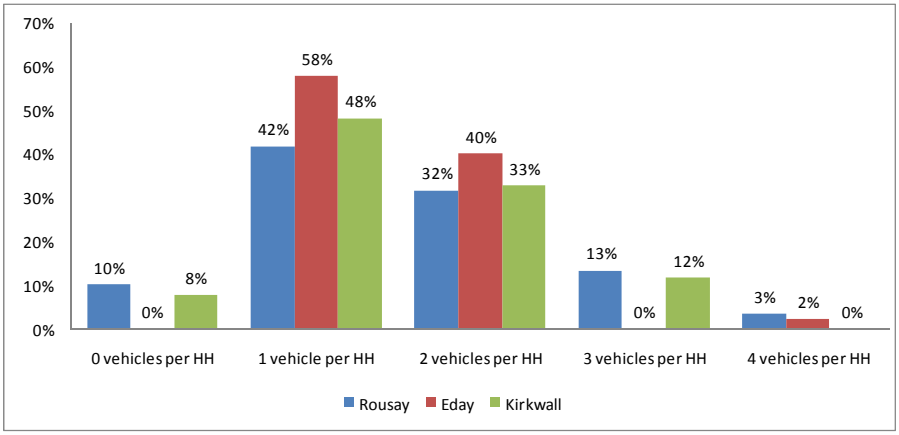


Figure II.6: Number of vehicles per households

Annex III Business and shops detailed results

	Shop 1 (Rousay)	Shop 2 (Rousay)	Eday Community Shop
Expenditure on local transport company	0	*500	**17,511
Expenditure on oil & fuel for vehicle	960	0	1,565
Expenditure on maintenance, insurance and other fees for vehicle	3,000	0	945
Expenditure on ferry transport	1,799	0	0
Expenditure on transport-related labor cost	***3,629	0	0

*The shop has to pay the amount to local transport company

**Annual payment of the shop to Jim Holland transport company

***Expenditure on transport-related labor cost (£) = UK minimum salary rate (£/hour) x Hours for purchasing products in mainland per time (hour) x Times to purchase products in mainland per week (time/week) x Number of week per year = 5.8 (£/hour) x 4 (hour) x 3 x 365/7 (week/year) = 3629 (£)

Annex IV Questionnaires