Establishing a Carbon Neutral Island

A Report for Highlands and Islands Enterprise

and

Highlands and Islands Community Energy Company

by

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1 Executive Summary

The core aims of the study were:

- To review proposals for similar initiatives elsewhere in the UK/ Europe and identify key lessons or recommendations that could apply in the Highlands and Islands context.

- To consider for a 'typical' island community the measures or actions that would be required to move that community to a carbon neutral status.

- From published data, quantify as far as possible the scale of effort required to support such an initiative.

An examination of various **existing studies and projects**, principally in the UK and Europe suggested that:

- Significant reductions in a carbon footprint can be achieved, even in the absence of high-profile government interventions. In particular, emissions associated with domestic energy, food and travel can be significantly reduced with conscious effort. High levels of home insulation, locally produced electricity, a high volume of locally grown organically produced food and reduced commuting can all have a significant impact.
- The above notwithstanding, most of the communities currently aiming at carbon-neutral status are currently falling well short of their ultimate aim. This is because they tend to focus on just one sector rather than adopting a holistic approach; and they tend to limit themselves to the 'low hanging fruit' of relatively easily and cheaply achieved targets.
- We have found little in the way of information about remote or rural communities that might be directly comparable to a Scottish island except a project in Samsø, Denmark. The indications from this project are that whilst there is enthusiasm for the idea of a 'green island' it may not be easy to gain acceptance for all solutions that are technically feasible. For example there has been consumer resistance to the use of electric cars.
- If taken on as a practical project, creating a carbon neutral island would almost certainly be widely regarded as ground-breaking in scope.

Our research into the **baseline carbon emissions** of Scottish island communities indicated that each citizen on a typical island of 1,000 people is likely to average about 9.50 tonnes of CO_2 per annum, compared to the UK average of 10.62 tonnes. High emissions associated with ferry use for islanders are more than outweighed by lower than UK average levels of consumption of goods and services. It is, however, important to note that there may be significant variations between islands.

Tourism is assumed to add 10% to the overall footprint of the typical island.

Of the total of 9.5 tonnes, '**direct emissions**' of electricity use, space and water heating, and the impact of food and vehicle use amount to some 45% of the total footprint. These are activities whose carbon emissions we believe could be eliminated by the introduction of technologies and changes in lifestyles on the island. The remaining 55% are '**indirect emissions**' associated with the consumption of goods and services – including aviation, centrally managed services and (above all) ferries – over which the island has little or no direct control. Unless we make assumptions about changes in society as whole, these emissions will need to be 'offset' to create a carbon neutral island.

A comprehensive examination of the **various options** open to island communities suggests that in general terms, a workable strategy could include the following elements. For direct emissions:

- Electricity consumed by island housing and services can be generated locally from renewable resources. This would require about 1.26 MW of installed capacity.
- Energy for space and water heating used by island housing and services could also be generated locally from renewable resources, especially biomass. This would require in the order of 480 hectares of sustainably managed woodland. (This acreage would be reduced by as much as 75% if a robust strategy were implemented to retrofit existing buildings and ensuring all new buildings met high ecological building standards.)
- A move towards organic agriculture, and a greater consumption of locally produced food could reduce related carbon emissions by up to 50%
- Although there may be difficulties in identifying an appropriate strategy, the island's vehicle fleet could become carbon neutral through the development of biodiesel and/or hydrogen. This would require about 150 hectares of land under oilseed rape where suitable land is available or 220 kW or more of additional installed wind power for hydrogen production.

Offsetting the remaining 55% of indirect emissions would require either:

- The export of significant additional electricity from an installed wind power capacity of circa 4 MW or;
- The equivalent in some other form of exportable power supply such as hydro, wave, tidal etc. or;
- The planting of permanent forest of between 1,500 and 4,000 hectares in extent to sequester the carbon emissions or;
- Some combination of the above.

We also look at two further scenarios under which the UK as whole makes significant reductions in its own carbon footprint of 55% and 90%. This would reduce the installed wind capacity required to produce Island electricity and offset emissions to 2.97 MW and circa 1.45 MW respectively.

There are of course many possible combinations of different approaches and various other options, such as using wind energy for space heating, are also appraised. The Workbook Tables show the detailed data collected that underpin the statistical analysis and, in spreadsheet form, enable some manipulation of the key parameters so that the implications of different assumptions can be examined.

Most of the recommendations made in this report are already either commercially viable at present, or potentially so in the foreseeable future. Outline strategies are laid out for the implementation of the recommendations in each of the technical areas concerned.

The creation of a carbon neutral Scottish island will involve a successful marriage of community and technology. Providing suitable technology or financial packages to encourage its use to a population of individuals who have no serious desire to undertake the changes required is unlikely to be effective.

Careful attention should be given in the choice of an island to optimize the project's chances of success. Key factors are considered to be a population that is broadly sympathetic to the project's aims, the availability of land suitable for the production of biofuel and biomass crops as well as rich and diverse renewable energy sources.

Optimistic press reports of public enthusiasm for embracing carbon neutrality notwithstanding, achieving this important goal is not likely to be easy. However, Scotland in general and Scotland's islands in particular are blessed with very significant potential for delivering renewable energy. If this combination of high levels of natural potential and relatively low population numbers which are typical of rural Scotland cannot deliver a 'carbon-neutral' solution, then it is not clear to us where in the industrialised world this might achieved more easily.

1.1 List of abbreviations

C	carbon
CO2	carbon dioxide
gCO2	grammes of carbon dioxide
tCO2	tonnes of carbon dioxide
tCO2pp	tonnes of carbon dioxide per person
MtC	millions of tonnes of carbon
MtCO2	millions of tonnes of carbon dioxide
CHP	combined heat and power
DC	direct current
g	grammes
g/km	grammes per kilometre
gha	global hectares - a measure used in ecological footprinting
h	hour
ha	hectare
kg	kilogramme
kgC	kilogrammes of carbon
kgCO2	kilogrammes of carbon dioxide
kgCO2/h	kilogrammes of carbon dioxide per hour
km	kilometre
l	litres
l/h	litres per hour
m	metres
M	million
OSR	oilseed rape
PV	photovoltaic
t	tonnes
U value	A measure of a building elements ability to conduct heat; the higher the U Value, the greater the conduction of heat.
W	watts
kW	kilowatts
MW	megawatts
GW	gigawatts
TW	terawatts
kWp	peak kilowatts
MWp	peak megawatts
kWh	kilowatt hours
MWh	megawatt hours
TWh	terawatt hours
kWh/l	kilowatt hours/litre

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2 Introduction

2.1 Background

We stand at a pivotal moment in human history. There is now unanimity among the world's leading scientists that human activities are a leading factor in the changing climatic conditions that we see around us worldwide. There is also unanimity that if we fail to arrest the rising levels of greenhouse gas emissions, the consequences are likely to be extremely serious, with substantial loss of ecosystems, economic wealth and human (and other species') life.

It is estimated that the Earth currently has the capacity to absorb 4 billion tonnes of carbon per annum. However, the impact of greenhouse gases already emitted could to reduce this capacity by around 40 per cent by the year 2030 to around 2.7 billion tonnes per annum.[1]

Global emissions stand at around 7 billion tonnes of carbon per annum – 43 per cent greater than current absorption rates. National average per capita carbon dioxide emissions levels range between, at the low end, 0.06 tonnes for Ethiopia and 0.24 tonnes for Bangladesh and, at the top, 24.3 tonnes for Luxemburg and 20.0 for the US. UK average per capita emissions currently stand at 10.62 tonnes per annum.

It is clear that agreement must be achieved on a grand strategy for dramatically addressing this problem. It is equally clear that such a strategy needs to be global in nature. Given that it is the developed countries that have emitted – and that continue to emit – the lion's share of emissions to date, any long-term global agreement is likely to be on the basis of equal shares for all the Earth's human population to emissions entitlements.

Despite the daunting scale of the challenge ahead, there are solid grounds for hope that substantial reductions in current levels of emissions can be achieved. Several books and papers have described how these targets can be reached using existing or near-mature technologies.[2]

It is, however, also apparent that while many of the necessary technologies and changes in behaviour can be achieved at relatively little cost or discomfort, deeper cuts in emissions are likely to necessitate a fundamental restructuring in how we provide for our needs. (This is the phenomenon known as 'low-hanging fruit', with early sustainability targets being 'harvested' easily and cheaply, but later targets becoming progressively more difficult to reach.)

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[1] C. Forrest, 'The Cutting Edge: Climate Science to April 2005,' citing C.D. Jones et al. (9 May 2003) 'Strong Carbon Cycle Feedbacks in a Climate Model With Interactive CO2 and Sulphate Aerosols', Geophysical Research Letters, Vol. 30.

[2] For a comprehensive review of this literature, see G. Monbiot (2006) 'Heat: How to Stop the Planet Burning'. Penguin.

While in the long term, global agreement on a carbon descent strategy will be necessary, there is much that can be done at the local level in the short term. This is both to set a good example (especially important if the low-carbon countries are to be persuaded that the high emitters are serious about significantly addressing the issues and thus be willing to enter into a global agreement) and to pioneer models that can be replicated by other communities once we start the journey into becoming lower-carbon societies.

There is a great opportunity here for Scotland to play a leading role in developing models for sustainable, low-carbon lifestyles. It is especially favoured in this respect by its abundant renewable energy resources and by its relatively low population density. This report sets out a strategy for how this could be achieved, using a notional island with a population of around 1,000 people as a model to explore the key issues involved.

2.2 Terms of reference

The core objectives of the study are as follows:

- To review proposals for similar initiatives elsewhere in the UK/ Europe and identify key lessons or recommendations that could apply in the Highlands and Islands context.
- To consider for a ‘typical’ island community the measures or actions that would be required to move that community to a carbon neutral status.
- From published data, quantify as far as possible the scale of effort required to support such an initiative.

The full terms of reference can be found in Appendix 9.2.

2.3 Overview of the report

Section 3 examines some of principal methodological issues faced in undertaking the study.
Section 4 looks at other related initiatives in the UK and Europe.
Section 5 describes proposed interventions for the island to move towards carbon neutrality, while Section 6 sets out three scenarios for carbon neutrality and makes recommendations on how these can be achieved.
Finally, Section 7 sets out various implementation strategies and identifies some of the key organisations that could be involved in project implementation.

The Workbook Tables show the detailed data collected that underpin the statistical analysis and, in spreadsheet form, enable some manipulation of the key parameters so that the implications of different assumptions can be examined.

3 Methodology

3.1 Nature of the island

The terms of reference for this study define a Scottish island with a target population of between 600-1,200 people. We use a population base of 1,000 in order to simplify the arithmetic. A list of representative islands is contained as Appendix 9.1.

3.2 Definition of carbon neutral

A carbon-neutral community operates on energy sources and materials that are not derived from fossil fuels. Alternatively, if fossil-derived fuels are used, their carbon emissions can be offset by deliberate new activities that replace or permanently absorb an equivalent amount.

3.3 Footprinting

The two principal footprinting tools that have been developed are ecological footprinting and carbon footprinting: the former seeks to measure all resources used and wastes created by a given population, while the latter measures only emissions associated with the use of fossil carbon. In fact, given that we live in such a fossil-fuel dependent economy, the two measures can be seen as being broadly analogous, even though the units of measurement differ (carbon footprints are measured in weight of carbon, ecological footprints in hectares of bio-productive land).

Consequently, while many of the existing studies that are referred to in this report are ecological footprint studies – since this discipline has a significantly longer history than the more recently-developed carbon footprinting methodology – these are of direct relevance to this study of carbon footprints and how to reduce them in the context of a Scottish island. (These methodological issues are explored in greater depth in Sections 3 and 5 below).

3.4 Timescale

We have assumed a 25 – 30 year timescale. This allows for the use of existing technologies and the development of various new ones that are not yet commercially available.

3.5 Bodies consulted

Extensive web and telephone-based research has been undertaken in compiling this report. This includes research into best practice among local government and other bodies seeking to reduce their footprints. Interviews were undertaken with those involved in research and field trials on Scottish islands in bio-fuels, with wood chip and pellet suppliers, wood boiler installers in the Highlands, combined heat and power (CHP) and micro CHP suppliers, and with staff at PURE, Unst. We have also drawn upon our own knowledge base about ecological footprinting and wind turbine performance in the Highlands and Islands.

3.6 Baseline data

There is a significant methodological challenge in determining what to include in measurement of an island's footprint. Conventionally, both ecological and carbon footprinting methodology is based on consumption rather than production: the total consumption of the target population is included, *irrespective of where the consumed goods and services are* produced. This method reflects the increasingly globalised nature of our economy, recognising that much that is consumed is no longer locally produced and that much local production is for export from the immediate region.

In the current context, and using this methodology, the footprint of an island with a large distillery would be exactly the same as one without one (unless, of course, the islanders drank a disproportionately large amount of whisky!) As an approach, this might at first seem somewhat counterintuitive. However, in today's world, not even a Scottish island can truly be considered independently from its wider (today, global) context. If we were to measure the island's production rather than consumption, this would give an even more distorted picture of its true carbon footprint.

This methodological issue should be taken into consideration in the case that an island with a major export-oriented enterprise, such as a distillery, were chosen for a carbon-neutral initiative. In this case, some production-related element of the enterprise's footprint could be included in that of the island as a whole if that were considered appropriate for the exercise. For the most part, however, this will not be the case as relatively few Scottish islands play home to major export-oriented enterprises.

Our baseline data is, therefore, based on the consumption profile of carbon emissions for the United Kingdom, with some adjustments on the basis of assumptions made for distinctive conditions on a Scottish island (see 5.1.2 for details). We have used the Carbon Trust's production-related model to disaggregate these data in ways that are more useful for current purposes. This is explained in greater depth in section 5.1.1 below.[3]

An alternative method of interpreting the challenge involved in carbon neutrality would be to address the issues by examining the carbon emitted 'by the island' rather than 'by the islanders'. Such an approach would take into account island production (including e.g. distilleries) and island consumption, but not the carbon component of activities taking place elsewhere. This would enable most of the significant 'indirect emissions' discussed in Section 5 to be removed from the equation, (excluding the ferry component) and would result in a set of outcomes similar to those identified in Section 6.3. It should be noted however, that this would not be a standard approach to the problem and we have taken a modified version of the 'consumption' approach as identified above.[4]

Table A below sets out the main statistical parameters for the study that we have used. The references for the data appear the Workbook Tables, and the basis for the calculations used is set out in Section 10.

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[3] The Carbon Trust is an independent company funded by the Government to help the UK move towards a low carbon economy.
[4] See also Section 5.1.2 for further details.

Table A - Main Parameters

Category	Quantities	Units
Island Population	1,000	
Visitors as percentage of Residents	10%	
Equivalent Population with visitors	1,100	
Persons per house[1]	2.2	
Houses on Island	500	
Houses connected to district heating	25%	
Land Area	10,000	ha
Households with cars	73%	
Cars on Island	365	

These are the baseline data inputs to the Workbook Tables in section 10. The Workbook spreadsheets are interactive, allowing for manipulation of data to permit the testing of different hypotheses and strategies using different assumptions. These interactive tables are numbered 1 through 10. Where part or all of these tables appear in the main text they do so using an alphabetical table enumeration system. Thus, Table A above is also 'Table 1' in the complete Workbook Table list.

3.7 Presentation of options for a carbon neutral island

The Carbon Trust counsels organisations committed to addressing climate change:

- Firstly, to reduce direct emissions, diminishing their carbon footprint and creating bottom line savings by implementing all cost effective energy efficiency measures. Where cost effective, to reduce the carbon intensity of their energy supply by developing low-carbon energy sources such as on-site generation;

- Secondly, to look at opportunities to reduce their indirect emissions, working with other organisations to develop strategies to reduce emissions and cut costs up and down the supply chain, look for new revenue opportunities such as developing new low-carbon products; and

- Thirdly, if appropriate, to consider the option of developing an offset strategy that purchases only high quality offsets from verified projects that create truly additional emissions reductions.[5]

We have followed this approach when examining the various options available for a carbon-neutral island. Direct emissions are associated with activities that take place on the island and over which the population has a relatively high level of control – including, for example, levels of insulation, locally-based energy generation, types of food consumed and so on. Indirect emissions are generally associated with goods and services that originate off the island and over which the local population has little control – including, for example, central government expenditures, consumer items

[5] Carbon Trust: Where does offsetting fit in a robust carbon management strategy? http://www.carbontrust.co.uk/carbon/briefing/offsets.htm

such as fridges and washing machines, etc. This report includes various options and proposals to address both direct and indirect emissions.

3.8 The wider stage

Any study into lowering a given population's carbon footprint entails making certain assumptions about events elsewhere. That is, as the wider society reduces its own carbon footprint, so indirect emissions associated with goods imported into the island could be expected to drop, while the potential for off-setting may also diminish. We have therefore factored in some simple assumptions about changes in technology that may affect the UK during the period of the study (see Section 6).

4 Similar Initiatives Elsewhere in the UK and Europe

4.1 Initiatives in the UK

There have been a number of related initiatives in the UK and it is clear that the general subject of carbon footprints has moved very quickly up the political agenda in recent years.

4.1.1 Central government response

The British government has taken the lead internationally in terms of the setting of targets for the reduction of greenhouse gas emissions. The new Climate Bill published in mid-March 2007 would make mandatory not only a 60 per cent reduction in carbon emissions on 1990 levels by 2050, but also an interim target cut of 26 – 32 per cent by 2020. Governments would be obliged to set five-year ‘carbon budgets’, stipulating maximum emissions with tax changes, regulation and ‘cap and trade’ mechanisms to achieve the desired cuts.

In addition, the Department for Communities and Local Government has announced plans for all new homes to be zero-carbon by 2016, and published a draft planning policy statement on climate change that brings carbon considerations into the heart of the planning system. English Partnerships, a government regeneration agency, has recently announced a ‘carbon challenge’ in which house builders will construct buildings aimed at creating zero-carbon communities on five sites across England.[6]

However, as in the United States, it is within local government that the first and most tangible steps have been taken, with ambitious targets of various kinds set along with innovative policies and schemes for their realisation.

An important early step was the drawing up the Nottingham Declaration by a small group of pioneering councils in 2000. This called on signatory local councils to:

∞ **acknowledge** the mounting evidence that climate change is happening and the ‘far-reaching effects on the UK’s economy, society and environment’ that it will have;

∞ **welcome:**
- the social, economic and environmental benefits which will come from combating climate change
- the emission targets agreed by central government
- the opportunity for local government to lead the response
- the opportunity for councils to encourage local residents and businesses to reduce their energy costs and to address fuel poverty in their communities.

It further called on signatory councils to

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[6] New Start magazine (16 February 2007) “Quango to run zero-carbon house building challenge”.

∞ **commit to**:
- working with central government on the implementation of the UK climate change programme
- preparing a plan to address the causes and effects of climate change
- a significant reduction in the emissions associated with its own operations
- encouraging and working with all sectors and groups in the local community to address the challenge
- monitoring progress against targets.

The second National Councils Climate Conference, held in Nottingham in December 2005, agreed to attempt to double the number of signatories to 200 councils within a year. This has now been achieved and the number of councils signed up to the Nottingham Declaration continues to grow.[7]

A similar Climate Change Declaration for Scotland has also been drawn up and has been signed by all of Scotland's 32 local councils.[8]

4.1.2 Local government response

What follows is a review of some of the most innovative and successful programmes undertaken to date by local councils in the UK.

The **Greater London Authority** has embraced climate change as among its core over-arching priorities. London was the first city in Britain to set statutory CO2 emission reduction targets of 20% by 2015, and 60% by 2050. On transport, the UK's first congestion charge has halved the number of people using their cars daily, and increased cycling by 72%. London has also led the way by setting challenging targets for the use of renewable energy, with its statutory planning guidance calling for 10% of renewables in all new major developments. It plans to double this target. The city's new Climate Change Agency has struck up a commercial partnership with French energy company EDF to build highly efficient combined heat and power (CHP) projects across the city, and is working with Greenpeace to build the first zero-carbon eco-suburb.

Kirklees won an Ashden Award for sustainable energy in 2005 for its domestic solar project, which has put solar electric and thermal panels on 500 homes. It has also slashed emissions on its own estate, exceeding a target set in 1995 to reduce emissions by 30% compared to 1990 levels by 2005. It has now set another target to cut emissions by another 30% by 2020. Kirklees' environment unit coordinates and manages £6 million worth of projects and has 195 full-time staff. It is one of IDeA's "beacon" councils on sustainable energy.

Shropshire County Council has both a corporate and community climate change strategy, with strong emphasis on sustainable transport and energy. It set up the Marches Energy Agency in 1995 to come up with innovative solutions to reducing emissions, and has the country's only petrol station with 100% biofuel. The agency

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[7] The full text of the Nottingham Declaration can be found at: http://www.nottinghamcity.gov.uk/sitemap/the_nottingham_declaration

[8] http://www.sustainable-scotland.net/climatechange/index.asp

seeks to create a bandwagon effect by focusing on individual market towns and villages and helping them develop a road map to reduce emissions (one small community, Ilam, is aiming to become the first community in the world to be incandescent light bulb-free).

Aberdeen City Council slashed CO_2 emissions on its own estate by 31% between 2005-7. Along with a wholesale switch to green electricity, it has a carbon management programme that includes energy audits, a street light replacement programme, a green travel plan for council officers, and energy efficiency measures in council homes. The council created the not-for-profit Aberdeen Heat and Power Company to develop CHP projects, the first of which provides heat and power for 288 flats in four tower blocks.

Southampton City Council has one of the oldest and most extensive district heating and cooling systems in the UK. It set up an energy services company, in partnership with French utility company Utilicom, to service more than 40 private and public owned buildings, and plans to expand the system throughout the city. The council's climate change strategy is linked to its air quality objectives, making it a statutory responsibility. It employed the first full-time climate change officer.

Woking Borough Council has cut CO_2 emissions in its council buildings by 77% through energy efficiency measures and the pioneering use of low- and zero-carbon technologies. Woking's climate change strategy calls for a "carbon-neutral approach" to all future services, and its guide for developers calls for an 80% reduction in greenhouse gas emissions on 1990 levels in new construction.

Leicester City Council has saved £1.5m in energy costs over five years by implementing a pioneering smart metering system in all 550 council buildings. By getting half-hourly data on water, gas and electricity use, the council was able to pinpoint wastage and take immediate action. The local authority offers training courses on installing low-carbon technologies, has a renewable energy loan scheme for residents, and has developed several small-scale CHP projects.

Cornwall County Council was the driving force behind the Cornwall Sustainable Energy Partnership, which brings together eight councils and 72 organisations, including businesses, community groups and the primary care trust. The partnership produced an energy strategy in 2004, setting out 32 actions to be delivered by all 72 signatories, including meeting challenging targets for renewable electricity.

Merton Borough Council has developed a groundbreaking prescriptive planning rule that all new commercial developments over 1,000 sq meters must have 10% of their anticipated energy needs met by onsite renewables. The rule, pushed through by the council's environment chief Adrian Hewitt, prompted a slew of imitators, including the Greater London Authority - which wrote it into its London plan - and Croydon, which extended it to all residential developments. Merton persuaded the government to adopt planning policy statement 22, confirming the legality of the policy and its desire to see other councils emulate it. To date, 18 councils have done so and another 73 have Merton-type rules in their draft plans.

The **Cairngorm National Park Authority** is, in conjunction with the Macaulay Institute, actively researching its carbon footprint and what steps it may be able to take to reduce it. This initiative is still at a very early stage.

4.1.3 Community-level initiatives

The '**Transition Town**' movement aims to co-ordinate various communities who wish to respond to the challenge of climate change. Members include Totnes in Devon, Lampeter in Wales and Kinsale in Ireland. Member communities are involved in creating and implementing 'energy descent' strategies. [9]

The village of **Ashton Hayes** in Cheshire recently hosted a 'Going carbon neutral' conference. They have produced an excellent CD pack, part funded by DEFRA which contains information about their own project, work done by the University of Chester and various other interested organisations. Although the initiative is perhaps at an early stage of grappling with the complexity of the issues, the conference attracted enough interest to suggest an emerging network of similarly motivated settlements and activists.

Biggar in Lanarkshire has announced a campaign to create the first 'carbon neutral' town in Scotland. Under the plan, the town, which has a population of about 2,000, would grow its own food, create its own electricity and implement a low-impact waste strategy.[10] A similar initiative is now under consideration in the village of Cardenden in Fife.[11]

4.2 European initiatives

This is a summary of a number of European initiatives and projects that are aiming for carbon neutrality or zero-emissions.

* **SunCities**: a demonstration project supported by the European Commission under the Fifth Framework Programme. It consists of 3 local projects of new housing developments of building integrated PV power (total 3.05 MWp)[12] The dwellings contain energy saving measures to reduce electricity and heating consumption and other renewable energy options (solar hot water, heat pumps, in-town wind turbines, or small scale hydro).

The Sun Cities are located in three European countries:
UK: Kirklees (250 houses, zero energy, 0.4 MWp) – see also above
Germany: Am Koldenfold (50 houses, low energy, 0.1 MWp), and
Netherlands: City of the Sun (1,410 houses, zero energy, 2.45 MWp)

The objectives of the project are:

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[9] See http://transitionculture.org/
[10] http://news.scotsman.com/index.cfm?id=607152007 The Scotsman 20 April 2007.
[11] http://www.goingcarbonneutral.net/
[12] MWp=peak megawatt: Unit used to measure the standardised power output (nominal output) of solar cells and photovoltaic modules.

- European local and regional authorities will demonstrate that they can implement a significant part of the EU targets on CO2 and PV, within their own built environment. Together with relevant market parties such as project developers, utilities and the building industry they will implement zero-emission urban developments with 1,760 new houses and 3.05 MWp of PV.
- To demonstrate that PV can be implemented in a normal but appealing way when fully integrated in the urban planning and the building process on an entire housing development site.
- The considerable cost reduction to less than 3.5 Euro/Wp in 2004 in several member states for the large-scale application of building integrated PV.
- To disseminate the results of the integral approach and to reduce risks associated with PV to increase the uptake by the traditionally risk-avoiding building industry.

* Several cities in the **Netherlands** aspire to become “energy-neutral” within a definite timeframe:

- Apeldoorn by 2020. Their strategy is to minimise energy demand, and to produce the required energy in a renewable way to the highest possible extent.
- Groningen by 2025, also wants to become the Netherlands’ most sustainable city. Groningen wishes to achieve this by focusing on energy and the quality of the environment: developing healthy districts that are low on energy demand. The Province of Groningen developed a cooperation agreement with energy companies for realising energy savings in existing dwellings, retro-fitting them with higher insulation materials, and installing solar panels and ground source heat pumps.

* The **WWF** claims that its Netherlands HQ is the first CO2-emission free building in Europe. This was achieved by high-standard insulation, solar panels and PV-panels, FSC-certified wood etc.

* The Ministry of the Flemish Community in **Flanders**, Belgium, is running a project named “sustainable building and refurbishing”. One of the main topics in this project is adopting energy certification for houses and passive housing (see below). All new buildings from 2030 onwards would have to comply with the standard. A few dozen projects have been worked out in other areas, e.g. stimulating home-sharing, working from home, …

* There are several ***passivhaus*** projects throughout Europe, although most of them are in Germany and Austria. The *passivhaus* standard for energy use in buildings was developed in Germany. It has rigorous requirements for primary energy consumption, and this is achieved by super insulation, passive solar design, air tightness and heat recovery ventilation.

Key Action 4 of the 5th Framework Programme of the European Commission is called “**City of Tomorrow & Cultural Heritage**”, and includes numerous sustainable city planning, natural resource management and sustainable transport projects.

* The Spanish government recently announced that **El Hierro**, one of the smallest of the Canary Islands, is to receive 100 percent of its electricity supply from renewable energy sources. El Hierro will rely on a combination of hydroelectricity and wind

power to generate its electricity. It is claimed that the island, which has a population of 10,500 "will be the first island in the world totally supplied by renewable energy". The technology to be used includes a system involving two reservoirs to power hydroelectric stations, a wind farm and a pumping system.[13]

* **Samsø** is a Danish island in the Kattegat Sea covering 11,400 hectares, with a population of about 4,400. There are proposals to convert its energy supply system over the course of 10 years from being based almost entirely on fossil energy sources to being based on renewable energy sources.
The key aspects of their strategy involve:

- Cuts in consumption and increased efficiency in terms of heat, electricity and transport, and adjusting people's behaviour patterns
- Expansion of the district heating supply system combined with utilisation of local biomass resources
- Expansion of individual heating systems using heat pumps, solar heating, etc.
- Erection of land-based and offshore wind turbines to cover electricity consumption
- Gradual conversion of the transport sector from petrol and oil power to electrical power or biodiesel.

Samsø Energy Company was set up to implement the 10-year energy plan, which runs from 1998. This company consists of representatives from the Samsø Municipality, the Commercial Council, the Farmers' Association, and Samsø Energy and Environment Office. The company set up a secretariat to coordinate all projects and activities. The secretariat also collaborates with the Danish Energy Agency, ARKE, PlanEnergi, Midtjylland (a firm of consultants) and other consultants as required.[14]

They have recently announced that, ahead of schedule, they have achieved an 'almost entirely self-sufficient energy system, which has improved life for the whole community'. They are now 100% self-sufficient in electricity and 75% of heating requirements come from a combination of solar power and biomass.[15] (See also below in Section 7.1) They have apparently created a new 'academy' aimed at promoting their work. It is encouraging to note both their success, and the similarity of approach to our own proposals for a carbon neutral Scottish island.[16]

* Gotland Energy Agency was established in **Sweden** in 1996. Its activities include raising awareness of energy issues at local authority level, dissemination of information on energy management and supporting the sustainable development of local renewable energy resources for the island.

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[13] http://www.myninjaplease.com/green/?p=512&akst_action=share-this
[14] See Lunden, M.A. (2003) Whisper of Wings. Vingesus. An overview of the island's strategy in both English and Danish. and http://w2.djh.dk/international/2001/samso/GreenIsland/index.html
[15] 'Denmark's Living Green Island' (No 52 Summer 2007) Positive News. This story was covered in more depth in Denmark e.g. 'Samsø viser hele verden vejen' (Samsø is showing the way to the whole world). (12 May 2007) Århus Stiftstidende newspaper. The article goes on to state: 'In a few years Samsø has created a CO2-free energy supply using clean sustainable energy. Now visitors are coming from the whole world to learn how to save the planet'.
[16] Samsø only came to our attention at an advanced stage in this report's development.

In April 2007 Prime Minister Stoltenberg of **Norway** presented a new climate policy. The proposal is intended to cut carbon emissions by 30 per cent by 2020, increase obligations made under the Kyoto Protocol, and pave the way for Norway to become a carbon neutral country by 2050.

4.3 Footprint studies

Carbon footprinting is a new discipline and to date, relatively few carbon footprint analyses have been undertaken of specific communities. Many ecological footprint studies have, however, been undertaken and, as explained above, our fossil-fuel dependent lifestyles mean that the two footprint methods can be considered as broadly analogous.

Ecological footprinting emerged as a discipline from the mid-1990s. It has been used to measure the footprint of most countries of the world together with countless communities of all sizes and many products and technologies.

As climate change has moved centre stage in public awareness and political debate, so there has been a greater focus on just one of the elements measured in ecological footprinting, namely carbon emissions. Thus has led to the emergence of the newer discipline of carbon footprinting.

A **carbon footprint** is a measure of the amount of carbon dioxide emitted through the use of fossil fuels in the case of a community, organisation or enterprise, as part of their everyday operations. Use of the term ‘footprint’ here is something of a misnomer, since carbon is actually measured by weight. It is borrowed directly from ecological footprinting.

The size of both carbon and ecological footprints is a function of

Population x Consumption x Technology

That is, footprints grow or shrink according to the size of the population, the level of consumption and the energy efficiency of the technology employed.

The findings of a number of ecological footprint studies that are considered relevant to the current study are detailed in Appendix 9.3. The main conclusions that can be drawn from these are:

- Relatively low levels of income, higher prices for many goods and a paucity of services mean that consumption levels of many goods and services tend to be lower on islands than on the mainland.
- Ferries consume substantial amounts of fossil fuels and may add significantly to the footprint of an island community.
- Domestic energy consumption, along with food and travel footprints can all be dramatically reduced with conscious effort. In particular, high levels of insulation, locally produced electricity, a high volume of locally grown

organically produced food and reduced commuting can have a significant impact.
- Low impact appliances, investment in public transport and tax incentives for environmentally friendly initiatives, can also lead to ecological/carbon footprint reductions

Especially interesting and encouraging for present purposes is the ecological footprint study undertaken in 2005 of the Findhorn Foundation community in Moray. This found that the community has succeeded in significantly reducing its footprint to around half the national average through activities and interventions at the community level alone – that is, without policy-level or government intervention.

Specifically, the community's 'food' and 'home and energy' footprints were found to be 37% and 21.5% of the UK national average, respectively. The key factors here are a high level of local, organic and seasonal food in the community's predominantly vegetarian diet, the fact that the community is a net exporter of electricity as a result of its four wind turbines and a range of highly energy-efficient houses.

The footprint relating to 'consumables' – personal ownership of goods – was found to be 48% of the UK national average. Car mileage was found to be just 6% of the national average, primarily as a result of workplaces being located close to residential dwellings, making commuting unnecessary for most. Air miles were however twice the national average.

4.4 Resources

Woking Borough Council has produced an excellent series of working papers in the series 'Carbon Neutral Development: A Good Practice Guide. These cover the fields of:

- Location and Transport
- Energy
- Site Layout and Building Design
- Sustainable Drainage Systems
- Water Conservation and Recycling

A copy of their strategy paper is attached as Appendix 9.4.

Beddington Zero Energy Development (BedZED) Carbon Neutral Development project.

The objective of this project is to produce and disseminate information showing data, including financial data, on how the construction industry can build desirable buildings that produce zero net carbon emissions and minimise environmental impact whilst yielding a respectable financial return on investment. The information is based on achievements at BedZED, an innovative low-impact eco-housing development in south London.

The Carbon Neutral Project consists of seminars, exhibitions and two reports: The Construction Materials Report and the Carbon Neutral Toolkit.

The first part of the project to be produced was the BedZED **Construction Materials Report** published in December 2002 alongside a supporting seminar.

The **Toolkit for Carbon Neutral Developments** was published in October 2003. This is a practical guide to producing carbon neutral developments and how to afford them. Based on the achievements at BedZED it describes all the measures taken on the scheme to reduce environmental impact during occupation. It includes technical descriptions, monitoring results, and financial mechanisms that have allowed the innovations at BedZED to become a reality.

The report also links with the more recent 'ZED in a box' design, which represents the next generation of the ZED design and development process incorporating further improvements since BedZED.[17]

* The **Ashton Hayes** community in Cheshire has also produced a Carbon-Neutral Toolkit, with funding from DEFRA. This includes a carbon calculator created in association with the University of Chester and various papers describing case studies and strategies for reducing carbon footprints.[18]

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[17] For more information and to receive a copy, visit <
http://www.bioregional.com/programme_projects/ecohous_prog/bedzed/bz_carbon.htm>

[18] This can be obtained on request from the Ashton Hayes project manager, Gary Charnock <charnock@t-e-s.co.uk

4.5 Summary of key findings

A number of key findings emerge from the various initiatives described in this section:

- Many of the case studies described above provide interesting models that are of relevance to the current study. Of especial mention are the following:
    - Several successful initiatives to reduce the carbon footprint of councils' own estates;
    - Innovative institutional arrangements, including the creation of Climate Change Agencies and Climate Change Officers and, in the Cornwall County Council as well as on Samsø Island in Denmark, the creation of cross-departmental secretariats to coordinate carbon-reducing strategies;
    - The introduction of various innovative energy and other technologies, including biodiesel, small-scale CHP and district heating systems and carbon-trading schemes; and
    - Programmes to mobilise communities to engage in carbon-reducing projects at the local level. A number of the case studies have generated resources that are relevant and potentially useful in the current context.
- The many and various initiatives currently underway indicate the high level of interest and enthusiasm that exists and suggests that considerable and growing political weight is mobilising behind the push for sustainable, low-carbon community solutions.
- Many of the initiatives currently describing themselves as carbon-neutral – or seeking to move in that direction – are a long way from achieving their goal. This is because they tend to focus on just one sector rather than adopting a holistic approach; and they tend to limit themselves to the 'low hanging fruit' of relatively easily and cheaply achieved targets.
- A conspicuous exception is Samsø Island, which has taken a holistic rather than a sector-specific approach, with all areas of community life that produce carbon emissions included. This found that while there is enthusiasm among the native population for the idea of a 'green island', certain ecologically friendly innovations, including the use of electric cars, met with resistance.
- Consequently, the desire for significant real reductions in the carbon-intensity of the lifestyle of the island's population (rather than continuing with 'business as usual', with substantial compensating, off-setting activities) is likely to need to be tempered by a certain resistance to change among that population. In short, certain measures are likely to prove more palatable than others.
- Nonetheless, the results of some ecological footprint studies suggest that significant reductions in carbon footprints can be achieved, even in the absence of policy changes or direct government intervention. In particular, domestic energy consumption and food and travel footprints can all be significantly reduced with conscious effort. High levels of home insulation, locally produced electricity, a high volume of locally grown organically produced food and reduced commuting can all have a significant impact.
- The reduced level of consumption of goods and services on islands relative to that on the mainland tends to reduce the baseline carbon footprint, but this is likely to be balanced, to some degree at least, by the impact of the island's ferry.

5 Proposed Interventions

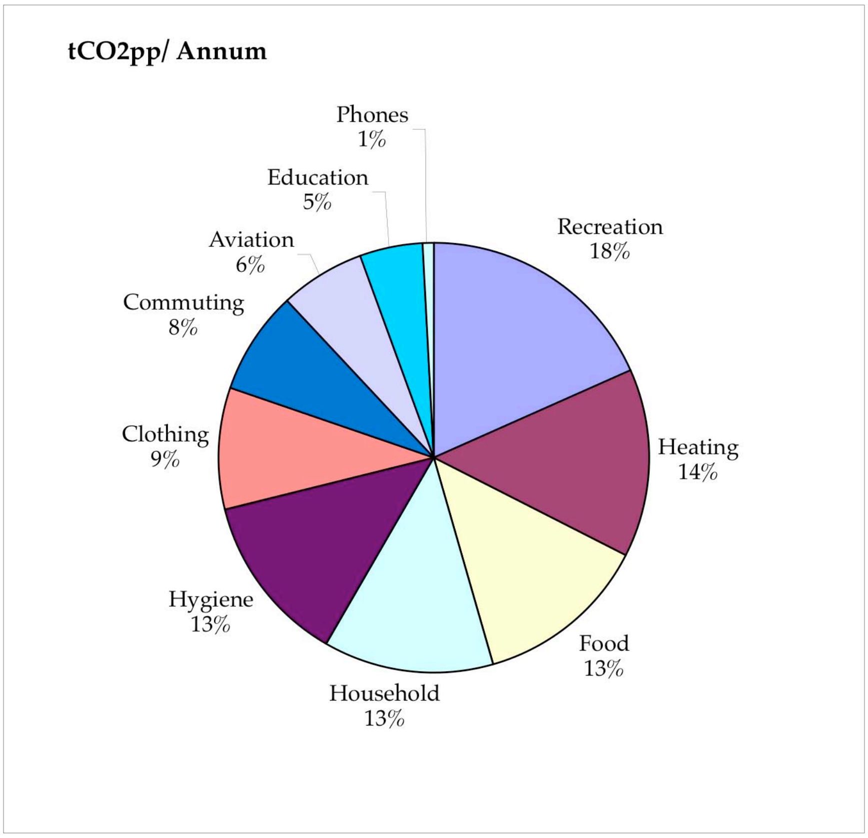
This section estimates the baseline carbon emissions of a generic Island and then identifies the options available to move that community to a carbon neutral status.

5.1 Baseline data

5.1.1 UK carbon emissions - production and consumption accounts

Since there is no data on carbon emissions specific to Scottish islands, our starting place will be the breakdown provided by the Carbon Trust of UK carbon emissions. This has been undertaken from a variety of perspectives including the ‘Consumer Need’ and ‘Production-based’ accounts.

The former gives average per capita emissions as 10.62 tonnes of CO_2, broken down as follows (see also Table 5 in the Workbook Tables for the numerical breakdown):



This method is useful in that it provides individuals with a useful perspective regarding their personal carbon emissions. This way of presenting the information is, however, less helpful from the point of view of determining what may be done to reduce emissions, as the disaggregation is between broad areas of activity and tells us little about how the emissions have been created – by transport, industrial processing, packaging, etc. For example their ‘recreation’ heading includes transport involved in holidays and the consumption of alcohol and tobacco. Thus, it is not at all clear from the consumption-based data, what impact the introduction of renewable electricity supplies or fuels for road transport would have.

For our purposes, the Carbon Trust's 'Production-based' breakdown of the same global data (10.62 tonnes of CO2 per capita) is more useful as it analyses UK carbon emissions in a way which enables an analysis of the impact of activities that can be addressed more directly. What is especially useful here is the disaggregation of direct and indirect emissions.

Table B

Production-based Account				
	MtC			
Electricity	45.77		26%	
Domestic Fuel	25.30		14%	
Small-Scale Commercial	5.92		3%	
Road Transport	26.18		15%	
Sub-total - Direct		**103.17**		**58%**
Larger Commercial	39.73		23%	
Public Sector	5.02		3%	
Water Transport	5.78		3%	
Aviation	11.00		6%	
Overseas trade	11.70		7%	
Sub-total - Indirect		**73.23**		**42%**
Total	176.40		100%	

From this perspective we can determine roughly what activities on the island result in 'direct emissions' and which are 'indirect'. These are rather fluid categories but if an activity is taking place on the Island and there is a reasonable possibility of it being replaced by an alternative available to the island community, then it can be said to be a direct emission. If on the other hand there is little or no such activity on the island and little prospect of islanders being able to confront the challenge directly it can be described as 'indirect'.

Direct emissions: clearly, islanders use electricity (although this category in the above table also includes electrical use by mainland industries on which they in part depend), use energy in their houses and operate cars and lorries. The impact of small scale commercial activities including agriculture, hotels and catering, construction and retailing that would often be found on a typical island can also be estimated.

Indirect emissions: larger commercial activities include refining, manufacturing etc. not normally found on a small island.[19] [20] Other activities with significant related indirect emissions – public sector, aviation, international trade and technologies used

[19] Distilling can have a very significant impact – see Appendix 9.5
[20] There are complications: for example, emissions for space heating for smaller commercial activities are likely to be 'indirect' from this perspective. Overall however, the impact is not likely to be very significant.

in water transport – are those which islanders would not normally have any direct ability to influence through their personal or collective choices.

We then attempted to provide more detail by using data that provides an energy breakdown by sector and the source of the energy supplied (coal, oil etc.) The detailed calculations are shown in Workbook Table 2. (As they form an intermediate step towards the creation of the main data in Table C they are not presented in the main text).

5.1.2 Adjusting the data for Scottish island conditions

There are a several significant differences between typical Scottish islands and the rest of the United Kingdom and we have attempted to take these into account using the following assumptions:

1. Domestic space heating and electricity demand is assumed to be similar to the UK average. Climatic factors suggest that the former may be higher than the average, although this is likely to be compensated by the relatively low average incomes on Scottish islands.
2. Services are assumed to be 50% of the UK average. This number is hard to quantify, but whilst some services used by islanders (e.g. Raigmore hospital in Inverness) will have a higher carbon tariff than the UK norm, the availability of services on islands is generally low. There are, for example, no railway stations, cinemas, or ice rinks.
3. Road transport is assumed to be 75% of the national average. Few islanders have long commutes by car, and whilst trips to mainland centres may involve long journeys, the opportunity for using vehicle transport on a day-to-day basis is relatively limited
4. The energy associated with food is assumed to be similar to the UK average. For foods produced locally it will be lower, but for foodstuffs arriving by ferry it will be higher.
5. 50% of the carbon emissions associated with the island's ferry are allocated to the island (the remaining 50% being allocated to the mainland).
6. Just as for services, we assume that the emissions associated with the consumption of industrial products is lower than the national average. A study of income and price data suggests that islanders may have an effective purchasing power of 65-70% of the UK national average.[21] Further, taking into account the reduced opportunities for spending (the islands have no shopping malls) and the inclusion of the production emissions of the relatively small island commercial sector as a separate compensating factor we assume that consumption of industrial products is just 50% of the UK average.

These various assumptions are open to question and debate and represent our best estimates on the various ways and degrees to which Scottish island conditions vary

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[21] Data from http://www.hie.co.uk/HIE-economic-reports-2007/Economic-report-H-and-I-2007.pdf http://www.scotland.gov.uk/Publications/2004/10/20075/45032 http://www.cne-siar.gov.uk/factfile/socioeconomicoverview.htm

from those in the rest of the UK. The core assumptions can be amended in column E of Workbook Table 3 to provide a revised set of summary figures.

So, using the Carbon Trust core data adjusted in line with the above assumptions, the per capita carbon footprint of the average inhabitant of a typical Scottish island is estimated as follows:

Table C - Estimation of CO2 Emissions on a typical Scottish island

Category		Island		Reduction
		tCO2pp	%age	Via
		in total		
Domestic heating		1.73	18%	Biomass
Services heating		0.28	3%	Biomass
Domestic electricity		1.04	11%	Wind or similar
Services electricity		0.47	5%	Wind or similar
Road Transport - island		0.28	3%	Biofuels
Food - island		0.50	5%	Local & organic
Sub-total - Direct		4.31	45%	
Road Transport - mainland		1.00	11%	
Ferry Transport		1.58	17%	
Other Transport		0.60	6%	Offsets
Food - mainland		0.49	5%	
Industry & Other		1.52	16%	
Sub-total - Indirect		5.19	55%	
TOTALS		**9.50**	100%	

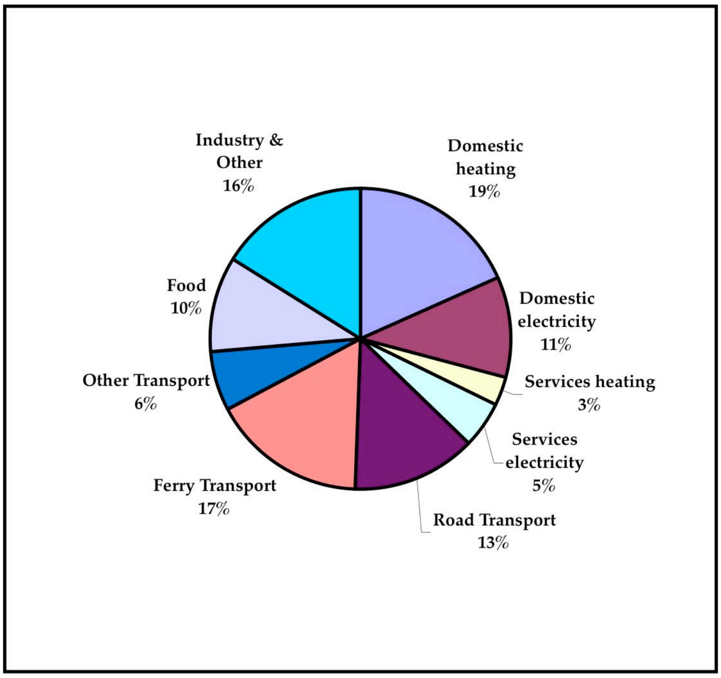
It is of interest that after making the various island-specific adjustments, per capita island emissions are around 10% lower than the UK average. In broad terms, lower than average commercial and industrial emissions outweigh the impact of the diesel used by the island's ferry.

We have also compared the above data with other data on energy use from Islay, which broadly corresponds to these findings (see Appendix 9.5)

The figures for our generic island can be summarised as follows:

	tCO2pp	%age
Direct Emissions	4.31	45%
Indirect Emissions	5.19	55%
Total Emissions	9.50	100%

Estimated Island Carbon Footprint from Table C (see also Workbook Table 3).



Note that direct emissions calculated by this method are substantially lower and indirect emissions correspondingly higher than in the Production-based Account for the UK in Table B.[22] This is primarily i) because of the large size of the footprint associated with ferries; and ii) most transport emissions associated with the delivery of goods and services to the islanders take place on the mainland. The definitions also imply that no electricity is used for heating. Whilst this is not the case, any additional electrical demand for heating would need to be included in the required electrical generation capacity and deducted from the heating load.[23]

We can now directly address direct emissions, and indirect emissions and offsets in an attempt to discover what an island community might be able to achieve.

5.2 Reducing direct emissions

There are numerous options available and thus a very large number of combinations of possible solutions. Thus, although in practical terms it would be unlikely that for example all space heating would be derived from biomass or all vehicles powered by biodiesel, we have assumed such would be possible, calculated the requirements and provided alternatives where they seem credible. The Workbook Tables provide the opportunity to use alternative assumptions.

[22] Another may be the artificiality involved in imagining a small carbon neutral island and a large mainland with high levels of carbon emissions.
[23] In other words our 'heating' category is really 'heating excluding electrical heating' which would be a rather unwieldy category name. In theory, average electrical heating needs should already be factored into the overall demand requirement.

5.2.1 Electrical use

Electrical consumption makes up more than a quarter of all UK emissions, and an estimated 16% of island emissions. (Tables B and C).[24] This is almost certainly the single easiest sector in which reductions in the carbon footprint can be made. An average Island household uses 5,300 kWh per annum resulting in CO2 emissions of 1.04 tonnes per person per annum and assuming a further 0.47 tonnes are emitted by island businesses, we need to find a way to generate around 3,900 MWh from renewable energy sources to eliminate carbon emissions from direct electrical usage. (See Workbook Table 6)

Fortunately this is not difficult. Scotland's islands are blessed with an abundance of wind, wave and tidal potential. The technologies in the latter two are still at an early stage of development, but onshore wind is a mature and well-understood industry. Although still dependent on the Renewables Obligation regime, which is under process of review by the DTI, HICEC's own publications indicate that a community-owned scheme is likely to be financially viable and indeed would generate a return for the community that owns it.[25] An installed capacity of 1.26 MW or more (assuming a capacity factor of 35%)[26] would result in the island becoming a net exporter of electricity for the foreseeable future.

Given the probable long-term increase in the costs of generating electricity by using fossil fuels, wind-powered generation is likely to become progressively more financially viable. Consequently, provided there are no major objections to turbines on conservation grounds and in the absence of grid capacity problems, this appears to be a more or less guaranteed strategy for eliminating carbon emissions, especially over the time scales under consideration.

Clearly, the assumption is that exported electricity offsets any electricity units imported not produced from renewable sources. This is a conventional approach in footprinting methodology.[27]

In situations for which wind is not a suitable solution, a micro-hydro unit may be an alternative as, for example, Knoydart demonstrates.

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[24] There is some debate about the total amount of carbon emitted by electricity generators. If the standard figure used in Workbook Table 2 is too low, then assuming the Carbon Trust's figures for average UK carbon footprints are correct, the percentage of CO2 being emitted by electricity production is higher than anticipated, and other impacts are correspondingly lower. The amount of carbon emissions to be offset for indirect consumption by an Island is therefore lower. Alternatively, if the implication is that the Carbon Trust's figures for average UK carbon are too low because they have underestimated the electricity emissions figure, then there would be no change to the Island strategy as all the electricity can be produced from renewable energy resources.

[25] See for example Energy4All Ltd. (2006) Empowering Communities: A Step By Step Guide to Financing A Community Renewable Energy Project. Inverness. HICEC

[26] This is a conservative estimate. Westray for example expect to achieve 40%. See http://www.orkneycommunities.co.uk/WESTRAY/

[27] See for example Tinsley, S. and George, H. (2006) Ecological Footprint of the Findhorn Foundation and Community. Moray. Sustainable Development Research Centre, UHI Millennium Institute.

5.2.2 Domestic heating

This sector makes up an estimated 18% of island emissions. If we include the island's commercial sector, the figure rises to around 21% of the overall island footprint (Tables B and C). On some islands the presence of household biomass boilers will mean that this average is lower than the norm, but our aim is to eliminate emissions wherever possible.[28]

5.2.2.a Biomass

Installing more solid biomass capacity is likely to be the most effective way to reduce carbon emissions in this context. In order to examine the potential (for both biomass and biofuels) we have used average statistics for available land – see Workbook Table 1.

Wood fuel may in fact exceed hydroelectric and wind as the largest source of renewable energy at present. Scotland's forests, which currently make up 60% of the UK resource base could provide up to one million tonnes of wood fuel per annum.[29] Logs, wood chip and pellet are optional forms of wood fuel.

The Forestry Commission is developing a Scottish Biomass Action Plan in conjunction with the Scottish Executive, and the latter is expected to provide a £7.5 million grant scheme to support biomass energy. There is growing demand for automatic wood pellet boilers which can be as convenient to use as conventional central heating systems, and which are economical to run as well as being carbon neutral. Growing trees provides a potentially useful synergy involving the crop, the amenity advantages of woodland and biodiversity. There is also local potential for energy crops such as short-rotation willow or poplar coppice, michanthus energy grass, agricultural wastes such as straw and manure, and forestry residues.[30]

5.2.2.b Combined heat and power (CHP)

As part of the input parameters, a percentage of houses on a district heating system is applied to the total heating load for the Island from Table 6. The district-heating scheme will depend on the size and geography of an appropriate town or village on the Island. The resulting load is then adjusted for losses in the system, which is dependent on the size of the heat distribution.

Ideally the biomass will be grown on the Island, and the area required is calculated (in Workbook Table 8). In addition to district heating, the CHP will generate electricity.

For houses not on the district heating system, the energy is identified and an average efficiency number applied. New wood pellet boilers achieve over 90% efficiency. However, a more modest house efficiency is applied taking into account the heating systems in the houses. From the built heating load, the area of short rotation crop

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[28] Peat is not however a renewable resource, except on very long timescales. (Brian Wilson's column in the 'West Highland Free Press' of 8 June 2007 notes that the Bord na Mona have managed successfully to argue a renewable classification in Ireland.)

[29] Scottish Executive Forum for Renewable Energy Development in Scotland (2005) http://www.scotland.gov.uk/Publications/2005/01/20616/51409

[30] http://www.renewscotland.org/biomass/forestry.html Renewscotland

forest necessary to grow the biomass sustainably is estimated. When combined with the forest area required for CHP, the amount of land for biomass production is compared to the potential.

There are significant variations in the productive capacities of Scottish islands, with the Orkney archipelago and the Western Isles representing extremes. Numbers for both are calculated.

We estimate a total of 483 ha of sustainably managed woodland is required to heat the Island from biomass. This is approximately 12% of available agricultural land on an Orkney island, but a significantly higher percentage in the Outer Hebrides.[31] If the Island builds passivhaus low-emission buildings, the land area required reduces to 118 ha.

There are likely to be islands where climatic factors, especially wind, mitigate against the growing of wood. Logs and woodchip are bulky low-value products that may prove uneconomic to import. In such circumstances wind-to-heat could provide a carbon-neutral alternative (see Section 5.2.2.e below).

The CHP unit would generate about 19% of the Island's electrical needs. However, because of the potentially complex interactions between different renewable solutions, we have assumed that this unit adds to the offsetting required for indirect emissions, rather than reduces the amount of installed wind power required. This would only be a practical consideration if the amount of offsetting required were assumed to be very low (see also Sections 6.3 and 6.4 and Appendix 9.7.below).

5.2.2.c Biogas and landfill methane

Biogas is a biofuel produced through the intermediary stage of anaerobic digestion consisting mainly (45–90%) of biologically produced methane. It is estimated that up to 0.4 GW of generating capacity might be available from agricultural waste in Scotland.[32] Small-scale schemes are currently being trialled. It is estimated that 0.33 m^3 of methane is produced per kg of BOD reduced in the anaerobic process. This type of process works well with a dairy herd and the US experience suggests that production can be economic for on-site farm use with a minimum herd of about 100 cows. Such systems may be applicable for island circumstances. However for commercial biogas produced from human waste streams in urban areas it has been estimated that a minimum population of 15,000 may be necessary.[33]

Landfill sites have further potential as the successful waste to energy plant at Lerwick attests. This plant burns 22,000 tonnes of waste every year and provides district heating to over 600 customers.[34] Although this involves the burning of wastes that

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[31] The ideal land to use would be the Scottish Agricultural Census category 'grass over five years' but in the Hebrides these would require about three quarters of the available quantity to be turned over to forestry. There is of course substantial additional poorer quality land where yields would be lower.

[32] RSPB Scotland, WWF Scotland and FOE Scotland (February 2006) The Power of Scotland: Cutting Carbon with Scotland's Renewable Energy.

[33] These figures are from projects the Associates are involved in, in Vermont USA and England.

[34] See http://sheap-ltd.co.uk/

produce CO2, there is a commensurate reduction in escaping methane, which is a significantly more harmful greenhouse gas. This plant takes waste from all over Orkney and Shetland and a small island is highly unlikely to be able to support such a project in the foreseeable future.

A 2003 study concluded that there was a positive case for a project using agricultural waste on Mull. [35] If, during the relevant time scale, biogas production is proven to be economic for local use on an island of the size we are considering this would reduce the land area required for other renewable fuels.[36]

5.2.2.d Distillery wastes

Whisky distilleries may have a locally important role to play in reducing emissions. Caithness Heat and Power, for example, has announced plans to tackle fuel poverty in Wick by utilising a wood-chip CHP scheme in partnership with the Old Pulteney Distillery. In general, this is only likely to apply to larger islands, although we understand a scheme to use waste heat from the distillery on Jura is being considered.

However, the opportunities offered by distilleries need to be understood in the context of their high levels of energy use. Thus, where an island has a distillery there are likely to be options for improving the existing levels of carbon emissions. However an island with one or more distilleries would not necessarily be an ideal candidate for attempting to achieve carbon neutrality (see also Appendix 9.5).

5.2.2.e Wind to Heat

Although likely to be both more expensive and less efficient, significant space heating on an island could be produced using electricity from wind power or other equivalent. We estimate that approximately 3.33 MW of installed capacity of wind turbines would be required to provide space heating to the island, in addition to the capacity required for other electrical use and offsetting. See also Appendix 9.7.

5.2.3 House construction

House building and renovation techniques also have substantial potential to significantly reduce the carbon footprint associated with domestic heating.[37] Gordon Brown, the Chancellor of the Exchequer announced in November 2006 that within a decade all new houses would have to be 'zero carbon'. However, in an island context, unless there are high levels of new build or very significant efforts put into retrofitting

[35] Maureen Cloonan (2003) Energy From Waste on the Isle of Mull: A Feasibility Study of an Anaerobic Digestion Plant.

[36] Biogas is commonly used on a domestic scale in developing countries however, health and safety issues make smaller scale use impractical in the UK.

[37] Indeed the the American Solar Energy Association (ASES) claims that renewable energy technologies combined with energy efficiency have the potential to provide most, if not all, of the US carbon emissions reductions that would be needed to meet a goal of a 60 to 80 percent emissions reduction by mid-century (while the economy continues to grow). Despite making what they claim to be relatively conservative assumptions, the ASES report concludes that energy efficiency alone is capable of providing 57% percent of the reductions needed. (‘Tackling Climate Change in the US - Potential Carbon Emissions Reductions From Energy Efficiency and Renewable Energy by 2030’ (2007) ASES)

existing houses, such gains are likely to be lower than in a wholly new-build development. Research suggests that the two most important factors in this regard are:

- High standards of insulation, including cavity wall insulation, low U value doors and windows, air tight construction techniques, and thermal mass.
- High levels of fuel efficiency, especially CHP systems and managed timed temperature and control mechanisms and ventilation systems.[38]

Other factors that may influence the carbon footprint of the housing and commercial building stock include the re-use of existing materials in the construction,[39] the use of more efficient domestic appliances, the commitment to rainwater harvesting and the approach to waste water treatment.

The latest high performance building standards (Passivhaus and AECB Gold Standard) provide substantially lower carbon emissions than the existing stock and also the current Building Control requirements (4-6kg/m^2/annum). Many houses on a typical Scottish island will not be constructed to existing standards. However, to be conservative, these numbers are compared with AECB and a percentage saving in heating energy calculated. This is then applied to the total domestic housing stock to give a figure for the long term potential for reducing energy use. A lower percentage saving is applied to services heating.

The adoption of low carbon emission designs would have the potential to lower the island's per capita carbon footprint by 1.5 tCO2pp, resulting in a significantly reduced heating requirement for the Island. This is summarised below.

5.2.3.a Geothermal energy

Geothermal energy is obtained by tapping the heat of the earth itself. Most systems in Scotland provide heating through a ground source heat pump that brings energy to the surface via shallow pipe works. An early example was the Glenalmond Street project in Shettleston, which uses a combination of solar and geothermal energy to heat 16 houses. Water in a coalmine 100 metres below ground level is heated by geothermal energy and maintained at a temperature of about 12 degrees C throughout the year. This water is raised and passed through a heat pump, boosting the temperature to 55 degrees C and is then distributed to the houses providing space and water heating.[40] There are now numerous examples of this technology in rural Scotland too.

Although the pumps may not be powered from renewable sources, up to four times the energy used can be recovered. Typical installation costs can vary from £7,000 to

[38] Findings of both the Black Country Housing and Community Service Group who have produced a 'Green Housing Toolkit http://www.hestiaservices.co.uk/Content/Files/Green%20Social%20Housing%20Toolkit/Richard%20Baines%20Green%20Housing%20Toolkit%20Presentation.pdf and of the Findhorn Ecovillage – see for example 'Simply Build Green' by John Talbott. Some of these findings are taken from an unpublished lecture by Richard Baines of BCS Associates Ltd. to the CIH conference in Aberdeen in March 2007.

[39] The Scottish Executive have set a target for at least 10% of the total value of projects exceeding £1 million to derive from reused or recycled products. See www.wrap.org.uk/document.rm?id=3019

[40] http://www.johngilbert.co.uk/resources/geothermal.html Shettleston project

£10,000 and grants may be available from the Scottish Community and Householders Renewables Initiative operated by HICEC for domestic properties to up to a maximum of £4,000.[41] Perhaps up to 7.6 TWh of energy is available in Scotland on an annual basis from this source.[42] See also Appendix 9.7 for details of the potential impact on the Island.

Air source heat pumps are also capable of reducing carbon emissions and are being trialled at present. We understand the DTI's 'Low Carbon Buildings Programme Phase 2' provides grants for installations.

5.2.3.b Solar energy

Despite Scotland's relatively low level of sunshine hours solar panels can work effectively as they are capable of producing hot water even in cloudy weather.[43] The technology was developed in 1970s and is well established. A combination of renewably produced space heating and solar panels can produce a significant impact in the move towards carbon neutrality. For example it has been estimated that solar hot water heating can reduce domestic energy demands by up to 13%.[44] See also Appendix 9.7.

There are few examples of photovoltaic cells in Scotland as the price is not currently competitive. The largest installation in Scotland is a 21 kWp system at the Sir E. Scott secondary school in Tarbert, Harris.[45] The UK's practicable resource is estimated at 7.2 TWh per annum,[46] which in the Scottish context is the approximate equivalent of 0.07GW or less of installed capacity, about 0.3% of total current consumption. Unless there are significant changes in the price regime this technology is unlikely to provide more than a tiny fraction of overall energy demand, although it could prove useful in specific locations.

5.2.3.c Potential impact of improved housing standards

There are a number of other ways in which individual buildings could reduce their carbon footprint. As the potential permutations are very large we have made no attempt to factor different options into our baseline calculations. Rather in Appendix 9.6 we indicate in detail how improved building standards reduce the need for renewable power to be produced by other means if replicated across many buildings.

The impact could be considerable, and all other things being equal would reduce heating demand by three quarters if all island housing and some island commercial properties reached *passivhaus* standards.

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[41] http://www.sepa.org.uk/publications/sepaview/html/28/groundforce.htm SEPA re. ground source heat pumps

[42] Nicola McLoughlin (12 July 2006) 'Geothermal Heat in Scotland'. Edinburgh. Scottish Executive. SPICe briefing 06/54 http://www.scottish.parliament.uk/business/research/briefings-06/SB06-54.pdf

[43] Energy Saving Trust quoting Malcolm Bruce MP. http://www.est.org.uk/housingtrade/news/dailynews/index.cfm?mode=view&articleid=8378980

[44] Information supplied by AES Ltd. of Forres.

[45] Comhairle nan Eilean Siar press release http://www.cne-siar.gov.uk/press/041102.htm

[46] 'The role of nuclear power in a low carbon economy' (2006) Sustainable Development Commission. London.

The overall carbon footprint of the island would thus fall from 10,445 tonnes to 8,800 tonnes - a reduction of 16%.

The land area required for biomass production for domestic heating would fall from 483 ha to 125 ha - a reduction of 74%.

5.2.4 Road transport

This sector makes up 15% of UK carbon emissions and an estimated 13% of island emissions (Tables B and C).

Transport provides one of the more complex challenges from a renewable energy perspective. The main difficulty is that for any given solution to be effective the, vehicle must have a rechargeable source of power in numerous locations. Thus, despite initial enthusiasm, only 5 electric vehicles were purchased in Samsø, Denmark (see Section 4.2 above). The main reason islanders gave for their choice was that the cars would not be practical when driven off the island. Similarly, whilst there is no theoretical reason why hydrogen-powered vehicles could not provide a major element of a future road transport carbon neutral solution, the potential infrastructure costs involved are very large. National policy is thus likely to play an important part in any proposed solution.

The use of agricultural vehicles also provides various challenges in the context of this study. Firstly, we have been unable to source hard data about how much additional fuel such vehicles are likely to consume. It is also likely that in the context of a crofting lifestyle, the distinction between an agricultural and a private vehicle may be difficult to draw. Thirdly, measuring the emissions created returns us to the methodological conundrum explored in Section 5.1 regarding the difference between consumption and production measurements. Agricultural vehicles are clearly in the latter category, and if this is taken into consideration, then some compensating reduction should be applied. (This would increase the transport footprint of the island, but correspondingly decrease the food footprint). Fortunately the likely impact is small. We have assumed that such vehicles add 10% to the total transport fuel consumed on the Island – which amount is approximately 0.3% of the total carbon footprint.

5.2.4.a Biodiesel

The annual transport fuel needs of the island are projected as 648,000 litres for ferries and 162,000 litres per annum for cars. There are grounds for believing that biodiesel may be able to meet near the total demand for fuel used by the island's cars – though not that of the ferry.

At the outset, it needs to be stated that there are problems associated with the production of transport fuels from crops. The principal of these is the competition for land between food-production and fuel crops, which is already pushing up food prices worldwide.[47] Interestingly, however, there are several environmental advantages to the production of oilseed rape (OSR) – the fuel crop that is best suited to Scottish conditions) including the favourable role it plays in enriching soil as part of a crop rotation regime and in arresting the decline in the population of a number of bird species, including the linnet.

Moreover, only relatively light applications of chemical fertilisers and pesticides are associated with OSR production and the crop has a favourable energy ratio, with a net energy balance of up to four units of energy gained for every unit of input. Energy balance can be further enhanced by the utilisation of by-products of biodiesel processing (see below). The Scottish Agricultural College (SAC) has expressed a strong interest in developing organic fertilisers that could be used in OSR production for biofuels. Assuming such production were possible, island vehicles would require 147 ha of OSR crop or thereby to achieve carbon neutrality. (See Workbook Table 9.)

Whatever the merits and drawbacks of biodiesel as an element of an emissions-reducing strategy, it is clear that policies both within the UK and at the European level are likely to guarantee a significant increase in its production in coming years. Under the EU's Renewable Transport Fuel Obligation (RTFO) directive, biofuels in member states should achieve a 5.75% share of the transport fuels market by the end of 2010. Growers of energy crops qualify for the EU Energy Crop initiative which has a premium payment of €45/hectare. In addition, the UK government offers a £0.20p tax rebate per litre on the fuel duty for biofuels.

The Scottish Executive strongly supports the RTFO and a £9 million grant has been offered to INEOS Enterprises, to establish Europe's largest single biodiesel production facility at its Grangemouth site in 2008. This will have capacity to meet 35% of the UK biodiesel needs.

In addition, a number of councils in the north of Scotland commissioned a study, Economic Evaluation of Biodiesel Production from Oilseed Rape in the North and East of Scotland, undertaken in 2005 by the SAC. While this found that economies of scale were important in the biodiesel industry (one of the main reasons for the competitive nature of biodiesel production in some European countries including Italy, France and Germany being the large size of their processing plants), it found grounds for optimism that processing at medium industrial-scale, community-scale and farm-scale could be viable.

The SAC report proposed the establishment of a medium-scale processing facility in the north of Scotland and estimates that it could produce biodiesel marginally cheaper (£0.41.3p/litre) than that imported from Germany.

The same report also suggests that small-scale processing might prove financially viable and recommended pilot trials. An economic analysis of three small-scale OSR processing technologies (costing between £7,300 and £81,200) estimated that they could produce biodiesel at a retail price range per litre of £0.90 - £1.07. The report concluded that when the £0.20p per litre tax rebate is included along with the

[47] See, for example,
http://business.timesonline.co.uk/tol/business/industry_sectors/consumer_goods/article602228.ece
http://business.timesonline.co.uk/tol/business/industry_sectors/consumer_goods/article1642746.ece

potential for use or sale of by-products, processing at this scale looks potentially viable.

Trials are now under way in various locations, including Orkney, involving small-scale crushing equipment and esterification technology (this process removes the glycerine which can block car engines).

Currently, Scotland produces around 52,000 tonnes for OSR and would need to increase this by 82% to achieve the EU target by 2010.

It would be ideal for OSR for biodiesel to be grown on the island where it is to be used. This is for two reasons. First, costs associated with the transport of the fuel would be reduced. Second, an important element in the financial viability of OSR production for transport fuel is the use of by-products: rapeseed meal from the crushing process and glycerine from the esterification process. Rapeseed meal is especially important as a component in animal feed and demand in Scotland is estimated at 30,000-40,000 tonnes per annum.

Of all the Scottish islands, significant OSR production is likely to be limited to the Orkney archipelago. The Shetland Islands and Hebrides have much less arable land of a type that would be suitable for OSR production - although significant steps towards carbon neutrality could still be made by importing biodiesel if sufficient capacity were available.

5.2.4.b Hydrogen

Although hydrogen offers significant potential as an alternative to hydrocarbons as a carrier of energy, neither hydrogen itself nor the associated fuel cell technologies are sources of energy in themselves. Nevertheless, the combination of renewable technologies and hydrogen is of considerable interest to those seeking alternatives to fossil fuels. The introduction of 'dual mode' hydrogen/petrol vehicles in the US may prove to be a significant step forward. There are a number of Scottish projects involved in this research, supported by the Scottish Hydrogen & Fuel Cell Association.

The PURE project on Unst in Shetland is a ground-breaking training and research centre that uses a combination of the ample supplies of wind power and fuel cells. Two 15kW turbines are attached to a 'Hypod' fuel cell, which in turn provides power for heating systems, the creation of stored liquid hydrogen and an innovative fuel cell driven car.

In the Western Isles a plan to enable a £10 million waste management plant into a hydrogen production facility was announced in June 2006. The Council has also agreed to purchase hydrogen-fuelled buses and hope the new plant, which will be constructed in partnership with the local Hydrogen Research Laboratory, will supply island filling stations and houses and the industrial park at Arnish.

ITI Scotland is a programme of intermediate technology institutes. It has attracted the Alterg project, a French company that is developing technology for the cost-effective storage of hydrogen.

There have been very significant investments in the hydrogen economy in Iceland. Mercedes-Benz fuel cell buses, which were introduced in 2003, have been operated successfully. The hydrogen refuelling station has delivered over 20 tons of hydrogen, mostly to the buses but also for other hydrogen activities. There is now an intention to diversify and plan for pre-commercial activities via the SMART–H2 (Sustainable Marine and Road Transport, Hydrogen in Iceland) project.

This has three main purposes; testing hydrogen passenger cars; designing and using fuel cell equipment as an auxiliary power unit (APU) on board a ship and a research path based on the data collected in the bus project.[48]

It is estimated that, using a system similar to the existing PURE technology, between 220 kW and 600 kW of installed capacity[49] would be required if all 365 island cars were powered by hydrogen fuel-cell vehicles. Details are available in Appendix 9.8.

Although in the medium to long-term the future of hydrogen-powered vehicles may be positive, their adoption is likely to be inhibited by the lack of support infrastructure already discussed and the currently high cost of the vehicles themselves.

Electric vehicles are currently available commercially and are a genuine alternative for island use, although the Samsø experience suggests there may be issues of consumer resistance to address. Such vehicles would require a similar electrical installed capacity as the hydrogen fuel cell cars to provide their power, although the fuel-cell alternative provides significant weight and range, and therefore performance advantages.

5.2.4.c Cellulosic decomposition

An alternative form of biofuel is the creation of ethanol from cellulosic biomass such as agricultural plant wastes (corn stover, cereal straws), plant wastes from industrial processes (sawdust, paper pulp) and wood. Although a substantially more difficult process than pressing rape and probably not suitable for a small-scale operation it is a potential technology for the future, especially for islands with agricultural challenges.[50]

As with conventional production of ethanol (from corn, wheat or soy beans), the process involves the enzymatic conversion of sugars into alcohol. The source of the sugars in conventional fuels is starch whereas this new technology involves the decomposition of cellulose and hemi-cellulose, both of which are more difficult to break down into sugars. Consequently the procedure involves several additional steps including mechanical pre-processing, pre-treatment, (with heat, pressure, acid or enzymes to release cellulose and hemi-cellulose from the biomass) and solid-liquid separation. Once the sugars have been released from the biomass ethanol is produced in the same way as conventional alcohol via fermentation/distillation/dehydration.

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[48] See 'Creating the worlds first hydrogen society' http://www.ectos.is/newenergy/en/news/?cat_id=22162&ew_0_a_id=284045

[49] Data provided by PURE. There are various options, with fuel cell vehicles offering greater efficiency than hybrid or internal combustion systems.

[50] See for example http://genomicsgtl.energy.gov/biofuels/ethanolproduction.shtml, www.harvestcleanenergy.org/enews/enews_0505/enews_0505_Cellulosic_Ethanol.htm

The main advantage of this procedure is the relatively cheap cost and abundance of the raw material.

Ethanol has been used successfully as a vehicle fuel in Brazil, which is currently probably the only country in the world with a vehicle fleet not almost entirely dependent on petroleum products.

5.2.5 Island commerce

5.2.5.a Tourism

The impact of tourism is assumed to add 10% to island's carbon footprint.[51] The Carbon Trust suggests that 'Hotels, catering, pubs etc.' constitute the largest single element of this category, accounting just under 5% of all emissions. However, the space heating and electricity issues described above should still cater for the lion's share of the impact of these activities. No specific mechanism is used to account for carbon emissions used to travel to the island by tourists other than the ferry discussion (below), which is a very island-specific phenomenon. These emissions are simply assumed to form part of the additional 10% impact of all tourists.

5.2.5.b Commerce and industry

Likewise, island activities such as construction, vehicle maintenance, commercial forestry and retailing are not likely to result in significant additional emissions not already accounted for. An exception, as previously noted, would be the high-energy demand of distillery operations.

5.2.5.c Ferries

Water transport is a powerful emitter of carbon. Per passenger mile travelled, some forms of water transport may exceed air transport emissions[52] and the UK total for this sector amounts to 3% of all emissions, largely from international transport of goods. As Tables C & D show, an island ferry is a surprisingly large contributor (17%) to total island carbon emissions. There are numerous difficulties involved in quantifying this impact, including:

- The considerable variations in size and capacity of Scottish ferries.
- Allocating the emissions. Footprint studies usually allocate 50% of air transport emission to the departure and destination locations and we have followed this principle here. There may be a case for allocating a higher percentage to a small island.
- Double insularity factors. The Orkney mainland enjoys single insularity, i.e. it can be reached by a single ferry journey from mainland Scotland. Westray, for example, has double insularity – in order to reach it by sea using public transport a second ferry is required. A detailed baseline study for an island with double or triple insularity would need to calculate the impact of this issue.

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[51] An estimate based on MacPherson Research's 1999 'Western Isles Visitor Survey'. There may be considerable variations between individual islands and it is likely that for Skye, Mull and Iona for example, the impact will be higher.

[52] See Monbiot (2006) 'Heat', page 185.

Table D – Carbon Emissions from Island Ferries

Average ferry travel to and from the Island has been taken as:		
	Units	Totals
Fuel consumption[1]	**litres/hour**	**507**
Duration of ferry travel per day[2]	**hours**	**7**
Emissions per hour	**kgCO2/hour**	**1,356**
Emissions per day	**tonnes CO2 / day**	**9.49**
Annual emissions	**tonnes CO2 / year**	**3,465**
Annual emissions per capita[3]	**tonnes CO2 / year**	**1.575**
Total Annual fuel consumption	litres/annum	1,295,997
Annual fuel consumption allocated to Island	litres/annum	647,998

Typical fuel consumption for Isle of Arran-size ferry 450 passengers, 60 cars		
Rear engine	1,520	kW
Load factor	85%	
Fuel consumption of engine[1]	189	g/kWh
Fuel consumption	290	litres/hour
Front engine	1,140	kW
Load factor	85%	
Fuel consumption of engine[1]	189	g/kWh
Fuel consumption	217	litres/hour
TOTAL	**507**	**litres/hour**

See Workbook Table 4 for further details and footnote information. The ferry fuel consumption figures are derived from an Arran Ferry specification by Caterpillar Marine Power Systems. This is a 450 passenger, 60 cars ferry, with both rear and front engines.

By studying the Caledonian MacBrayne timetable an average duration of ferry travel per day has been set. This when combined with fuel consumption gives emission numbers, which form a significant part of an Islander's carbon footprint.

5.2.6 Food

We have estimated that the carbon footprint of food consumption on the island amounts to 10% of the total footprint, which is similar to the UK average. (Table C). The three main variables in the size of the food footprint are:

- food miles – how far the food is transported from producer to processor to consumer
- organic or chemical – non-organic agriculture tends to have a significantly higher carbon content as a result of the application of fertilisers and pesticides
- level of animal products in the diet – it takes significantly more energy inputs to create a kilo of meat than a kilo of grain. Meat production in the UK generally involves the shipping in of animal feed, significant quantities of which can be sourced from developing countries.

This means that the more local, seasonal, organic and vegetarian the diet, the lower the footprint. The Findhorn Foundation community's food footprint was found to be 37% of the national average because its diet was found largely to fit this low-carbon profile. Ministry of Agriculture Report figures suggest that organic arable production creates only 34% of average emissions, and organic dairy, 74%. We have therefore assumed that using locally produced organic agriculture could reduce associated carbon emissions by 50%.

Low-carbon food can be promoted in various ways, including the favouring of local food in government procurement. For example, the Soil Association's 'Food For Life' programme, which is operational in Scotland, sets targets for the use of 75% wholesome and minimally processed, 50% local and 30% organic food in school meals. Farmers' markets, community-supported agriculture schemes and buy-local campaigns can also be effective tools for strengthening the local food economy. The Highlands and Islands Local Food Network is active in all these fields.

5.2.7 Public sector services

The public sector is a not a large consumer of carbon in the UK context. If we exclude its transport and other indirect demands, this may amount to little more than 3% of the emissions total (Table B). We can thus subsume this factor into our calculations for 'services electricity' and 'services heating' already addressed above.

5.2.7.a Reuse, recycling & waste management

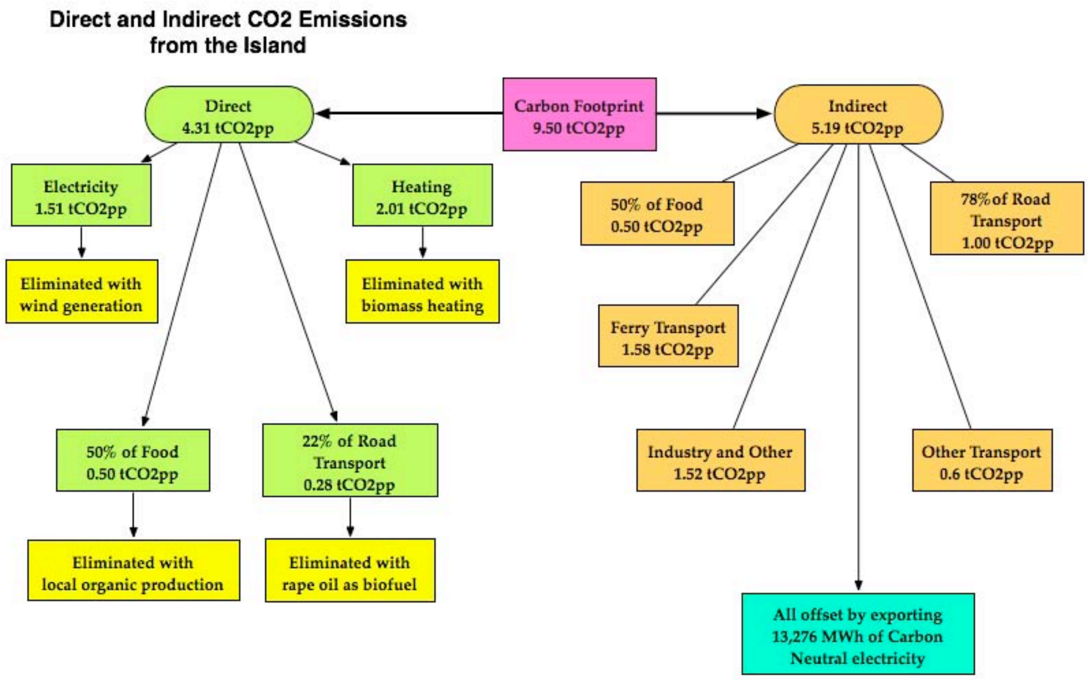
Reuse of and recycling of materials is likely to be a factor in creating a carbon neutral island, although it may be the case that the role of these activities has a higher profile in the public's awareness than their actual importance merits. They certainly have value as symbolic measures that can galvanise individual efforts. Although a relatively small island is unlikely to host significant glass, paper, plastic or clothing recycling facilities in the near future, we would certainly encourage public sector support for such activities as an alternative to landfill. It is worth noting that due to high levels of recycling, the Findhorn Foundation community had a zero score for its waste component of its ecological footprint. The efforts of Mull and Iona Environmentally Sensitive Solutions in this regard are similarly exemplary.

5.2.7.b Waste water treatment

The carbon footprint of waste water treatment in the UK is less than 0.3% of total carbon emissions. Although island treatment systems are typically passive, using for example, septic tanks, this method generates methane, a very harmful greenhouse gas. Active systems will reduce the impact, especially if powered by renewable energy. Where centralised treatment is needed, low-footprint, natural treatment systems are recommended, although this is unlikely to be a significant issue in most island contexts.

5.2.8 Conservation and land use

A key factor in UK carbon emissions may prove to be the land management of heather moorlands. The Stockholm Environment Institute has recently warned that the warming climate and poor land management techniques are leading to the drying out of Britain's peatlands, and that this hidden problem could amount to 10% of all carbon emission in the UK.[53] Any island committed to carbon neutrality should therefore ensure that such landscapes are managed consciously.



53 See for example The Independent newspaper report of 15.03.07.

5.3 Reducing indirect emissions

Ferry transport, and aspects of food consumption and road transport on the mainland contribute to indirect emissions as discussed above. In addition to this, manufacturing industry and larger commercial organisations (23% of UK emissions), aviation (6%) and overseas trade (7%) contribute to the islands indirect emissions created when islanders consume goods and services provided from the mainland and elsewhere. Although likely to be lower than the average for UK citizens we still estimate that off-island other transport and industrial activities contribute an extra 22% or more of the islands' footprint taking total indirect emissions to 55% of the total (see Table 3).

Island consumer choices and lifestyles could make a significant difference to this impact including attitudes to recycling and the purchases of lower impact goods and services.

Table E - Offsetting Indirect Emissions by Exporting Carbon Neutral Electricity from Wind

National electricity[3]	**0.43**	**kg/kWh**
Carbon to be offset[5]	**5.19**	**tCO2pp**
%age to be offset[6]	**100%**	
Exported power	**13,276**	**MWh**

Category	Number	Unit
Island annual generation[1]	3,868	MWh
Capacity factor of turbines[2]	35%	%
Average electrical demand for Island	1.26	MW
Power to be exported	13,276	MWh
Less power generated from CHP[4]	739	
Power generated from wind	16,406	MWh
Power generated from CHP	739	MWh
Total power generated from wind & CHP	17,145	MWh
Installed capacity of wind turbines required	5.35	MW
Nominal rating of turbine	1.00	MW
No. of turbines	6	

See also Workbook Table 7 for further details and footnote information.

This indicates that the total amount of electricity that needs to be exported to off-set the carbon associated with indirect emissions is 13,276 MWh, requiring a total installed capacity (including electricity for island use) of 5.35 MW – or say 6 x 1 MW turbines.

5.3.1 More speculative technologies

Scotland has an estimated potential of 7.5 GW or more of tidal power, 25% of the estimated total capacity for the European Union and up to 14 GW of wave power potential (10% of the EU capacity).[54]

5.3.1.a Wave

The success of the Pelamis wave converter, the presence of EMEC in Orkney and the interest being shown by the renewables industry in wave power suggests that unlocking the potential of this renewable source of energy is only a matter of time. Clearly there are significant opportunities for using this source of energy as an alternative to onshore wind, (although it may be harder to justify allocating the electrical production to any given island, depending on the location of the generators).

5.3.1.b Tidal

Unlike wind and wave, tidal power is an inherently predictable source. The technology is still in its infancy and the resource localised, but the Pentland Firth has been described as the 'Saudi Arabia of tidal power'[55] and may be capable of generating up to 10 GW alone.[56] During the course of the next twenty-five years it is therefore likely that the potential in the vicinity of various Scottish islands will be developed and make a contribution to their carbon neutrality. As the devices are likely to be located relatively close to the shore it may be easier to justify ‘allocating’ this production to them than might be the case for offshore wave facilities.

5.3.1.c Mainland options

Numerous other possibilities exist for generating carbon free, or lower carbon energy sources, although few of them are likely to be installed on smaller or even medium sized Scottish islands in the near future. These include:

- Nuclear fusion, which offers the potential for significant power production without the dangers inherent in nuclear fission plants. Conceivably a fusion plant could be considered 'renewable' as the hydrogen fuel source is vast.
- Nuclear fission itself may also form a significant aspect of future UK government strategies to reduce the overall carbon footprint, although in the present climate it is unlikely new generation will be constructed in Scotland.
- Doosan Babcock Energy Limited have conducted research into the clean coal concept and recently secured a contract with SSE for the retrofit of a 500 MW power station at Ferrybridge. Similar plans for Cockenzie and Longannet power stations were announced in May 2007. The installation of a 'supercritical clean coal boiler' could save up to 500,000 tonnes of carbon dioxide a year compared to current performance. The process has however been criticised and is at best a means of ameliorating carbon emissions.
- Carbon capture and storage or carbon sequestration is a technology that involves the storage of CO_2 created as a by-product of industrial processes by

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[54] RSPB Scotland, WWF Scotland and FOE Scotland (February 2006) The Power of Scotland: Cutting Carbon with Scotland's Renewable Energy. RSPB et al and Scottish Energy Review. (November 2005) Scottish National Party Framework Paper. Edinburgh.
[55] Scottish Renewables Review No 32. (November 2006).
[56] Marine Briefing (December 2006) Scottish Renewables Forum. Glasgow.

injecting it into oil fields. It is not a form of renewable energy production but it may be a way to significantly reduce the impact of fossil fuels whilst renewables are developed. The technology has been successfully pioneered in Norway but is still a relatively untried concept. The British Geological Survey estimate that potentially 755 billion tonnes of CO2 could be stored in the North Sea (Scotland's annual CO2 output is circa 50 million tonnes). The process also aids the recovery of oil and gas as it increases pressure in the oil field. The DTI estimate that as much as 2 billion additional barrels of oil could be recovered as a result of CO2 injection. However, although this process could reduce CO2 emissions from conventional power plants by as much as 80-90%, if combined with increased oil recovery the net savings in carbon emissions may be much less as the total volume of oil and gas used from that field would increase.

- BP in partnership with Scottish and Southern Energy plan to create a hydrogen based power station at Peterhead. The project would take natural gas extracted from the North Sea and crack the gas to produce hydrogen and carbon dioxide and burn the hydrogen as the fuel source to create electricity in a 475MW power station. The CO2 would be returned to the Miller field reservoir more than 4 kilometers under the seabed using carbon sequestration techniques. The scheme was expected to be in production by 2009 at a projected cost of $600m, although its implementation is now in doubt. If completed, the plant would be the first industrial-scale, hydrogen power station in the world.[57]
- More speculative examples include the potential for DC Cables to be used to transmit electricity produced in desert-based photovoltaic arrays[58] and the role of 'super capacitors' as a means of storing locally produced electricity.[59]

The impact of these technologies on a carbon neutral strategy for an island is hard to gauge. On the one hand increasing use of non-CO2 producing sources of energy will have an impact on the provision of many of the goods and services an island uses and so reduce its carbon footprint. On the other hand the higher the percentage of electricity produced from renewable means on the mainland, the less easy it is to justify island exports as genuine offsets.

5.4 Carbon offsetting

This involves individuals or organisations compensating for their use of fossil fuels by making payments to projects that aim to neutralise or otherwise compensate for the impact of these carbon emissions. The most common forms of offsetting are tree-planting and the financing of renewable energy projects, often in developing countries, to displace activities that previously involved the burning of fossil fuels. Although the idea has become fashionable, the theory of 'carbon offsetting' has received serious criticism of late.[60]

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[57] http://www.peterheadhydrogenpower.com/ Peterhead hydrogen project
[58] http://www.trecers.net/ TREC – 'clean power from the deserts'.
[59] See for example http://www.mpoweruk.com/supercaps.htm
[60] In addition to Monbiot (2006) see for example Hamilton, Alan (29.01.2007) 'Efforts at an ecological code upset by trains, planes and automobiles, The Times' newspaper, and Steven Swinford (21.01.2007) G8 summit 'carbon offset' was hot air, The Sunday Times newspaper.

The weaknesses of the approach include:

- uncertainty as to whether the offsetting activities might have occurred anyway (this is called the principle of additionality);
- problems of ensuring that trees planted remain standing in permanence;
- concern that other offsetting activities (such as providing low energy light bulbs) will simply mean that the money saved will be used on other energy consuming projects.
- the possibility of fraud or corruption.
- community-based and public sector organisations are unlikely to wish to fund projects happening outside of their geographical area of remit.

The export of energy is likely to be the most effective offsetting strategy in the current context. However, an additional credible option may be to plant trees within the local bioregion and maintain the forest on a permanent basis, so locking up carbon produced by burning fossil fuels. In British growing conditions this method can compensate for more than 2 tonnes of carbon per hectare per annum planted over a 100-year period. Thus a 60 ha plantation could uptake 3-4,000 tonnes of carbon over twenty-five years.[61] This is the equivalent of more than 11-15,000 tonnes of carbon dioxide[62] and there is likely to be a greater level of credibility inherent in a nearby and visible project than in one organised at a considerable distance by third parties.

Thus, in theory an island could offset its 13,276 tonnes of CO2 emitted per annum by planting circa 60 ha of trees every year for 25 years = 1,500 ha x (a factor for island growth rates versus the average for the UK of trees) x (a factor to take into account any potential of the release of carbon from existing peat on the planted land) over the next twenty five years. This is a simple enough idea, and arguably the easiest way for an island to obtain carbon neutrality, although clearly the issues of land purchases and/or compensating landowners and the difficulty of ensuring genuine 'permanence' suggest it is likely to be at best one aspect of more comprehensive strategy.

There are considerable variations in the estimates for the carbon capture provided by trees in different locations, ranging from 2.8 tonnes CO2/ha to 15 tonnes CO2/ha.[63] [64] We have used estimates at the lower end of the scale but in some island circumstances yields are likely to be even lower and a significantly larger acreage may be required.[65]

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[61] Peter Taylor (August 2005) 'Carbon offsets, local renewables and nature conservation – realising the links'. In 'Carbon and Conservation' ECOS - Quarterly Review of the British Association of Nature Conservationists. Volume 26 No.2.

[62] http://pages.prodigy.net/afmo/co2disc.htm CO2 Recovery in Managed Forests: Options for the Next Century.

[63] http://www.carbon-info.org/_documents/Carbon%20Offset%20Data%20Model.pdf

[64] Figures from the US suggest averages of between 0.75 tonnes and 2 tonnes of carbon per hectare per annum over 100 years. See J. Doyne Farmer. Methodology for Forest Guardians' Carbon Offset Program. Santa Fe Institute. http://fguardians.org/support_docs/document_carbon-calculation-methodology_2-07.pdf

[65] The Edinburgh Centre for Carbon Management's 2002 'Estimation of Carbon Offset by Trees' suggest somewhat lower figures for mature lowland native trees. We assume this is for annual sequestration in mature forests and excludes the growth phase.

Furthermore there are complications involved relating to the differential growth rate of the planted trees, which is generally less during the early stages of growth.[66]

Exporting renewable produced electricity or fuels to compensate for emissions is a different form of offsetting and is discussed at length above.

[66] See Mark Broadmeadow, and Robert Matthews (June 2003) Forest, Carbon and Climate Change: The UK Contribution. Forestry Commission website.

6 Scenarios and Recommendations

Below, we outline three scenarios that describe possible national and global level progress in reducing emissions and the impact that each would have on the island's emission-reduction strategy. We then provide a summary overview of recommendations on the basis of the discussion of the various technology and lifestyle options discussed in the previous section and in the context of these three scenarios.

6.1 Low-level societal uptake

In this scenario the island or islands are largely on their own. Despite political rhetoric, carbon emissions in the UK as whole change little during the timescale under investigation.

For an island to be carbon neutral in such circumstances, the activities required would essentially those outlined above to:

- Produce electricity used on the island from renewable resources.
- Provide space heating from biomass, including if possible a district-heating scheme.
- Grow (or import) biofuels to power vehicles or incorporate additional installed wind power for hydrogen production.
- Concentrate agricultural production on organic produce and consumption on local produce.
- Plus offsetting the remainder of the footprint by exporting ~13,300 MWh of electricity. An alternative for offsetting would be the planting of 60 ha or more of permanent forest per annum.

6.2 Significant UK reductions in carbon emissions

In this scenario the island's activities are matched by wider society. UK carbon emissions decline by 55% during the timescale under investigation, roughly as suggested in the Stern Review.[67] Note also in all scenarios there is an assumption that whatever levels of economic growth are experienced in future that this will not increase carbon emissions.[68]

The impact on the island would depend on the specific circumstances. As suggested above, one effect could be to reduce the potential for the export of electricity generated by renewable energy. However, given i) that Scotland has a disproportionately large share of the UK's renewable energy resources and ii) the UK would continue to be generating at least 45% of its current level of emissions, it would be fair to assume that there would still be a substantial market for renewably

[67] Sir Nicholas Stern (2006) The Economics of Climate Change. London. HM Treasury.
[68] This assumption is now widely held to be an appropriate approach. However it is an untested assumption. In the past, energy use, carbon emissions and economic growth have almost always been in direct relationship with one another.

generated electricity. Nonetheless, it would be prudent to assume some reduction in the viability of offsetting through the export of renewable energy as a strategy.

In parallel, however, the island's indirect carbon footprint would have reduced as a result of the decline in emissions associated with goods and services produced on the mainland, so reducing the need for offsets.

Under this scenario, it is likely that significantly more organic produce would be available in Scotland as a whole, enabling consumption to be less dependent on produce grown on the island itself.

In these circumstances the total amount of energy to be exported would be ~5,900 MWh, requiring a total installed capacity (including electricity for island use) of 3 MW.

6.3 Dramatic UK reductions in carbon emissions

In this scenario future governments make climate change a very high priority and society as whole makes radical changes in its consumption patterns. During the timescale under investigation, UK carbon emissions fall by 90%.[69] In all likelihood this would make a carbon neutral strategy for an island much easier to accomplish. If most UK citizens were driving carbon neutral vehicles and most goods and services were being undertaken without significant carbon emissions, then islanders could do likewise more easily. Additional electricity production to offset indirect emissions might not be required at all. Air transport emissions are a particularly difficult challenge as no technology currently exists using a renewable fuel to replace kerosene. Remaining emissions could be offset by smaller scale renewable exports or conceivably tree planting.

In the latter circumstances the total amount of power to be exported is nil, requiring a total installed capacity for electricity for island use only of 1.26 MW. Alternatively, if electricity is used to offset the remaining indirect emissions a total installed capacity of 1.45 MW would be required. This very small additional requirement might even be met by increasing the size of the proposed biomass CHP unit.

It is possible that carbon-neutral ferries might be a low national priority and islanders find themselves with a much higher than average carbon footprint and little legitimate opportunity to offset this with exported electricity, but this is a somewhat pessimistic outcome (for the island, although not for the UK) which we need not dwell on.

[69] Unlikely perhaps, but some commentators including George Monbiot and Paul Mobbs believe this is what is actually required to prevent serious climate change.

6.4 Tabulated overview of recommendations

Table F repeats the information in Table C but adds an additional column showing the outline requirements to achieve carbon neutrality.

Table F – Overview of Strategy for Carbon Neutrality

Category		Island tCO2pp in total	%age	Reduction Via	Requires
Domestic heating		1.73	18%	Biomass	
Services heating		0.28	3%	Biomass	483 ha
Domestic electricity		1.04	11%	Wind or similar	
Services electricity		0.47	5%	Wind or similar	1.26 MW
Road Transport - island		0.28	3%	Biofuels	147 ha
Food - island		0.50	5%	Local & organic	
Sub-total - Direct		4.31	45%		
Road Transport - mainland		1.00	11%		
Ferry Transport		1.58	17%		Varies
Other Transport		0.60	6%	Offsets of	depending
Food - mainland		0.49	5%	electricity exports	on scenario
Industry & Other		1.52	16%	or possibly	chosen
Sub-total - Indirect		5.19	55%	tree planting	
TOTALS		**9.50**	100%		

Our research suggests that a workable strategy would include the following elements. For direct emissions:

- Electricity consumed by island housing and services can be generated locally from renewable resources. This would require about 1.26 MW of installed capacity.
- Energy for space heating used by island housing and services could also be generated locally from renewable resources, especially biomass. This would require in the order of 480 hectares of sustainably managed woodland. (This acreage could be reduced by as much as 75% if a robust strategy were implemented to retrofit existing buildings and ensuring all new buildings met very high ecological building standards.)
- A move towards organic agriculture, and a greater consumption of locally produced food could reduce related carbon emissions by up to 50%.
- Although there may be difficulties in identifying an appropriate strategy, the island's vehicle fleet could become carbon neutral through the development of biodiesel and/or hydrogen. This would require about 150 hectares of land under oilseed rape where suitable land is available or 220 kW or more of additional installed wind power for hydrogen production.

Offsetting the remaining 55% of indirect emissions would require either:

- The export of significant additional electricity from an installed wind power capacity. (The quantity to be offset is shown in Table E. This indicates that the total amount of power to be exported is ~13,300 MWh, requiring a total

installed capacity, including electricity for island use of 5.35 MW – say 6 x 1 MW turbines) or;
- The equivalent in some other form of exportable power supply such as hydro, wave, tidal etc. or;
- The planting of permanent forest of 60 ha or more per annum resulting in a forest of 1,500 ha or more in extent to sequester the carbon emissions or;
- Some combination of the above.

If the UK as a whole makes significant reductions in its own carbon footprint of 55% or 90%, this would reduce the installed wind capacity required to offset emissions to 1.7 MW and less than 0.2 MW respectively (assuming the use of a CHP biomass system).

A factor to be taken into consideration is that although burning fossil fuels inevitably adds CO_2 to the atmosphere, the Earth does have some capacity to absorb this by natural processes, albeit that this may decline significantly, as suggested in Section 2.1.

7 Implementation Strategies

7.1 Introduction

The attempt to create a truly carbon-neutral island is as challenging as it is exciting. This is especially so given the highly fossil-fuel dependent nature of the global economy, which renders economically competitive, goods and services produced in unsustainable ways and flown across the world to their final market. As long as this remains the case, efforts to shift towards lighter carbon lifestyles will prove difficult as locally produced goods manufactured on a relatively small scale will generally be more expensive for the consumer.

At this stage, and under these conditions, optimal conditions need to be chosen to give the proposed initiatives a fair chance of being successful. Already, Scotland as a whole brings many advantages given the range and scale of its renewable energy technologies and its relatively low population density. The choice of island for an experiment of this nature should also depend heavily on its natural, cultural and political characteristics and attributes so as to maximize the chances of success. The ideal island would include as many of the following characteristics as possible:

- Abundant renewable resources such as wind, geothermal, hydro, wave and tidal.
- Access to a national or regional grid with the capacity to accept additional load from the Island.
- An attractive enough natural environment to encourage a long-term commitment from those involved in the project, but one which lacks large numbers of heritage or conservation constraints which might limit carbon neutral projects.
- Adequate good quality agricultural land for the production of biofuels, especially oilseed rape.
- Enough poorer quality land on which trees could be grown either for biomass fuel or cellulosic decomposition.
- One or more settlements which could benefit from a district heating system.
- Little or no industry with a high-energy demand such as distilling, unless this industry is also powered from renewable resources.
- Proximity to either the mainland or a larger/neighbouring island(s) with which mutual exchanges in for example organic foods and recycling could be undertaken.
- Access to a clear and robust national or even continental strategy providing a road map to an appropriate carbon neutral road transport system(s) based on fuel(s) such as hydrogen, ethanol or bio-diesel.
- Access to a national strategy for replacing existing ferry and fishing boat engines with those using an appropriate carbon neutral fuel supply.[70]
- A strong commitment to a carbon neutral ethos from within the public and private sectors and above all the local community as a whole.

[70] Current government policy involves providing small percentages of biodiesel/diesel mix for all diesel engine use via wholesalers.

- In particular, a commitment from within the local community and its geographical neighbours to low carbon producing food supplies, especially organically produced local products.
- An option for creating permanent new forestry to offset some existing emissions.
- Access to a national commitment to carbon reduction, so reducing the need for ‘offsets’ to deal with the 'indirect emissions' for imported goods and services, including…
- … an international strategy to reduce the impact of carbon emissions from air transport (and a low propensity amongst island residents for ‘frequent flying’, especially on long-haul routes).

The creation of a carbon neutral Scottish island is bound to be a successful marriage of community and technology. Providing suitable technology to a population of individuals that has no serious commitment to using it is unlikely to be effective.[71] We therefore emphasise the value of community ownership in the drive for carbon neutrality. As the profile of climate change moves ever-higher up the political agenda we increasingly have a citizenry willing to adapt, but generally with little access either to a credible strategy or the technology to support it. It is, thus, axiomatic that a project of this nature would need to:

- Adapt to local conditions.
- Engage the local population in enthusiastic support of the ideals.
- Provide access to the required technology and the means to implement it. This includes both the financial means and a supportive regulatory regime.

It is recommended that a secretariat be established to act as a central focus for the programme. Its initial aims would be i) to inform and educate the local population; ii) to engage them in a genuinely participatory process of designing the parameters and principal interventions; and iii) mobilise the good will, expertise and experience within the community in the service of the programme. A key aspect of any such endeavour would be ongoing research into available options and monitoring the impact of both new technologies and changing island lifestyles. An assumption of the report is that carbon emissions and western lifestyles can be de-linked and that continuing economic growth will not result in increases in the underlying carbon footprint. A diagrammatic overview of possible activities is provided below.

The programme secretariat would also act as a hub for discussions, negotiations and coordination between the many technical agencies that would be likely to have inputs, a good many of which have been mentioned in section 5.

A model for the kind of institutional arrangements that could work well here is provided by Ecodyfi, the local regeneration organisation for the Dyfi Valley, in Mid Wales. Ecodyfi’s mission is to "to foster sustainable community regeneration in the Dyfi valley” and towards this end, it works to strengthen the local economy and to

[71] See J. Dawson (2006) ‘One Planet Living’, Resurgence magazine. http://www.resurgence.org/selection/dawson0206.htm for a discussion of the limitations of the BedZED initiative as a result of insufficient community engagement and commitment.

promote community-based energy regeneration, eco-tourism, low-carbon transport systems, sustainable waste management and fair trade.[72]

The Dyfi Valley region has enjoyed substantial synergies between interventions in these various sectors and has enjoyed success in drawing tourists and other visitors attracted by the green image that the area has developed. Such benefits are also plentifully available for a Scottish island following a similar sustainability strategy. Already, a number of opportunities for local economic diversification have been identified in this report. These include the need for enterprises to process OSR residue into animal feed-cake, the development and repair of farm- or community-scale biofuel processors and other renewable energy technologies, coppicing, the production and processing of food and so on.

Moreover, an island pioneering in a serious and committed way models for carbon neutrality would attract substantial interest from visitors of all kinds: academics, local government officials, tourists and the general public.

It is recommended that any practical exploration of a carbon neutral island project should involve making contact with the management of the Ecodyfi initiative to explore its strategies, achievements and lessons learned.

The Samsø initiative (outlined in Section 4.2 above) also has a great deal to recommend it. We would therefore also suggest that the Samsø Energy Company be approached as part of any further research into this concept.

Considerable thought has been given to the idea of 'carbon neutral neighbourhoods' in an urban context in the UK. Whilst much of what is proposed (e.g. integrated rail networks, high density mixed use housing) is not directly relevant to an island situation there is also much that could be learned from developments in this environment.[73]

One final point may be worth emphasizing in this context. Scotland in general and the Highlands and Islands in particular are blessed with very significant potential for delivering renewable energy. If this combination of high levels of natural potential and relatively low population numbers cannot deliver a 'carbon-neutral' solution, then it is not clear to us where in the United Kingdom this might be achieved more easily. To put it simply, if not here then where?

7.2 Financial costs and strategy

An important aspect of our recommendations is that most of them are already either commercially viable at present, or potentially so in the foreseeable future. The possible impact of 'peak oil' and the high profile of climate change issues may well hasten this process.

[72] http://www.ecodyfi.org.uk/ecodyfi.htm
[73] A consultation process conducted earlier this year is described at http://www.communities.gov.uk/index.asp?id=1505157 - Building a Greener Future: Towards Zero Carbon Development.

The financial prospects for the installation of wind generation facilities are well known and requires little elaboration here. Typical costs are £1 – 1.2 million per megawatt installed, but in the right circumstances the financial returns can be handsome. Assuming constant national regulatory systems (including the crucial renewables obligation element) there is no reason why such schemes cannot proceed, and indeed several are already in the pipeline. On smaller islands with suitable grid connections and sites, the pertinent issue is essentially local support rather than finance, although the planning process can certainly prove both costly and high-risk. In this context (and for hydro-power proposals) the presence of a motivated local community, a sympathetic planning regime and existing support structures available via HICEC and others are probably sufficient. This is not currently the case for tidal and wave power, but no doubt their day will come during the duration of the studied period.

Biomass is a much more complex issue. Where land is available, but not currently forested, there will be long lead times (8-10 years for short rotation crop systems) between planting and production. At £100,000 or less, the equipment (including a chipper, drying sheds and tipping truck) needed to produce wood chips on a small scale is by no means prohibitive, but entrepreneurs interested in supplying the product would need to be assured of a market. Prices for small scale wood pellet pressing machinery currently start at approximately £75,000 and this technology might well require subsidies to be viable in an Island environment. Many of the houses not connected to the envisaged CHP plant might choose to use wood pellets. Wood prices have historically been stable, whilst hydrocarbon prices have not. It may be that some minimum price guarantee might have to be in place to encourage the process. The actual availability of land is also an issue, but the significant growth of community ownership on the islands is a potentially positive factor in the equation. Grants are currently available to support biomass crops and the Forestry Commission is active in promoting the sector.

A related issue is the cost of converting to biomass boilers. For domestic consumers at circa £3,000 after grants, this is likely to be broadly similar to the cost of replacing existing systems, most of which are likely to require this over the next twenty-five years. Installing a CHP unit with the related district heating connections is a much larger project that would require both significant financing and collaboration. Estimated plant costs for a 1.5 MW system are £900,000 plus connection costs for the distribution system at £50 per metre. Total installation costs would be of the order of £1,000,000. One option, for both this and other conversions, would be to use a financial partner who would pay the up-front capital costs and recoup this from the operation of the system. There are some innovative schemes available, albeit that none to our knowledge that have been tried in remote rural areas to date.

Biodiesel is perhaps more straightforward. Where suitable land and ecological conditions are available, oilseed rape is already being grown commercially in Scotland. Small scale pressing equipment is available from £30-£60,000. In some circumstances the purchase of farm machinery to assist with planting and harvesting may also be required. Car conversions to use the product currently cost circa £200-£400, although if the uptake is significant nationally this price is likely to drop considerably. Thus with relatively modest subsidies it would be possible to encourage both use and production on the Island. Were oil prices to continue to climb it is likely that production of this fuel will increase even if in-situ production proves harder to create in some circumstances. Although unlikely to be the whole answer to the renewable transport challenge due to the finite quantity of agricultural land, this is probably the most accessible strategy currently available. The national tax regime will inevitably be a factor in the economics of such a transition. The hydrogen option does have potential, but at present it is likely to require considerable subsidy and/or other government support at a regional/national level as well as locally to realise this opportunity.

Converting agriculture to organic production involves training of both practitioners and their support systems. There is also a potential financial burden during the certification phase when the land must be free from synthetic chemicals but is not yet able to produce authentic organic produce. The Soil Association is of course the main support organisation for organic farming in the UK. However the move to organic production is aimed at lowering the carbon footprint of agriculture and does not necessarily require certification.

There is increasing expertise in the architectural and building trades for the provision of lower emissions buildings. Clearly the costs involved in converting an entire island to passivhaus standards would be considerable, and would require the combined efforts of private homeowners, the private rental sector housing associations and the local authority. Co-ordinating such an approach would be a considerable task in itself and while we would encourage such an undertaking, knowing the benefits it could bring, we are not aware of any serious attempts to retrofit existing buildings to these standards on the scale and in the circumstances being considered here.

A detailed baseline study of the actual emissions relating to a specific island or its surrounding region would be an important step towards the creation of a strategy. Ideally this would include information not just about existing usage, but also about the aspirations and needs of the individuals and stakeholder organisations involved.

7.3 Public sector support

The public sector is likely to be a key player in delivering any carbon neutral strategy.

7.3.1 Local authorities

Councils in particular can act in three main ways to reduce their emissions of greenhouse gases and to help their community adapt to the impacts of climate change.

As ***Estate Managers.*** Local Authorities are large employers and major consumers of energy and other resources. Through better management of transport and buildings, councils can cut emissions and save money. They can also consider how their estate can be better adapted to the changing climate.

As ***Service Providers.*** For all the services they provide, from emergency planning to social care, councils can ensure that the impacts of climate change are properly taken into account and emissions are cut as far as possible.

As ***Community Leaders.*** Through strategic local partnerships, local authorities can work with other public and private agencies and the wider community to help cut the overall emissions of their area and develop an integrated response to climate change adaptation. The authorities role in determining planning applications is clearly a key issue in this regard.

The exemplary strategy of Working Borough Council is incorporated as Appendix 9.4.

7.3.2 Other agencies

We take it as read that Highlands and Islands Enterprise and the Highlands and Islands Community Energy Company would be supportive to such a project in providing advice, and where appropriate grant funding and finance for renewable energy projects developed by Island individuals, groups and organisations.

Support may also be forthcoming from Development Trusts Association Scotland and HISEZ CIC for a community development trust and/or a social enterprise as a delivery vehicle for part or all of a given strategy.

In more general terms support and advice may be available from various organisations including those mentioned in the report and particularly:

- The Scottish Renewables Forum, which is an important intermediary organisation for the industry, hosting the annual Green Energy Awards.
- The Climate Change Business Delivery Group, which aims to act as a way for businesses to share best practice and address the climate change challenge.
- The Scottish Agricultural College is undertaking substantial research into various dimensions of the sustainable production and processing of various food and energy crops.
- The Highlands and Islands Local Food Network promotes various community-level initiatives seeking to boost local, organic and seasonal food production and consumption in the north of Scotland.
- UHI Millennium Institute, providers of research information.
- The Carbon Trust.

7.4 Private sector opportunities

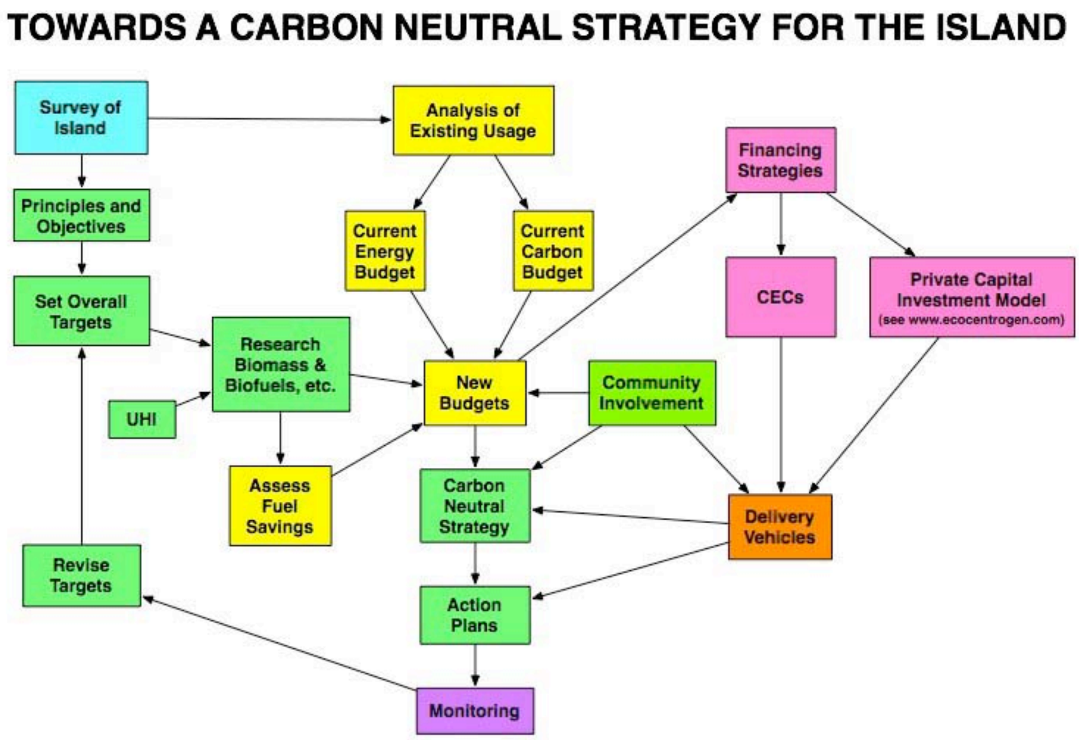
The provision of electricity generation, biomass and biofuels and organic agriculture create both financial and employment opportunities for this sector, which would provide an important aspect of any detailed development strategy.

Maximising the benefits to local employment and of the supply chains involved would clearly require some expert assistance.

It is also possible that the national private sector at large may be able to provide some support and sponsorship for this undertaking. This could include the provision of finance, goods or services at a reduced or nil cost and credit on favourable terms. If the project were to develop a high public profile this support might be considerable - although clearly this is only likely to be true for the pioneer islands involved rather than those that came later.

7.5 Community organisation

Given the enthusiastic support that any such project would require from a significant percentage of islanders, and the various public and private sector organisations involved in delivering goods and services both on and to the Island, the presence of a respected and democratic community organisation to represent and co-ordinate the needs and wishes of the islanders is almost certainly a pre-requisite for success in any endeavour to create a carbon neutral island.



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9 Appendices

9.1 Some islands within the target range

This table gives a flavour of the diversity of the islands under consideration. Some are fertile, others relatively rocky or barren. Population density ranges from 4/km^2 to 18/km^2.

Name	**Pop'n**	**Main Settlement**	**Area** (ha)	**Rainfall** (mm)	**Soils etc.**
Benbecula	1,219	Balivanich (c.500 – small army presence)	8,203	1,400	Abundant machair
Barra	1,078	Castlebay (c.500)	5,875	1,400	Machair in west Hilly in centre, Rock/peat in east
Tiree	770	Scarinish	7,834	1,200	66% machair Very little peat
Westray	563	Pierowall	4,713	900	Largely farmland
Yell	957	Mid Yell	21,211	1,200	Peat and heather

The main villages are probably in the 150-200 range unless otherwise stated.

Principal reference:
Haswell-Smith, Hamish (2004) The Scottish Islands. Edinburgh. Canongate.

Other sources:
2001 UK Census per Scottish Island Network - Population Statistics at http://www.scottishislands.org.uk/Population.html
www.scottishproperty.gov.uk
http://www.undiscoveredscotland.co.uk/

See also Table 1 of the Workbook for agricultural land details.

9.2 Terms of Reference

Establishing a carbon neutral island – review of process and measures

INTRODUCTION

Highlands and Islands Enterprise (HIE) is the development agency for the north of Scotland and its remit is to stimulate sustainable economic and social development across the Highlands and Islands. Renewable energy is one of a number of priority sectors which have been identified as being of key strategic importance to the development of the region's economy.

HIE is committed to encouraging growth and development across a range of technologies which will contribute to the overall renewable energy targets set by the Scottish Executive and the UK Government, and which will also provide local economic benefit. Home to an abundance of natural energy resources, the Highlands and Islands is strategically well placed to take advantage of the opportunities created by the development of renewable energy, and HIE has an aspiration to establish the area as a leading centre for renewables research, development and demonstration.

The Highlands and Islands is also home to a growing level of activity in community and household renewables. The Highlands and Islands Community Energy Company (HICEC) has been established by HIE to provide practical and financial support to communities wishing to install renewable energy kit. To date it has worked with over 200 communities across the Highlands and Islands, including some that are moving towards supplying all of their electricity needs from renewable sources.

HIE has recently considered the opportunity to support a community or island move to becoming carbon neutral. Similar initiatives are proposed elsewhere in the UK, for example both Woking and the City of London have plans to become zero carbon zones. The purpose of this study is to scope out the measures necessary to create and sustain a carbon zero island or community in the Highlands and Islands.

OBJECTIVES / SCOPE OF WORK

The key objective is to produce a report which scopes out the measures and activities that would be required to make an island or community in the Highlands and Islands carbon neutral.

The following scope of work will apply:

1. To review proposals for similar initiatives elsewhere in the UK/ Europe and identify key lessons or recommendations which could apply in the Highlands and Islands context.
2. To consider for a 'typical' community the measures or actions that would be required to move that community to a carbon neutral status (definition to be agreed). For the purposes of this work, the successful bidder may wish to use published data about an existing community in the Highlands and Islands by way of a case study.

3. From published data, quantify as far as possible the scale of effort required to support such an initiative. This should take into account financial support, but also the role of both the community and external agencies. The report should aim to set out and appraise options for further consideration ranging from supporting a community to become fully carbon neutral to interim measures/steps which could be adopted.

METHODOLOGY

The work should primarily rely on desk based research using existing sources of information.

EXPERIENCE

The successful bidder will be expected to demonstrate an understanding of sustainable development, carbon footprinting and renewable energy, particularly within an H&I context. S/he will have excellent research, appraisal and report writing skills.

9.3 Communities that have undertaken footprint studies

Worldwide, a significant number of communities have undertaken footprint studies. Several have been identified as especially relevant to the current study. All are ecological footprint studies.

9.3.1 Isle of Wight

This 1999 study, undertaken by Oxford-based footprinting experts, Best Foot Forward in association with Imperial College London and Biffaward, measured the per capita ecological footprint of the Isle of Wight at 5.15 hectares. Of this, 0.68 hectares was attributed to the tourist population and 4.47 to island residents. It concluded that “If the Isle of Wight were to be self-sufficient or bioregionally sustainable while maintaining current lifestyles and technologies, the island would need to be two and a quarter times its actual size, or the population would need to reduce by 56 per cent.”

The Isle of Wight study included a detailed analysis of the island’s energy footprint. This found that energy consumption was substantially lower than the national average (0.45 ha per capita as compared with 1.2 ha per capita) primarily because of lower than average use of electricity by industry (which is relatively undeveloped on the island).

The energy footprint by energy type was as follows:

Source	Footprint (ha.)	% of total
Electricity	49.534	88
Gas	3,760	6.5
Coal	2,565	4.5
Oil	438	1

Of the electricity used on the island, 51 per cent is used by the domestic sector, 37 per cent by industry and 12 per cent by ‘other users’.

The breakdown of the passenger transport footprint is also interesting for current purposes.

Mode	Footprint (ha.)	% of total
Car travel (inhabitants)	49,602	
Car travel (tourism and business)	17,313	
Air	13,483	
Ferry	8,913	
Bus	202	
Rail	41	

The total ecological footprint of passenger transport for the Isle of Wight was found to be 89,554 Gha., equivalent to 0.71 Gha. per capita. Of special interest here is the relatively high footprint associated with ferries. The Isle of Wight study found that the footprint per passenger kilometre was higher for ferries than for any other

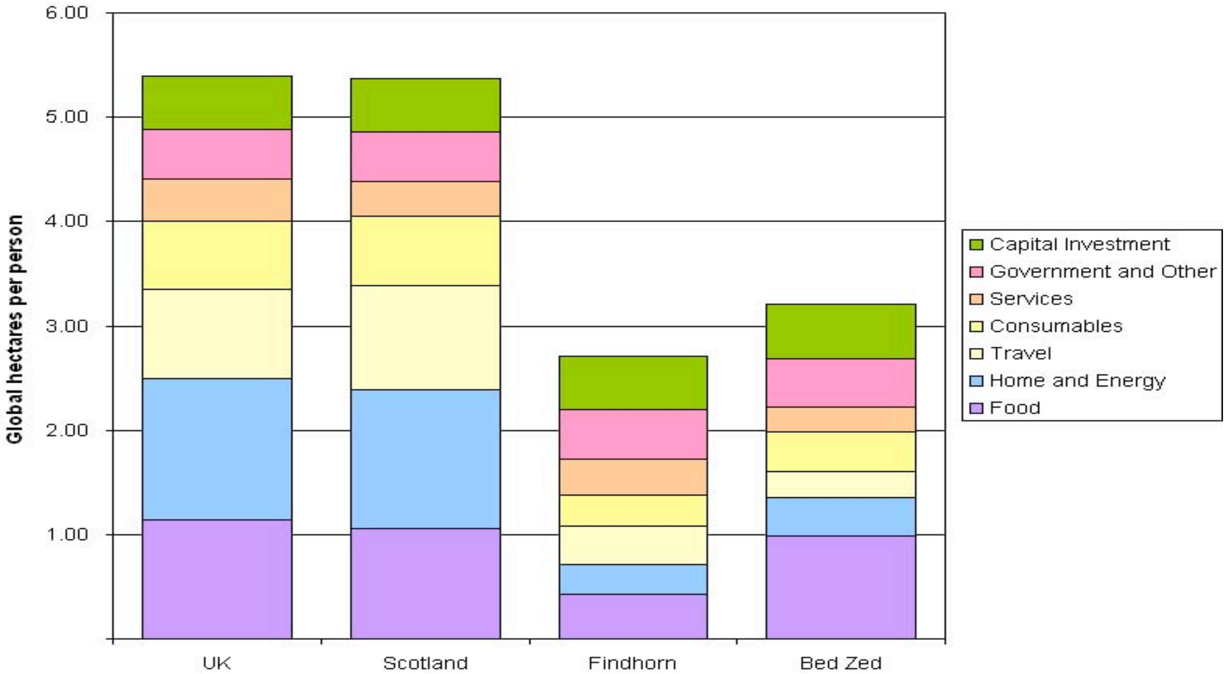
transport mode: 15 per cent higher than for airplane, 67 per cent higher than for cars, 418 per cent higher than for buses and 428 per cent higher than for trains.
The researchers suggested that this high score could be a result of relatively low occupancy rates. However, another study from Norway appears to confirm this surprising finding regarding the large footprint associated with ferry transport: the carbon footprint of a ferry travelling at 48 kph was calculated as being 20 times greater than that of a train travelling at 200kph and several times greater than that of a commercial airline (Quoted in Monbiot (2006) 'Heat', p.185).

9.3.2 Findhorn Foundation community

This 2006 study was undertaken by the Forres-based Sustainability Development Research Centre in association with the Stockholm Environment Institute at the University of York. This study was distinctive in that most of the data on consumption and waste was generated by questionnaires sent to residents and precise measurements of resource flows, rather than the aggregate national-level data used in most footprint studies.

The study calculated what is probably the lowest ecological footprint for any community measured in the industrialised world – a little over half the Scottish average at 2.71 Gha. The table below compares the footprint of the Findhorn Foundation Community resident with those of the UK, Scotland and the innovative London eco-development, the Beddington Zero Energy Development in London (BedZED).

Category	UK	Scotland	Findhorn Residents	Bed Zed
Food	1.14	1.06	0.42	0.99
Home and Energy	1.35	1.33	0.29	0.36
Travel	0.85	0.99	0.37	0.26
Consumables	0.65	0.67	0.30	0.37
Services	0.41	0.33	0.35	0.24
Government and Other	0.47	0.47	0.47	0.47
Capital Investment	0.51	0.51	0.51	0.51
Total	5.40	5.37	2.71	3.20



Three major factors explain this historically low footprint. First, a relatively high proportion of the food consumed in the community is local and organic. A significant amount of the food is provided by EarthShare, the UK's oldest and largest organic Community-Supported Agriculture (CSA) scheme. EarthShare is used as a demonstration resource for both the Soil Association (the UK's leading promoter of organic agriculture) and, more recently by the Highlands Food Network.

Second, there is enough employment on the community's two sites for most residents (in the region of 250), thus reducing the need for commuting to a minimum. The largest employer is the Findhorn Foundation that employs around 100 people. However, there are scores more: Scotland's only solar panel manufacturer (AES), the award-winning earth restoration charity, Trees for Life, ecological waste water treatment systems designers, architects, a school, a theatre, two cafés, a shop, a publishing house, artists and therapists of many kinds, eco-construction companies, small retreat centres, craft studios. As a result of the integration of residential, commercial and industrial uses and the concomitant low levels of commuting, Findhorn's footprint for car use was found to be six per cent of the national average.

Third, Findhorn's energy footprint is relatively low because i) it generates than its own electricity needs with four wind turbines and ii) it has a growing number of energy-efficient houses with solar thermal installations and other ecologically-benign design features.

9.3.3 Prince Edward Island, Canada

Price Edward Island in Canada has an ecological footprint of Gha. 8.98. This has grown by 65% over the last 20 years (primarily as a result of increased consumption) and is forecast to grow by another 20% over the next 20 years. Significant differences were identified between the wealthiest 20 per cent of the population (a per capita footprint of 11.4 Gha.) and the poorest 20 per cent (7.63 Gha.).

The report concludes, "Prince Edward Islanders could quickly and easily reduce their collective footprint by almost one-quarter of a million hectares, from 8.98 Gha. to 7 Gha. per capita without compromising their quality of life: consuming fewer of some items, shifting certain consumption choices and changing public policy priorities can actually improve well-being and quality of life while reducing our impact on the environment.

A few intelligent energy choices can reduce household energy consumption by 50% and save significantly on household energy costs:

- Switch to a time-base, programmable thermostat and turn down the thermostat at night to 17 degrees
- Switch to halogen or compact florescent bulbs
- Install a low-flow shower-head
- Switch to energy-efficient appliances
- Add an insulating blanket to hot water heater
- Clean furnace filter regularly

Intelligent choices can be made that will substantially reduce the food footprint and the impact of food consumption patterns on the environment. In particular, islanders can:

- Eat locally-produced foods and support local farmers, thus reducing high transportation and energy inputs into the food system
- Eat organically-grown and sustainably-farmed food, thus reducing footprint-intensive energy and synthetic, petroleum-based inputs to agriculture."

Beyond such individual choices, this report also points to the social and political decisions that are necessary to reduce the island's ecological footprint:

- Investments in public transportation and bicycle lanes
- Integrated land use/transportation planning to counter suburban sprawl
- Tax incentives to support environmentally friendly co-housing initiatives
- Support for local agriculture, sustainable farming methods and nutritional education.

9.3.4 Angus

The ecological footprint of the council area of Angus was undertaken by Best Foot Forward in 2003. It found that the per capita ecological footprint of the residents of Angus is 4.78 Gha, broken down as follows:.

Component	Angus footprint	Per capita Angus footprint	Per capita UK footprint
Eco-footprint	**525,602**	**4.78**	**5.45**
Domestic energy	68,455	0.62	0.60
Services energy	29,131	0.26	0.37
Materials & waste	165,171	1.50	1.98
Food	156,999	1.43	1.55
Personal transport	83,171	0.76	0.62
Built Land	22,675	0.21	0.32

Breakdown in fuel types used for domestic uses and services were found to be as follows:

Fuel type	Per capita footprint	% of fuel type
Domestic energy		
Electricity	0.18	30.5
Natural gas & LPG	0.38	64.5
Heating oil, kerosene & gas oil	0.03	5.0
Services energy		
Hotel & restaurants	0.01	3.5
Health & education	0.08	28.5
Community, social & personal	0.06	21.5
Office & administration	0.06	21.5
Commerce	0.07	25.0

9.4 Woking Borough Council strategy document

Strategy paper attached.

9.5 Islay energy use

A Sankey diagram from “Strategy And Technology Deployment For Achieving 100% Renewable Energy Supply For The Island Of Islay” by F. Born et al provides a useful comparison with our assumptions. Excluding the very high volume of hydrocarbons used in the distillery industry, we have estimated the differences between our analysis of the existing Island footprint above (see Table C) and the Islay report. This comparison assumes an island with the population of Islay i.e. 3,500. All figures are in GWh per annum.

	Islay	From Table C	Variation
Domestic	48.1	38.5	+25%
Services	7.8	9.2	-15%
Road Transport	23.5	18.3	+28%
Food /Agriculture	7.0	13.0	-46%
Other (inc Marine)	12.2	23.9	-49%
Total (ex Distilleries)	98.96	102.9	-4%

The comparison is hard to undertake without a precise knowledge of the assumptions involved but we estimate that the differences are probably as a result of the following.

Domestic – our per capita figures do not take into account tourism, which is factored into the equation later on the basis of a 10% additional load. It may be that we are underestimating heating costs.
Services – We may be over-estimating the services footprint.
Road Transport – per Domestic above. Residents of larger islands may also have more scope for increasing their road transport miles.
Food vs Agriculture – The Sankey figures do not include the indirect costs of retailed food supply in this category
Other (inc Marine) - We could be over-estimating the footprint.
Ferry – The Sankey diagram includes a figure for ‘marine’, but it is very low and is unlikely to be an estimate of the actual ferry footprint, which may have been omitted. Our figure for Islay would be an additional load of ~40 GWh for the ferry.
Total - all things considered, excepting the ferry issue above, the estimates are similar at this level, the variations within the categories notwithstanding. The distillery consumption figures for Islay are large, accounting for a further 122 GWh – over half of the total for the island.

9.6 Building to Passivhaus standard housing

The latest high performance building standards (Passivhaus and AECB Gold Standard) provide substantially lower carbon emissions than the existing stock (4 to 6 kgCO2/m2/annum) and also the current building control requirements (~23 kgCO2/m2/annum). Many houses on a typical Scottish island will not be to current building control numbers. However, to be conservative, these numbers are compared with AECB and a percentage saving in heating energy calculated. This is then applied to the total domestic housing stock to give a figure for the long term potential for reducing energy use. A lower percentage saving is applied to services heating.

The adoption of low carbon emission designs lowers the potential Islander's personal carbon footprint by 1.5 tCO2pp, resulting in a significantly reduced heating requirement for the Island. This is summarised in a new set of tables.

The data below assumes that all housing and 50% of commercial properties achieve the standard.

Table 3 - Island Carbon Footprint

Category[2, 3, 4]	tCpp	tCO2pp	Island Situation	Island tCO2pp in total	%age of tCO2pp	Reduction Potential as %age	Island tCO2pp Eliminated
Domestic heating	0.47	1.73	22%	0.38	5%	100%	0.38
Domestic electricity	0.28	1.04	100%	1.04	13%	100%	1.04
Services heating	0.15	0.56	25%	0.14	2%	100%	0.14
Services electricity	0.26	0.95	50%	0.47	6%	100%	0.47
Road Transport[10]	0.46	1.71	75%	1.28	16%	22%	0.28
Ferry Transport[9]				1.58	20%	0%	0.00
Other Transport	0.16	0.60	100%	0.60	8%	0%	0.00
Food[5 & 8]	0.27	0.99	100%	0.99	12%	50%	0.50
Sub-total	2.07	7.58		6.48			2.81
Industry & Other	0.83	3.04	50%	1.52	19%	0%	0.00
TOTALS[7]	**2.89**	**10.62**		**8.00**	100%		**2.81**

Table 6 - Heating and Electrical Consumption

Categories for Island energy[2]	Island tCO2pp	Island tCO2	MWh
Domestic heating	0.38	418	1,672
Domestic electricity	1.04	1,142	2,655
Services heating	0.14	154	616
Services electricity	0.47	522	1,213
Total heating	**0.52**	**572**	**2,288**
Total electricity	**1.51**	**1,663**	**3,868**

From Table 8, heating and CHP for Island with houses built to passivhaus standard.

For Houses & Services on District Heating

Category	Number	Unit	Comments
Percentage of Island heating load on district heating	25%	%	Table 1
Total heating load	2,288	MWh	Table 6
District heating load per annum	572	MWh	
Losses in system (depends on size and design of distribution)	25%	%	Estimated
Built district heating load per annum	763	MWh	
Load factor[1]	23%		
Thermal rating of CHP plant	0.38	MW	
Area of forest required for CHP from sustainable wood[3]	26	ha	
Electrical generation from CHP[2] as percentage of thermal rating	25%	%	
Electrical rating of generator	0.09	MW	
Electrical generation from CHP per annum	191	MWh	

For Houses & Services not on District Heating

Category	Number	Unit	Comments
Total heating load	2,288	MWh	Table 6
Houses & services not connected to district heating	1,716	MWh	
Average efficiency of house heating systems	80%	%	Estimated
Built heating load per annum for those houses	2,145	MWh	
Area of forest required for heating load not on CHP from sustainable wood[3]	98	ha	
Total Heating Load	2,908	MWh	
Total area of forest required for production of sustainable wood[3]	125	ha	
Forest land required as % age of land available for biomass			Table 1
Orkney Model	3%		
Western Isles Model	5%		

Note that a simplification is that electricity is not used for heating in this model. Clearly wind-to-heat projects, local ownership of turbines etc. would tend to increase the amount of electrical demand on the Island, so increasing the required electrical capacity and reducing the biomass requirement.

When considering energy consumption reduction approaches, the ‘rebound effect’ needs to be taken into consideration. This is the phenomenon whereby savings in energy costs accruing to consumers are then used to purchase extra goods or activities that incur new carbon emissions (such as additional car or air journeys).

9.7 Wind to Heat, solar thermal and micro CHP

Table 6 gives the current delivered heating load required by the Island as 8,868 MWh/annum. If we assume the same electrical generating capacity factor as used in Table 7 (35%) and losses in the system of 15%, the extra installed wind turbine capacity required is 3.33 MW.

Ground source heat pumps deliver about four times the electrical input in heating energy. If all houses had geothermal sources of heat, the extra wind turbine capacity drops to less than 1 MW. The energy saving through geothermal heating for each Island house is ~11,000 kWh/annum.

Solar thermal panels with an area of 3m2 will deliver ~2,000 kWh/annum. This is ~13% of the current domestic heating load. Small ground source heat pumps that are used for hot water only are an alternative.

There are benefits from preheating the hot water tank using solar thermal and boosting with a ground source heat pump to the required water temperature for domestic hot water and space heating.

The potential interaction between this approach, which could deliver a carbon neutral energy supply to housing, and the passivhaus option discussed above, which would reduce the energy supply required, needs to be taken into consideration for ‘new-build’.

Household scale micro-CHP equipment, which is carbon neutral, is being developed in Germany. This will use wood pellets as the fuel for a Sterling Engine to generate electricity, while also supplying heating for the house. This equipment could be networked using the Island's electricity distribution system to form an "energy internet". Currently there is a gas-fired micro-CHP system on the market called 'WisperGen'. The "energy internet" is the subject of a comprehensive Greenpeace report.

9.8 Hydrogen for vehicles

There are various vehicle designs with different fuel efficiencies. The main options are fuel cell only, hybrid hydrogen internal combustion and battery, and hydrogen internal combustion only. We are indebted to PURE of Unst for these calculations.

Category	Number	Unit
Fuel Cell Vehicle		
Vehicles to be powered	365	cars
km/annum/vehicle	6,643	km/annum
Distance traveled	2,424,695	km/annum
Fuel efficiency	29	km/litre
Usable hydrogen required	244,881	kWh equivalent
Total hydrogen required	81,900	cubic metres
Electricity required	692,307	kWh/annum
Capacity factor	35	%
Wind turbine rating required	226	kW
Hybrid Vehicle		
Vehicles to be powered	365	cars
km/annum/vehicle	6,643	km/annum
Distance traveled	2,424,695	km/annum
Fuel efficiency	22	km/litre
Usable hydrogen required	326,508	kWh equivalent
Total hydrogen required	109,200	cubic metres
Electricity required	923,076	kWh/annum
Capacity factor	35	%
Wind turbine rating required	301	kW
Hydrogen Internal Combustion Engine Vehicle		
Vehicles to be powered	365	cars
km/annum/vehicle	6,643	km/annum
Distance traveled	2,424,695	km/annum
Fuel efficiency	11	km/litre
Usable hydrogen required	653,015	kWh equivalent
Total hydrogen required	218,400	cubic metres
Electricity required	1,846,151	kWh/annum
Capacity factor	35	%
Wind turbine rating required	602	kW

From the PURE data, the hydrogen-powered vehicles are clearly an efficient way of converting wind energy to car kilometres travelled. However capital costs for hydrogen generation and the vehicles themselves need to be factored into the life cycle cost calculations.

10 Workbook Tables

Table 1

The basic inputs for the Island are given in Table 1. The land areas are calculated from averages for the five islands shown and the Scottish Agricultural Census of 2006. An Island population of 1,000 has been chosen, which is expanded by 10% from tourism. This figure varies widely for Scottish islands from a high for Iona at 100,000 visitors a year to low numbers for many remote places. The tourism figure has an important influence on the rest of the Tables. The numbers for households and cars on the Island are calculated from Scottish statistics.

Note that statistics for Benbecula alone are not available and this is an estimate based on data for South Uist, including Benbecula and other smaller islands. Benbecula is less mountainous than South Uist and the available arable and agricultural land may be higher than the South Uist average scaled down to the actual area of Benbecula as shown in the table.

Table 2 - Scotland: Current energy demand

The main sectors of energy demand in Scotland are broken down into electricity and other energy demand for the applicable sectors in Table 2. According to the Final Report for Inquiry into Energy Issues for Scotland by the Royal Society of Edinburgh, Scotland consumed approximately 176 TWh of delivered energy across the main demand sectors: domestic, transport, industry and services.

Table 2 converts the carbon emissions CO2 emissions per sector. The personal annual carbon footprint numbers (tCO2pp) are then calculated.

Starting from the Scottish Domestic Sector Energy Split, and Scotland's population figures, the total amount of domestic CO2-emissions per capita comes to 2.79 tonnes per annum (33% of CO2-emissions). Domestic energy consists of space heating, water heating and electricity.

Road transport accounts for 1.71 tonnes per annum (20% of CO2-emissions). Other transport (Aviation, Marine and Rail) accounts for 0.6 tonnes per annum (7% of CO2-emissions).

Industry is responsible for 1.84 tonnes per annum (22% of CO2-emissions).
This includes sectors like chemicals, engineering, paper, plastics and rubber.

Services are accountable for 1.51 tonnes per annum (18% of CO2-emissions)
Services consist of commercial enterprises, non-residential buildings, banks, retail and warehousing.

Table 3 - Direct and indirect emissions from the Island

Table 3 starts by summarising the UK average carbon footprint per person in tCO2pp. These numbers are also given in Table 5.

The Island situation is then assessed. Domestic heating and electricity are assumed to be the UK national averages. However, because of the particular situation of the islands, the services numbers are shown as 50% of the UK national averages.

Road transport is assessed at 75% as the use of road transport on and off the Island as it is likely to be less than for the nation. However this is more than compensated for by the emissions from ferries. Other transport is for the remainder of the transport sector and includes aviation, marine in addition to ferries and rail.

The food sector is taken as the UK average carbon footprint. However the remainder for industry and other is assessed at 50%, because it is assumed that the Island lifestyle consumes less from these sectors.

While the UK national carbon footprint per annum is 10.62 tonnes, the Island's is computed at 9.5 tonnes. This includes both direct and indirect emissions. The direct emissions for the Island can be eliminated partially or wholly by activities on the Island itself. This includes all of the heating and electricity, the fuel for Island cars, but not other road transport and half of the food sector. All this amounts to 4.31 tCO2pp of direct emissions, which can be eliminated. The remainder at 5.19 tCO2pp will be offset by the generation and export of carbon neutral electricity. For this report, this is assumed to be from wind and some CHP, although it could be from tidal or wave power.

Table 4 - Ferries

The ferry fuel consumption figures are derived from the Aran Ferry specification (Caterpillar Marine Power Systems). This is a 450 passenger, 60 cars ferry, with both rear and front engines.

By studying the Caledonian MacBrayne timetable an average duration of ferry travel per day has been set. This when combined with fuel consumption gives the emission numbers. These numbers form a significant part of an Islander's carbon footprint. Of the total, 50% is apportioned to the Island, while the other 50% is for the mainland use.

Table 5 - UK personal carbon footprint

The UK personal carbon footprint is given in Table 5. This comes from a study by the Carbon Trust titled "Your Carbon Footprint Revealed".

Table 6 - Annual heating and electricity consumption

From the emission numbers given in Table 3, the annual heating and electricity consumption numbers are generated, including average domestic heating and electricity numbers per house.

Table 7 - Electricity

The first table gives the electrical power to be generated and exported to offset the indirect carbon emissions calculated in Table 3. In addition power is required on the Island and is shown in the second table as estimated in Table 6.

The power is assumed to be generated from wind. Most Scottish islands have good wind capacity and a relatively high capacity factor has been assumed. This provides an average electrical demand for the Island. It is assumed that the Island will have an adequate cable connection to the national grid. When there is spare capacity to what is required on the Island, power will be exported and vice versa for light winds. The average size of wind generation required is therefore the same as the average Island electrical demand.

When the power to be exported is added to the Island's annual generation, less the power derived from the CHP plant (Table 8), the total power requirement from the wind installation is given. The number of turbines is then calculated at a typical size of turbine.

Table 8 - Combined Heat and Power from Biomass

As part of the input parameters, a percentage of houses on a district heating system is applied to the total heating load for the Island from Table 6. The district-heating scheme will depend on the size and geography of an appropriate town or village on the Island. The resulting load is then adjusted for losses in the system, which is dependent on the size of the heat distribution. The load factor is then applied from data from a DTI and DEFRA study of CHP plants in UK.

The area required to grow biomass is estimated from data provided by UHI from trials being conducted in Orkney. In addition to district heating, the CHP will generate electricity. The amount is estimated from data provided by Wood Energy Ltd. – a leading UK company in the provision of medium and large-scale CHP plants.

For houses not on the district heating system, the energy is identified and an average efficiency number applied. New wood pellet boilers achieve over 90% efficiency. However a more modest house efficiency is applied taking into account the heating systems in the houses. From the built heating load, the area of short rotation crop forest necessary to grow the biomass sustainably is estimated. When combined with the forest area required for CHP, the amount of land for biomass production is compared to the potential. The Western Isles have quite a different ecology to the Orkney Isles. Both numbers are used, based on the Scottish Agricultural Census Summary Sheets by Geographical Area of 2006 (see Table 1).

Table 9 - Biofuels for use in Island road transport.

For the purpose of this study, it is assumed that the biofuel will be rape oil. Most of the information on this option has come from an SAC study on biofuel production for North and East Scotland of 2005.

The first part of Table 9 gives the basic characteristics of rape oil. The number of cars on the Island and their use is estimated from Scottish statistics. Although the estimate for the carbon emissions from all road transport is taken as 75% of the national average, it is assumed that Islanders will consume the same amount of fuel for cars and agricultural vehicles as the rest of Scotland.

The emissions number from replacing diesel with a carbon neutral fuel is calculated from European data. The amount of embedded energy in the rape itself will depend on agricultural practices and if the production is local. The number chosen assumes reasonable growing conditions for rape and that all of the production takes place on the Island. The number for the annual energy saved in tCO2pp is then calculated, leaving the remainder to be offset as detailed in Table 7. The total volume of biofuel is then calculated, along with the land required for growing the annual rape crop.

The proportion of this land to the potential is then given for the Orkney Isles and the Western Isles, based on the Scottish Agricultural Census Summary Sheets by Geographical Area of 2006 (see Table 1).

Finally the estimate of production, tax and retail price is given, based largely on the SAC report.

Table 10 - Summary of Statistics

This Table summarises all the key numbers from the other tables.

Table 1

Summary of Main Inputs to Island Model

Category	Quantities
Island Population	1,000
Visitors as percentage of Residents[5]	10%
Equivalent Population with visitors	1,100
Persons per house[1]	2.2
Houses on Island	500
Houses connected to district heating	25%
Land Area in ha	10,000
Households with cars[6]	73%
%age to be offset by wind turbines	100%
Cars on Island	365

Note on the column marked "Quantities".
The quantities should by treated as inputs to the Workbook. The Workbook is linked, allowing specific strategies to be tested.

Island	Population	Total Land (ha)
TIREE	957	7,834
BARRA	1,078	6,835
BENBECULA	1,219	5,700
WESTRAY	563	4,713
YELL	957	21,211
TOTALS	4,774	46,293
Average	955	9,259

Island Computer Models	Permanent Population	Total Land[2] (ha)	Land available for Rape[3] (ha)	Land available for biomass[4] (ha)
Orkney model	1,000	10,000	1,150	3,900
Western Isles model	1,000	10,000	90	600

References:

1. National Statistics Online: http://www.statistics.gov.uk
2. Rounded from 9,259 ha for 955 people to 10,000 ha for 1,000 people.
3. Based on Scottish Agricultural Census Summary Sheets by Geographical Area: June 2006.
This is classified as "grass under five years". For Orkney, it is 11.5% of all land.
For the Western Isles, it is 0.9%.
4. Based on Scottish Agricultural Census Summary Sheets by Geographical Area: June 2006.
This is classified as "grass over five years". For Orkney, it is 40% of all land.
For the Western Isles, it is 6%. Substantial amounts of poorer quality grazing land are likely to be available.
5. Tourism firgure from 1999 MacPherson Research survey of Western Isles.
6. Reference for Scottish Statistics - scotland.gov. uk

Table 2

Scotland - Current Energy Demand

According to the Final Report for Inquiry into Energy Issues for Scotland by the Royal Society of Edinburgh, Scotland consumes approximately 176 TWh[1] annually of delivered energy accross the main demand sectors: domestic, transport, industry and services.

Category	Source	Energy Split[2]	kgC/kWh[3]	MtC	MtCO2	tCpp[4]	tCO2pp[4]	%tCO2pp
Domestic	gas	62%	0.0518	1.808		0.35	1.30	
	electricity	22%	0.1170	1.456		0.29	1.05	
	oil	10%	0.0680	0.385		0.08	0.28	
	solid	5%	0.0817	0.231		0.05	0.17	
	renewable	1%	0	0.000		0.00	0.00	
	TOTAL TWh	**56.04**		**3.88**	**14.24**	**0.76**	**2.79**	33%
Services	gas	43%	0.0518	0.60		0.12	0.43	
	electricity	42%	0.1170	1.32		0.26	0.95	
	oil	10%	0.0680	0.18		0.04	0.13	
	solid	0.1%	0.0817	0.00		0.00	0.00	
	renewable	5%	0	0.00		0.00	0.00	
	TOTAL TWh	**26.82**		**2.11**	**7.73**	**0.41**	**1.52**	**18%**
Road Transport	**TOTAL TWh**	**35.54**		**2.37**	**8.70**	**0.46**	**1.71**	**20%**
Other Transport	**TOTAL TWh**	**11.53**		**0.84**	**3.08**	**0.16**	**0.60**	**7%**
Industry	gas	50%	0.0518	0.91		0.18	0.65	
	electricity	29%	0.1170	1.21		0.24	0.87	
	oil	15%	0.0680	0.36		0.07	0.26	
	solid	3%	0.0817	0.09		0.02	0.06	
	renewable	3%	0	0.00		0.00	0.00	
	TOTAL TWh	**35.32**		**2.56**	**9.41**	**0.50**	**1.84**	**22%**
Oil Refinery Oper.	**TOTAL TWh**	**11.00**						
Grand totals		**176.25**		**11.76**	**43.15**	**2.31**	**8.46**	**100%**

References:

The carbon footprints are for energy only.

1. AEA Technology: Scottish Executive Energy Study; Volume 2
2. AEA Technology: Scottish Executive Energy Study; Volume 1
3. Annex A of UKETS(01)05 (Guidelines for the measurement and reporting of emissions in the UK Emissions Trading Scheme)
4. Population figures for Scotland of 5,094,800; National Statistics Online: http://www.statistics.gov.uk/CCI/nugget.asp/ID=6
5. The tCO2pp figures are for direct energy only. Additional carbon emissions not produced by direct energy use make up the difference between the figure of 8.46 tonnes and the Carbon Trust's 10.62 tonnes per capita.

Table 3

Estimation of CO2 Emissions from the Island that can be Eliminated and Offset

Category[1, 2, 3, 4]	tCpp	tCO2pp	Island Situation	Island tCO2pp in total	%age of tCO2pp	Reduction Potential as %age	Island tCO2pp Eliminated
Domestic heating	0.47	1.73	100%	1.73	18%	100%	1.73
Domestic electricity	0.28	1.04	100%	1.04	11%	100%	1.04
Services heating	0.15	0.56	50%	0.28	3%	100%	0.28
Services electricity	0.26	0.95	50%	0.47	5%	100%	0.47
Road Transport[10]	0.46	1.71	75%	1.28	13%	22%	0.28
Ferry Transport[9]				1.58	17%	0%	0.00
Other Transport	0.16	0.60	100%	0.60	6%	0%	0.00
Food[5 & 8]	0.27	0.99	100%	0.99	10%	50%	0.50
Sub-total	2.07	7.58		7.98			4.31
Industry & Other	0.83	3.04	50%	1.52	16%	0%	0.00
TOTALS[7]	**2.89**	**10.62**		**9.50**	100%		**4.31**

Scotland's Ecological Footprint[6]	5.35	gha/capita
UK's Ecological Footprint[6]	5.45	gha/capita
UK personal CO2 Footprint[7]	10.62	tCO2pp
Ferries[9]	1.58	tCO2pp
Island's Modified Carbon Footprint	**9.50**	**tCO2pp**
Modified Footprint inc tourism	10.44	tCO2p resident

Category	Island tCO2pp	%age
Direct Emissions	**4.31**	**45%**
Indirect Emissions	**5.19**	**55%**
Total Emissions	**9.50**	**100%**

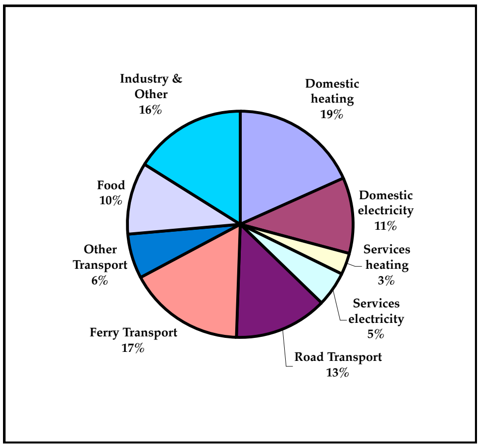
References and Notes:

Domestic and services heating and electricity & road and other transport are all taken from Table 2. Ferry transport is from Table 4. Food is reference 5 & 8 below. 'Other' is the difference between the UK carbon footprint (Table 5) + ferries (Table 4) and the sub-total of domestic heating to food above.

The "Island tCO2pp Eliminated" is the carbon that can be reduced or eliminated by actions on the Island. The figure for direct emissions in tCO2pp can then be taken from the personal carbon footprint of an islander, to leave the CO2 to be offset by exporting carbon neutral electricity or other means.

1. AEA Technology: Scottish Executive Energy Study; Volume 2.
2. AEA Technology: Scottish Executive Energy Study; Volume 1.
3. Annex A of UKETS(01)05 (Guidelines for the measurement and reporting of emissions in the UK Emissions Trading Scheme).
4. Population figures for Scotland of 5,094,800; National Statistics Online: http://www.statistics.gov.uk/CCI/nugget.asp?ID=6.
5. Appendix "Reallocation to consumer need" of the Carbon Trust's publication The carbon emissions generated in all that we consume. 'Food and non-alcoholic drink' at 14.47 MtC + 'Alcohol and tobacco' at 1.73 MtC = 16.2 MtC = 0.27 tCpp.
6. Scotland's Footprint - February 2004. Scotland's carbon footprint per capita is taken as the same as UK's, as the ecological footprints are so similar. See Table 5.
7. Carbon Trust's study - "Your Carbon Footprint Revealed". See Table 5.
8. UK Ministry of Agriculture Report, 2000. Organic arable production created 34% of average emissions. and organic dairy, 74%. The 50% potential reduction is an intermediate 'average' figure.
9. For ferry calculations, see Table 4.
10. From the road transport on the Island, based on estimated number of cars and estimated km/annum/car.

Island emissions in total = 9.5 tCO2pp



Island emissions eliminated = 4.3 tCO2pp

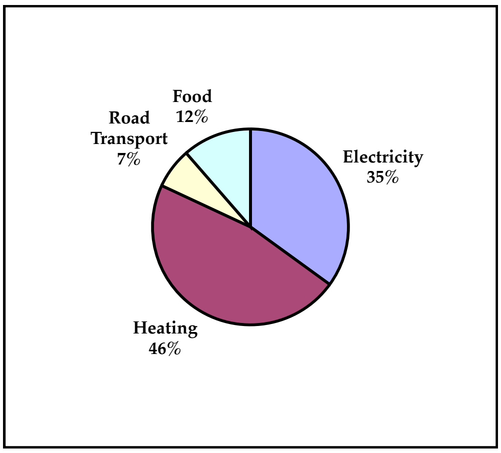


Table 4

Carbon Emissions from Island Ferries

Diesel oil conversions	
1,187	litres/tonne
12,668	kWh/tonne
0.25	kgCO2/kWh
10.7	kWh/litre

Average ferry travel to and from the Island has been taken as:		
	Units	Totals
Fuel consumption[1]	**litres/hour**	**507**
Duration of ferry travel per day[2]	**hours**	**7**
Emissions per hour	**kgCO2/hour**	**1,356**
Emissions per day	**tonnes CO2 / day**	**9.49**
Annual emissions	**tonnes CO2 / year**	**3,465**
Annual emissions per capita[3]	**tonnes CO2 / year**	**1.575**
Total Annual fuel consumption	litres/annum	1,295,997
Annual fuel consumption allocated to Island	litres/annum	647,998

Typical fuel consumption for Isle of Arran-size ferry 450 passengers, 60 cars		
Rear engine	1,520	kW
Load factor	85%	
Fuel consumption of engine[1]	189	g/kWh
Fuel consumption	290	litres/hour
Front engine	1,140	kW
Load factor	85%	
Fuel consumption of engine[1]	189	g/kWh
Fuel consumption	217	litres/hour
TOTAL	**507**	**litres/hour**

References:

1. Caterpillar Marine Power Systems - technical data for Mak M 20 C.
2. Caledonian MacBrayne timetables & fleet.
3. Annual emissions for half the journeys.

In order to calculate ferry emissions a percentage to the Island and a percentage to the mainland have to be apportioned.
In the absence of any obvious alternative, 50% has been used. It is understood that this could be challenged and the percentage has an impact on total Island emissions.

Table 5

Carbon Trust's Footprint Study
"Your Carbon Footprint Revealed"
Consumption account

Category	tCO2pp/ Annum	tCO2pp %
Recreation	1.95	18%
Heating	1.49	14%
Food	1.39	13%
Household	1.37	13%
Hygiene	1.34	13%
Clothing	1.00	9%
Commuting	0.81	8%
Aviation	0.68	6%
Education	0.49	5%
Phones	0.10	1%
Total	10.62	100%

Notes:
Except for aviation, the tCO2pp numbers above include transportation. For example, Food above is 13% of the total of 10.62 tonnes, while in Table 3, the figure is 10%, which does not include transportation.

Carbon Footprint per person per annum

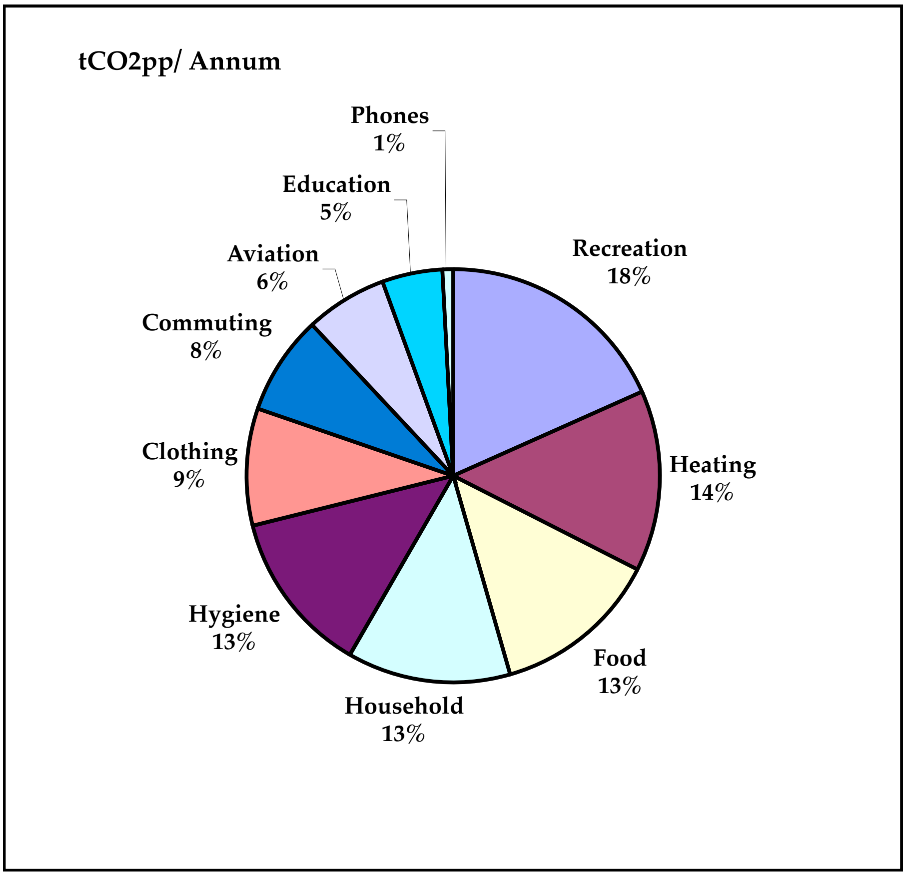


Table 6

Estimate of direct domestic and services energy consumption on the Island.

Equivalent Population with visitors	1,100
Heating conversion[1] of gCO_2 to kWh	0.25
Electrical conversion[1] of gCO_2 to kWh	0.43

Categories for Island energy[2]	**Island**	**Island**	
	tCO2pp	**tCO2**	**MWh**
Domestic heating	1.73	1,908	7,630
Domestic electricity	1.04	1,142	2,655
Average domestic heating per house			15.26
Average domestic electricity per house			5.31
Services heating	0.28	309	1,238
Services electricity	0.47	522	1,213
Total heating	**2.02**	**2,217**	**8,868**
Total electricity	**1.51**	**1,663**	**3,868**

References

1. Carbon Trust - Annex A of UK ETS
2. From Table 3

Table 7

Electricity
Offsetting indirect emissions by exporting carbon neutral electricity from wind.

National electricity[3]	**0.43**	**kg/kWh**
Carbon to be offset[5]	**5.19**	**tCO2pp**
%age to be offset[6]	**100%**	
Exported power	**13,276**	**MWh**

Category	**Number**	**Unit**
Island annual generation[1]	3,868	MWh
Capacity factor of turbines[2]	35%	%
Average electrical demand for Island	1.26	MW
Power to be exported	13,276	MWh
Less power generated from CHP[4]	739	
Power generated from wind	16,406	MWh
Power generated from CHP	739	MWh
Total power generated from wind & CHP	17,145	MWh
Installed capacity of wind turbines required	5.35	MW
Nominal rating of turbine	1.00	MW
No. of turbines	6	

References:
1. From Table 6.
2. Estimated as typical of the islands.
3. Annex A of UKETS(01)05 (Guidelines for the measurement and reporting of emissions in the UK Emissions Trading Scheme).
4. From Table 8.
5. From Table 3
6. From Table 1.

Table 8

Combined Heat and Power
Potential for the Island

For Houses & Services on District Heating

Category	Number	Unit	Comments
Percentage of Island heating load on district heating	25%		Table 1
Total heating load	8,868	MWh	Table 6
District heating load per annum	2,217	MWh	
Losses in system (depends on size and design of distribution)	25%		Estimated
Built district heating load per annum	2,956	MWh	
Load factor[1]	23%		
Thermal rating of CHP plant	1.47	MW	
Area of forest required for CHP from sustainable wood[3]	102	ha	
Electrical generation from CHP[2] as percentage of thermal rating	25%		
Electrical rating of generator	0.37	MW	
Electrical generation from CHP per annum	739	MWh	

For Houses & Services not on District Heating

Category	Number	Unit	Comments
Total heating load	8,868	MWh	Table 6
Houses & services not connected to district heating	6,651	MWh	
Average efficiency of house heating systems	80%		Estimated
Built heating load per annum for those houses	8,314	MWh	
Area of forest required for heating load not on CHP from sustainable wood[3]	381	ha	
Total Heating Load	11,270	MWh	
Total area of forest required for production of sustainable wood[3]	483	ha	
Forest land required as % age of land available for biomass			Table 1
Orkney Model	12%		
Western Isles Model	81%		

References:
1. Future energy solutions - renewable heat and heat from CHP plants - study and analysis, Report to DTI & DEFRA.
2. Information from Wood Energy Ltd.
3. HIU research on sustainable biomass production on Orkney.
Area of forest required for sustainable wood production is ~0.7 ha/house. Average Island House uses 15,260 kWh/annum (Table 6).

Notes:
1. If the delivered heating load for the Island is supplied from electricity, the extra wind turbine capacity required is 3.33MW of installed capacity, assuming a 35% capacity factor for the turbines and 15% losses in the system.
2. If heating is supplied by ground source heat pumps, the demand is reduced by ~11,000 kWh/house/annum. If all houses adopted geothermal energy heating the extra wind turbine installed capacity would be less than 1 MW.
3. Solar thermal water heating reduces the heating requirement by ~2,000 kWh/house/annum, using a 3m2 panel. The potential saving for all 500 houses is 1,000 MWh/annum, which is 13% of the total domestic load of 7,630 MWh/annum (Table 6).
4. A combination of all these technologies will be the most probable outcome.

Table 9

Biofuels for the Island

Category	Number	Unit	Comments
Rape Oil[2]			
Energy	6.257	kWh/l	Analysis of Rape Oilseed
	6.876	kWh/kg	Analysis of Rape Oilseed
Yield of oil[7]	1	tonne/ha	SAC Report
	1,099	litres/ha	Analysis of Rape Oilseed
Rape biofuel	£ 0.40	£/litre	Cost of production
	£ 0.90	£/litre	Retail price with tax
Emissions[4]	160	g/km	European average
Island			
Cars[1b]	365		73% of households
Usage/annum/capita[1a]	9,723	km/cap./annum	5,700 miles + 6% since 2003/4
Additional 10% for ag. Vehicles	10,695	km/cap./annum	Average Island usage
Car occupancy[1b]	1.61	people	Average for Scotland
Usage/annum/car	6,643	km/car/annum	
Emissions[4]	1,063	kgCO2/car	European average
	0.35	tCO2pp	Personal carbon footprint
less embedded in rape	20%		Percent used to produce rape
Emissions "saved"	0.28	tCO2pp	Of personal carbon footprint
Total for road transport	1.28	tCO2pp	Of personal carbon footprint
remainder to be offset	1.00	tCO2pp	Of personal carbon footprint
Consumption - diesel[5]	6.0	l/100 km	
Consumption - rape[6]	6.67	l/100 km	Calculated
Island Consumption	161,647	l/annum	Calculated as rape
Growing area for rape	147	ha	Calculated
%age of land			
Orkney model	13%		
Western Isles model	163%		Not viable
per capita	0.13	ha	Calculated
per car	0.40	ha	Calculated
Approx Capex	£ 30,000		SAC Report, 2005[3]
to	£ 60,000		SAC Report, 2005[3]
Est Cost of oil	£ 0.40		SAC Report, 2005[3]
to	£ 0.60		SAC Report, 2005[3]
Tax	£ 0.28		
Typical retail	£ 0.90	or more £/litre	SAC Aberdeen

References:

1. Reference for Scottish Statistics - scotland.gov. uk

1a. /Resource/Doc/157751/0042649.pdf

1b. /Topics/Statistics/Browse/Transport-Travel/TrendCarOccupancy

- 73% of households have cars in remote Scottish towns.

2. Website: canola-council.org

3. "Economic Evaluation of Biodiesel Production from Oilseed Rape grown in North and East Scotland" - SAC, October 2005.

4. Average CO2-emissions for cars from the European Automobile Manufacturers Association (ACEA) - represents over 90% of car sales in the EU in 2005.

5. Fuel Consumption Database of the Flemish Institute for Technical Research (VITO)

6. "The Benefits of Biodiesel" by Andrew Korfhage - Coop America - July/August 2006. Biofuels by Robin Maynard - The Ecologist - 2006.

7. The SAC Report (#3 above) quotes the UK average yield of biodiesel at 1.48 tonnes/ha and the Scottish average at 1.4 tonnes/ha. In the North East of Scotland the rape yield is given as 1.0 tonnes/ha and this is the number used in this analysis.

NOTES:

1. There are issues to be resolved about refining the oil and the potential necessity to blend with diesel.
2. Fuel tax and grants have a substantial effect on economics.

Table 10

Summary of Main Statistics

Category	Quantities	Units	Tables
Island Population	1,100		1
Island Houses	500		1
Land Area	10,000	ha	1
Island annual CO2 emissions	10,445	tonnes	3
Island energy consumption per annum			
Electricity	3,868	MWh	6
Heating	8,868	MWh	6
Total	12,736	MWh	6
Island CO2 emissions from energy			
Electricity	1.51	tCO2pp	3
Heating	2.02	tCO2pp	3
Total	3.53	tCO2pp	3
Energy as %age of total CO2	37%		3
Island carbon footprint	9.50	tCO2pp	3
Island CO2 that can be eliminated	4.31	tCO2pp	3
Island CO2 to be offset	5.19	tCO2pp	3
Power per annum to be exported to meet offset	13,276	MWh	7
Island electrical generation per annum for own use	3,868	MWh	7
Average electrical demand for Island	1.26	MW	7
Total electrical power to be generated per annum, including offset	17,145	MWh	7
Electricity for Island per annum from wind with CHP power	16,406		7
Output of wind turbines required	5.4	MW	7
No. of 1 MW turbines	6		7
Total annual heating load for Island	11,270	MWh	8
District heating potential	2,217	MWh	8
Area of forest required for growing sustainable biomass for CHP.	102	ha	8
Thermal rating of CHP plant	1.47	MW	8
Electrical rating of generator	0.37	MW	8
Electrical generation from CHP per annum	739	MWh	8
Houses not connected to district heating require after losses	8,314	MWh	8
Area of land required for growing sustainable biomass for non-CHP houses	381	ha	8
Total area of land required for growing sustainable biomass	483	ha	8
Forest land required as %age of land available for biomass			
Orkney Model	12%		8
Western Isles Model	81%		8
Cars on Island	365		1
Island annual consumption of biofuel	161,647	litres	9
Land area for growing oilseed rape on Island	147	ha	9
Land for rape production as % age of suitable land			
Orkney Model	13%		9
Western Isles Model	163%		9

Notes:
The land for biomass production assumes only the use of intermediate quality land.
Substantial ares of rough grazing with lower yields will be available.