

**FEASIBILITY STUDY OF  
RENEWABLE ENERGY ON  
DURNESSE ESTATE**

*Final Report for*  
**Durness Development Group Limited**

*Prepared by*  
**Grangeston  
Economics**

**May 2004**

50 Southside Road  
Inverness  
IV2 4XA  
Tel: 01463 729107  
Email: [grangeston@aol.com](mailto:grangeston@aol.com)

# CONTENTS

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Background</b>	<b>3</b>
<b>3</b>	<b>Review of Technologies</b>	<b>9</b>
<b>4</b>	<b>Assessment of Shortlisted Technologies</b>	<b>33</b>
<b>5</b>	<b>Conclusions</b>	<b>35</b>

## **Introduction**

### **1.1 INTRODUCTION**

This is the final report of an evaluation of the feasibility of developing a renewable energy programme on Durness Estate. This study was undertaken on behalf of Durness Development Group Limited (DDG).

### **1.2 PROJECT OBJECTIVES**

The overall objective of the study is to evaluate the feasibility of developing a renewable energy programme on Durness Estate. The specific objectives of the study include:

- **Explore and analyse the potential for renewable energy development in the area of Durness including:**
  - The renewable energy generation potential of the area including a strategic look across the estate at availability, applicability and quantity of wind, solar, hydro, ground source heat pumps, biomass and biogas;
  - The potential for electricity and heat generation for domestic properties, halls, community facilities, including an analysis of demands and infrastructure, e.g. loads, roads, grid, spare grid capacity;
  - Potential income streams from the sale of renewable energy and the possibilities for job creation resulting from cheaper energy for local facilities e.g., nursing home;
  - Potential spin offs and opportunities for local tourist attractions;
  - Potential for new, innovative and locally appropriate renewable energy development including the possibility of 'test bed' facilities, e.g., hydrogen production and export;
  - Identify potential sources of further funding.

- **Identify and provide a prioritised list of specific renewable energy projects which warrant further exploration and which have community support. A brief description should be provided of:**
  - The location of the project, the building and the load type, e.g., heat, electricity, or mix;
  - The potential for embedded generation vs. export to grid for each project identified above;
  - Key contact;
  - Any other information which would be advantageous prior to further exploration of the project concerned.

### 1.3 METHOD

The methods employed to meet the study objectives included:

- Meetings with the client group to explore the potential of the Durness area as a location for renewable energy projects that would benefit the local community;
- A review of available documentation relating to the application of renewable energy technologies within the Highlands and Islands;
- A review of available technologies in context of Durness; and
- Presentation/workshop open to the Durness community to discuss potential technologies.

### 1.4 STRUCTURE OF REPORT

**Chapter Two** provides the background to the study in terms of government policy and the opportunities for, and aspirations of, the Durness community. **Chapter Three** presents a review of range of possible renewable energy technologies and reviews their applicability in the context of Durness. **Chapter Four** undertakes an assessment of the shortlisted technologies and **Chapter Five** presents the conclusions.

## **Background**

### **2.1 INTRODUCTION**

This Chapter provides a review to the development of renewable energy in Scotland and the Highlands and Islands in the context of the opportunities for and aspirations of the Durness Community.

### **2.2 BACKGROUND**

In the past few years alternative and renewable sources of energy have become increasingly important both as a response to issues of global warming and because appropriate technologies are being developed and proven to be successful. Over the next 15 to 20 years renewable energy sources will become increasingly important for the generation of power within the UK. Given the availability of the right conditions, much of the pressure for development of renewable energy is going to fall within Scotland, in particular the Highlands and Islands.

The UK government is committed to achieving 10% of power generated from renewable sources increasing to 15% by 2015. In comparison, the Scottish Executive has an 18% renewables target by 2010 and 40% by 2020.

To encourage greater generation of renewable power, and achievement of these targets, the Renewables Obligation Scotland (ROS) came into force in April 2002, under which licensed electricity suppliers are required to supply a certain proportion of their energy from renewable sources, which they demonstrate by purchasing Renewable Obligation Certificates (ROCs) from generators of renewable energy.

In April 2001, the Climate Change Levy (CCL) was introduced and is effectively a tax on the consumption of energy by non-domestic customers. However, electricity produced from renewable sources is exempt from this levy. This effectively creates additional demand for energy produced from renewable sources.

Between them, these two 'certificates' provide the additional income that makes investment in renewable generation commercially attractive and financially viable.

Within Scotland, the prime sources for renewable energy in the coming years will focus on on- and off-shore wind and hydro power. Thus Scotland is going to be the focus for much activity by the main generating companies in terms of building up alternative energy generating capacity. In addition, finding alternative uses for waste are central to the development and implementation of the National Waste Strategies. Producing energy from waste will therefore provide another area of potential development.

A recent report for the Highland Council (*An Evaluation of Alternative/Renewable Energy Schemes, December 2003, by IPA Energy Consulting*) evaluating renewable energy schemes within the Highlands and Islands identified a number of important generic risks applicable to any renewable energy project, and that could play a significant role in the extent to which Durness can turn the opportunities it is presented with into realisable benefits. The risks are:

- Planning Risk;
- Performance Risk;
- Availability of Resource – 'Volume Risk';
- Sustainability of the Renewables Obligation;
- Electricity/ROC price risk; and
- Offtaking Agreements – 'PPA Risk'.

These are described briefly below in the context of Durness.

### **Planning Risk**

Developments progressing through the planning phase have the risk of being rejected for a number of reasons including:

- Visual intrusion;
- Cumulative impacts; and
- MOD/radar interference.

Many projects do not get through the planning stage and it is estimated that in Scotland about 10% of renewable energy planning applications are refused compared with around 50% in England.

In the case of the Durness area, any renewables projects are going to need to be especially sensitive to issues of visual intrusion. The area is largely dependent on the tourism/visitor market and the community needs to be sensitive to the

potential negative impacts of a number of the renewable energy options. The potential negative impacts on the visitor market needs to be balanced against potential community benefits and employment opportunities.

Second, in respect of the Durness area, MOD activity at Cape Wrath and the general use of Sutherland as a low fly zone means the wider area could face objections to windturbines and new electricity pylons. However, it appears that low flying aircraft is not an issue for the immediate Durness area because of the use of the firing range at Cape Wrath.

Overall, the community need to consider whether they are supportive of wind farms, or perhaps more importantly how they would like windfarms to be developed and controlled.

### **Performance Risk**

The performance of the technology will affect an investor's view of the risk and therefore returns on an investment. Basically, the willingness to invest in a technology will depend on any perceived risks in relation to the ability of the technology to perform. The more uncertain the level and consistency of performance of a technology the greater the return required by investors. Some of the technologies that may be of interest to DDG may not be feasible given these risks and the need of the community to attract outside investors.

### **Availability of Resource**

This is represented by the load factors for each of the technologies. For example onshore wind has a load factor of around 30%, indicating that power is only produced 30% of the time throughout the year. However, local and site specific characteristics will result in variations in the load factor. Furthermore, the unpredictable nature of the weather means that there could be periods of limited rain or wind impacting on the ability to generate electricity.

While it may be difficult to imagine that Durness could suffer from insufficient rain or wind, it is certainly a risk that outside investors will need to consider. If Durness offers a much lower 'availability of resource risk' compared to other areas this will help to counterbalance other risks that may be higher in Durness.

### **Sustainability of the Renewable Obligation**

The viability of many renewable projects is dependent on the extra income received via the Renewables Obligation. As the RO is a government initiative it is possible that a change in government, or government policy, could radically change the Obligation.

### **Electricity/ROC Prices**

Price risk reflects potential fluctuations in income to the project as a result of movements in electricity and/or ROC prices. These in turn depend of the demand and supply balance in the system. The prime concern for renewable developers is to secure a long term guaranteed price.

### **Off-taking Agreements**

There is a risk that a developer may not be able to sell all of its output and so not be able to fully realise the benefits of the development. Due to the Renewables Obligation the demand for renewable energy in the short to medium term will be high. However, as more and more renewable developments come on line buyers of renewable power may start to cherry pick the best developments, i.e. those with the most predictable resources. Those developments with less predictability may then receive lower prices or may not even be able to sell their output.

### **Conclusions**

In conclusion, renewables projects face a number of risks to their commercial viability that need to be considered by potential investors in any projects in the Durness area. In addition, the community needs to be aware that potential outside investors will assess the returns on a project against projects elsewhere in Scotland and the UK and not just in the context of other options within the community. In other words an acceptable return to the community may not always be sufficient to attract outside investors.

## **2.3 OPPORTUNITIES FOR DURNESS**

In the context of Durness Development Group's investigations into the feasibility of community ownership of Durness estate lands, it is important that the Group maximise their impact and explore as wide a range of potential schemes as possible. The relevance of renewable energy resources to a community like Durness is increasing both with the availability of grants and funding to undertake such activities and in greater accessibility to small scale energy systems. The community recognise that there is an opportunity to benefit economically and socially from exploiting renewable energy within the area.

Renewable sources of energy such as wind and wave power are abundant in Sutherland. The transformation of this raw energy into useful electrical energy is the challenge that renewable energy developers have to overcome. To exploit the renewables resources effectively the Durness community has a number of choices to make in terms of achieving their optimum balance between maximising income and employment through the export of electricity to the grid

or maximising the production of local power for the local community. These choices are not mutually exclusive.

The DDG could focus on maximising income from renewable energy by encouraging the development of wind farms on Durness Estate by a large generating company. In this scenario Durness community could play a number of roles including:

- Being the developer and operator of renewable energy schemes exporting to the grid as a commercial operation;
- Being the community partner with a large developer/operator; and
- Negotiating community benefit with a developer/operator.

Each of these possibilities has an associated risk and return to the community. Clearly the greater the risk and financial input of the community the greater the potential rewards. However, operating in this market is expensive. As a rule of thumb it is estimated that to produce 1MW of electrical capacity a capital expenditure of £700k-£1m is required. In addition smaller businesses or communities will need to access financial backing that can only be provided by large finance houses or corporations. Added to this is the need to develop an alliance with a utilities company that can in effect carry the energy.

It is most likely that a major operator would develop the site with the community mainly benefiting from rentals paid to the landowner and any agreed payment to the local community.

In general any project relying on export from the area will need to be very carefully assessed.

At the other extreme DDG could focus on maximising the environmental sustainability of the community through a series of projects that provide renewable energy to the community as well as address other local environmental issues such as the disposal of waste. Such an approach will probably have a less significant impact on income but may create more employment opportunities as well as make the area more attractive as a 'green' tourism destination.

We can therefore consider the criteria against which the community may wish to assess the potential renewable energy options in terms of the following community **objectives**, in relation to:

- Creation of jobs;
- Income;
- Attract visitors/tourists;
- More energy being produced locally for local consumption; and
- Develop reputation of Durness as a 'green' community in the same way Unst is promoting itself as 'Green Island'.

These criteria will be returned to later in the report.

## Review of Technologies

### 3.1 BACKGROUND

The objective of this **Chapter** is to explore and analyse the potential for renewable energy development in the area. This review includes the applicability of each of the main technologies in the context of the physical, environmental and social conditions in Durness as well as the potential markets that could be addressed. The following technologies are reviewed:

- Wind;
- Solar;
- Hydro;
- Tidal and ocean Thermal;
- Geothermal;
- Biomass;
- CHP; and
- Hydrogen and Fuel Cells.

The review of each of the individual technologies is based on a range of publicly available sources. These sources are referenced at the end of this **Chapter**.

### 3.2 WIND ENERGY

The UK has a large potential wind resource. Harnessing wind as a renewable energy source involves converting the power within a moving air mass (wind) into rotating shaft power. Individual turbines vary in size and power output from a few hundred watts to 2-3 megawatts. Uses range from very small turbines supplying energy for battery charging systems (e.g. on boats or in homes), to turbines grouped on wind farms supplying electricity to the grid.

Wind speed increases with height, so it is best to have the turbine high on a mast or tower. The ideal siting is a smooth-top hill with a flat, clear exposure, free from excessive turbulence and local obstructions such as large trees, houses or other buildings.

**Small scale wind power** is particularly suitable for remote off-grid locations where conventional methods of supply are expensive or impractical. Most small wind turbines generate direct current (DC) electricity and off-grid systems

require battery storage and an inverter to convert DC electricity to AC. A controller is also required to ensure the batteries are not over or under-charged and can divert power to another useful source (e.g. space and/or water heaters) when the battery is fully charged.

Normally such a system would be combined with a diesel generator for use during periods of low wind speeds. This gives greater efficiency and flexibility than a diesel-only system, as the generator can be used at optimum load for a short period to charge the batteries, rather than by constant direct use of the diesel generator at varying loads.

Systems can also be installed where there is a grid connection. A special inverter and controller converts DC electricity to AC at a quality and standard that is acceptable to the grid. No battery storage is required. Any unused or excess electricity can be exported to the grid and sold to the local electricity supply company.

A good wind site will produce an average output of 30% of the rated capacity of the turbine. For off-grid systems, the size of the battery bank determines the time appliances can be run if there is no wind. The size of the inverter installed determines the number of appliances that can be run at the same time from the stored electricity.

### **Cost and maintenance**

A wind turbine will vary in cost depending on the size of the machine and where it is installed. Indicative characteristics including installation costs are reported in **Table 3.1** below.

<b>TABLE 3.1: CHARACTERISTICS OF WIND TURBINES</b>			
Size	Application	Rated Output	Installed Cost
Small	Battery Charging	50/70W	<b>£350-£500</b>
Small	Battery Charging	600W	<b>£3,000</b>
Medium	Battery Charging/Grid Connection	6kW	<b>£18,000</b>
Medium	Grid Connection	60kW	<b>£90,000</b>
Large	Grid Connection	600kW	<b>£390,000</b>
Large	Grid Connection	2MW	<b>£1.4 m</b>

Systems for households or businesses can cost between £5,000-£25,000, including turbine, mast, inverters, storage (if required) and installation, depending on the size and type of system installed. A 6kW system can provide 12,000-15,000 units of electricity (kWh) per year depending on site and location.

There are very few maintenance requirements. A service check every few years may be required. Turbines can have a life of up to 20 years. For battery storage systems, typical battery life is around 6-10 years depending on the type, so batteries may have to be replaced at some point in the system's life.

For the smaller turbines, the p/kWh will be very high with payback periods in the region of over 50 years. For grid-connected turbines, simple payback periods can drop to under five years. Together with operation and maintenance costs (about 2-3% of the capital cost), running costs for the larger wind farm projects are around 2.5-3p/kWh at which point it becomes competitive with the main carbon dioxide-producing fuels: gas, oil and coal.

Wind turbines are typically four times more effective than solar PV at producing electricity.

### *Noise*

Noise emission of wind turbines is perceived as the only really important environmental problem. Dutch wind turbine manufacturers have reduced the mechanical noise of wind turbines.

### *Wildlife*

The disturbance of wildlife (birds) by wind turbines involves three factors:

- Disturbance of birds during installation periods;
- Mortal collisions with the tower or blades; and
- Disturbance of breeding or resting birds in the vicinity of the turbine.

Several investigations on these issues have been carried out in Denmark, both for onshore and off-shore sites. The conclusions so far are:

- That mortal collisions between birds and wind turbines are only a small fraction of the background mortality due to other (natural) reasons;
- That most migrating species will change their routes if they pass a wind farm, but wind farms should not be placed on major migration routes; and
- That during the construction period some species will move away from the construction site before breeding, staging and foraging. After commissioning they tend to move back.

### 3.3 SOLAR ENERGY

#### **Types of Technologies Associated with Solar Power**

There are two main technologies associated with solar power. The first, solar thermal technologies use the sun to generate heat. The second, photovoltaics, directly convert solar radiation into electricity through the photoelectric effect.

#### **Solar Thermal Technologies**

- **Concentrating solar power systems** generate electricity with heat. Mirrors and lenses concentrate and focus sunlight onto a receiver which absorbs and converts the sunlight into heat. This heat is then transported by means of a heated fluid (either water or molten salt) through pipes to a steam generator or engine where it is converted into electricity.
- **Flat plate solar collectors** are usually large flat boxes with one or more glass covers. Inside the boxes are dark coloured metal plates that absorb heat. Air or liquid flows through the tubes and is warmed by heat stored in the plates. These systems are particularly useful for providing hot water to households.
- **Passive solar heating design** methods use features such as large south-facing windows and building materials that absorb the sun's thermal energy. The result is that in cold weather the large thermal mass in the room absorbs solar energy and radiates heat throughout the room. During warmer times the thermal mass absorbs only the warm air already in the room. This leaves the air cooled in warmer seasons and heated in cooler seasons.

A solar thermal tube system 3m<sup>2</sup> costs £3,000-£5,000, while a 4m<sup>2</sup> flat plate panel system costs around £2,500-£4,000 to install.

#### **Photovoltaics**

Photovoltaics (PV) use the sun's light to create electricity. PV cells can be classified into two main types - crystalline silicon (mono or poly) which have about 90% market share, and thin film (amorphous silicon, cadmium telluride, copper indium diselenide) which have the potential for low cost automated production in the future.

The main applications for PV in the UK are in consumer products (calculators, garden lights, caravan ventilators), remote professional applications (telecom relay stations, weather and traffic monitoring, navigational aids) and street furniture (parking meters, bus stops, street lighting). While these are already commercially attractive, integrating PV into or attached to houses and other buildings is currently very costly.

A typical home uses about 3,300kWh/yr electricity. The average house probably has about 20m<sup>2</sup> of south facing roof space. In the UK, the sun's energy delivers about 1,000kWh/yr for every m<sup>2</sup>, such that a south facing roof collects about 20,000kWh/yr of energy. However, the panels are generally only between 10% and 20% efficient at turning the sun's energy into electricity, thus typically it is possible to achieve in the region of about 150kWh/yr for every m<sup>2</sup> of PV. Thus to generate sufficient electricity to meet typical house needs would require around 22m<sup>2</sup> of PV

PV is an expensive option although the costs have been coming down. A typical household system can cost between £8,000 - £18,000. This will provide approximately 50% of the household's electricity saving in the region of £100 off the electricity bill every year.

During operation, PV and solar thermal technologies produce no air pollution, little or no noise, and require no transportable fuels. One environmental worry with solar technologies is the lead-acid batteries that are used with some systems. The impact of these lead batteries is lessening however as batteries become more recyclable, batteries of improved quality are produced and better quality solar systems that enhance battery lifetimes are created.

### 3.4 HYDROPOWER

Hydroelectricity (or hydropower) is one of the oldest and most widely used forms of renewable energy. It exploits the energy of flowing water (from a reservoir, river or in a tidal current) to drive a turbine connected to an electricity generator. The amount of power generated depends on the rate of flow and the volume of water available to drive the turbine.

Hydropower has become the leading source of renewable energy. Worldwide, about 20% of all electricity is generated by hydropower and it provides more than 97% of all electricity generated by renewable sources.

Hydropower schemes are generally of two broad categories namely large-scale (over 5MW) and small-scale (less than 5MW). Systems of a few tens of kilowatts are often referred to as "micro hydro" and are not usually connected to the electricity grid. Micro hydroelectricity is a proven technology which has now reached maturity. It is ideal for electrification of remote sites, although it can also contribute to national electrical production. A small scale hydro scheme with a capacity of 100 kW would typically supply electricity to 150 households

The requirements for operating a hydroscheme are:

- Suitable rainfall catchment area;
- Hydraulic "head" (vertical distance from the reservoir/river to the turbine);
- Water intake above a weir or behind a dam;
- Pipeline or channel to transport the water from the reservoir or river to the turbine;
- Flow control system;
- Turbine, a generator, associated buildings and grid connection; and
- Outflow, where the water returns to the main water course.

Characteristics	Large Scale Hydro	Small Scale Hydro
Output	25MW+	0.25 – 5MW
Retaining Structure	7.5m – 25m	Weirs up to 2.5m
Drawdown	7.5m – 15m	Less than 2.5m
Scenic impact	Visible concrete constructions that become landscape features and visible access roads	Small local-stone constructions blending into landscape. Limited access tracks to reduce visual impact
Environmental Impact	Large drawdown with potentially significant barren zones and ecological implications for fish, bird and plant life	Small drawdown limiting impact on ecology

Hydropower schemes are designed to offer power generation with high levels of availability over a long operating life. With suitable maintenance the mechanical and electrical lifetime of a hydro power plant can be up to 50 years. When compared to wind power, small hydro schemes have a number of advantages including:

- Hydro projects have more than twice the lifespan of wind farms which are decommissioned after 25 years;
- More efficient - the most modern plants have energy conversion efficiencies of up to 90%;
- Inconspicuous with much less impact on the landscape; and
- Quieter.

#### **Loch Poll, Assynt, Sutherland**

Assynt Hydro Limited, an associated company of Highland Light and Power Limited, operates a 225kw hydro scheme located at Assynt, near Drumbeg, some 15 miles from Lochinver. The scheme was delivered in partnership with the Assynt Crofters Trust. This station commenced operations in September 2000 and has been successfully integrated into a National Scenic Area coupled with

the designation of SPA (Special Protection Area), covering the protection of black-throated divers and fresh water pearl mussels.

The scheme is based on water storage on four lochs. The scheme features two different weir designs. A 1.5 metre tilting weir is used on Loch Poll which can be moved up or down to change the water levels in the loch. The 3 remaining weirs are built using local stone and vary in size from 2m to 2.5m. The penstock is completely buried and feeds the water to a timber turbine house. The water is then returned to its natural water course through the tailrace.

In building the scheme, the company worked closely with SNH and the Highland Council to develop a Construction Method Statement which has been shown to minimise the environmental impact of the scheme. The scheme generates enough electricity to power around 340 households.

### 3.5 TIDAL AND OCEAN THERMAL

**Tidal energy** uses the gravitational energy of the Sun, Earth and Moon. **Wave power** converts the energy released in crashing waves, driven onshore by wind. **Ocean thermal systems** exploit the solar collector properties of the sea.

Tidal energy works on the same fundamental principal as the water wheel with the difference in water elevation caused by the fluctuation between low and high tides. A dam or barricade is built across an estuary to block the incoming tide, the outgoing tide, or both. When the water level on one side of the dam is higher than the level on the other side due to a tidal change, the pressure of the higher water increases. The water is then channelled through a turbine in the dam, which produces electricity by turning an electric generator.

Tidal energy is being harnessed in several countries around the world with Britain's Severn Estuary and Canada's Bay of Fundy have potential capacities of as much as 8,000MW and 30,000 MW, respectively. The Severn Estuary average tidal range is 26 feet, and the Bay of Fundy boasts a 32-foot tidal range, ideal for substantial electricity generation. But exceptionally high tides are rare and found only at high latitudes in relatively remote areas, a major limitation to this energy source. **A tidal range of at least 21 feet is needed to build a sufficient head of water for the turbines.** There are few places in the world that make such a facility economically worthwhile.

**Wave energy** potential is greatest in regions with strong on-shore winds. The best areas are on the eastern edges of the oceans (western side of the continents) between the 40° and 60° latitudes in both the northern and southern

hemispheres. These optimal wind zones produce the highest concentrations of wave power — a low-frequency energy that can be converted to a 60-Hertz frequency. The waters off California and the United Kingdom are regarded as the best potential sites. California's coastal waters are sufficient to produce between 7MW and 17 MW per mile of coastline.

**Ocean Thermal Energy Conversion (OTEC)** is a promising source of renewable, non-polluting energy for the future. The oceans collect and store an enormous amount of solar energy. Ocean thermal-energy conversion exploits the temperature gradient between the varying depths of the ocean, requiring at least a 36°F difference from top to bottom, as is found in tropical regions. This difference in temperature is the "heat engine" for a thermodynamic cycle. Cool water brought up from the ocean depths is used to condense the vapour, just as the cooling towers of other power plants do.

The large amount of equipment, chronic maintenance problems, and very low efficiency rates suggest that it will be some time before OTEC power generation will make a significant contribution to renewable energy production.

### **Tidal and Ocean Thermal Energy Projects**

#### **LIMPET (Land-Installed Marine-Powered Energy Transformer)**

In early 1999, the wave energy company Wavegen was awarded a contract under the third round of the Scottish Renewables Obligation (SRO-3) for its LIMPET wave power project, located on Islay, Scotland. The project will generate electricity for sale to the power grid.

LIMPET is a second-generation shoreline wave energy collector. The LIMPET employs the Oscillating Water Column (OWC) principle, and uses a combination of Wells turbines and induction generators to convert the pneumatic power captured into electricity. The LIMPET is built into the shoreline, relying on existing cliff edge for support. Alternatively, LIMPET units may be incorporated within rubble mound or caisson breakwaters to provide self-financing coastal protection schemes.

The low profile of the structure gives a low visibility so that, in contrast to coastal wind energy schemes, the LIMPET does not create a significant visual intrusion. Material colours are chosen to blend with the surrounding shoreline. The device derives power from the energy in water and therefore contributes no pollution to the environment.

The SRO-3 contract price for electricity is 5.95 p/kWh. The construction of both the prototype and the LIMPET has provided significant local employment.

### **The Portland Wave Energy Converter**

The Wave Energy Converter (WEC) to be installed off the coast of Portland, Victoria will be the first commercial offshore wave power generator in the world to provide publicly available power. The system, developed by Ocean Power Technologies (OPT) is known as the PowerBuoy and is able to harness wave energy by using a piston like device. A computerised system housed in a watertight canister at the top of the buoy allows uniform power to be derived from the random motion of ocean waves. The power is then carried via underwater cables to shore.

Each buoy generates on average 20 kilowatts of electricity, or enough to power about 25 households. Depending on the needs of the area served, the system can be "scaled up" by means of additional buoys connected together in a field. The OPT system is typically placed more than a mile offshore, is mostly below water and can't be seen from the shore. The system's minimal visual and noise impacts are one of its major advantages.

The power output of the system is on average 20 kW, its typical operational range is between a wave height of 1.25m and 2.75m. The structure is composed of mild steel. The shell is cylindrical in shape, 4.5m in diameter and 20m in length, it is closed at top, and open on the bottom with some open compartments on the side to allow water in and out. The system converts the natural energy of the ocean into mechanical energy and then to electrical energy. The system anchor provides a counteractive force for operation, and secures the system in storm conditions.

Weighing 30-35 tonnes and completely submerged with the exception of the mast and navigational markings, the system uses seawater for lubrication and cooling. The system is designed to have all periodic service done on land, using diver/service-removable components - this insures that products such as oil used during maintenance are not introduced to the site environment.

### **Offshore Wave Energy**

Ocean Power Delivery Ltd has developed a novel offshore wave energy converter called Pelamis. Pelamis has a similar output to a modern wind turbine. The first full-scale pre-production prototype is being tested at the European Marine Energy Centre in Orkney.

It is anticipated that future 'wave farm' projects would consist of an arrangement of interlinked multi-machines connected to shore by a single subsea cable. A typical 30MW installation would occupy a square kilometre of ocean and provide sufficient electricity for 20,000 homes. Twenty of these farms could power a city such as Edinburgh.

The Pelamis is a semi-submerged, articulated structure composed of cylindrical sections linked by hinged joints. The wave-induced motion of these joints is resisted by hydraulic rams, which pump high-pressure oil through hydraulic motors via smoothing accumulators. The hydraulic motors drive electrical generators to produce electricity. Power from all the joints is fed down a single umbilical cable to a junction on the sea bed. Several devices can be connected together and linked to shore through a single seabed cable.

Ideally the Pelamis would be moored in waters approximately 50-60m in depth (often 5-10km from the shore). This would allow access to the great potential of the larger swell waves but it would avoid the costs involved in a longer submarine cable; if the machine was located further out to sea.

### **Stingray Development Programme**

Engineering Business Ltd (EB) has been developing technology for extracting energy from tidal streams.

On Friday September 13th 2002, Stingray was successfully deployed for the first time in Yell Sound. Very simple power cycles were completed in a range of tide speeds and significant power output was observed. Initial power cycles completed with 'manual' control of the hydroplane angle produced a peak hydraulic power of 250kW and a time averaged output of 90kW in a 1.5 m/s measured current.

EB will continue to develop its offshore power station concept with the aim of commencing installation of a grid connected 5 MW Stingray farm as early as summer 2004.

## **3.6 GEOTHERMAL ENERGY**

Geothermal energy is energy derived from the natural heat of the earth. The earth's temperature varies widely, and geothermal energy is usable for a wide range of temperatures from room temperature to well over 300° F.

There are two main applications of geothermal energy: The first is based on using heat from the earth to create electricity or to provide direct services, such as hot water heating or warming of greenhouses. The second application of geothermal energy is based on using the thermal mass of soil or ground water to drive a heat pump, which can be used for either heating or cooling applications. These are known as geothermal ground source heat pump applications.

In the UK the earth, a few metres below our feet, keeps a constant temperature of about 11-12C throughout the year. Ground source heat pumps (GSHP) can pump this heat from the ground into a building to provide **space heating and, in some cases, pre-heating domestic hot water**. A GSHP will usually only pre-heat domestic hot water so top up heating (e.g. an immersion heater) will be required. For every unit of electricity used to pump the heat, 3-4 units of heat are produced.

There are three elements to a GSHP:

- **Ground loop** - comprises lengths of plastic pipe buried in the ground. The pipe is a closed circuit and is filled with a mixture of water and antifreeze, which is pumped round the pipe absorbing heat from the ground.

Three options are available for the ground loop: borehole, straight horizontal and spiral horizontal (or 'slinky'). Horizontal trenches cost less than boreholes, but require greater land area. For slinky coil, a trench of about 10m length will provide for about 1kW of heating load.

- **Heat pump** - A heat pump works by using the evaporation and condensing of a refrigerant to move heat from one place to another. In this case, the evaporator takes heat from the water in the ground loop; the condenser gives up heat to a hot water tank which feeds the distribution system.

A compressor, which uses electricity, moves the refrigerant around the heat pump. It also compresses the gaseous refrigerant to increase the temperature at which it condenses, to that needed for the distribution circuit.

- **Heat distribution system** - consists of underfloor heating or radiators for space heating and water storage for hot water supply. Some systems can also be used for cooling in the summer.

A GSHP can be a cheaper form of space heating than oil, LPG and electric storage heaters.

The installed **cost** of a GSHP, for a professional installation, ranges from about £800-£1,200 per kW of peak heat output, excluding the cost of the distribution system. Trench systems tend to be at the lower end of this range.

The market for heat pumps is still in its infancy, but it's growing fast. Due to the one-off cost of a ground loop, the minimum price for a small system is about £4,000, while the cost of installing a typical 8kW pump is around £6,400-£9,600 plus the cost of the distribution system. As the technology matures and the

industry grows these prices are likely to drop. Payback periods may be quite long compared to mains gas, and still tend to be in excess of 10 years.

#### **Geothermal Energy Project - Vetleflaten Nursing Home, Voss**

The Vetleflaten Nursing home is heated by four heat pumps collecting thermal energy from 20 wells drilled in solid rock. The heat pumps cover 90% of the total energy demand for heating of the premises and 100% of the heating of tap water. Vetleflaten Nursing Home for elderly people has a total of 84 apartments, and covers 7,300 m<sup>2</sup>.

#### **Moor provides heat to nursing home**

When Våler municipality planned their new nursing home, a flexible heating system was requested. The nursing home is situated next to a moor, and the moor was regarded suitable as a low temperature heat source for a heat pump system. The nursing home was built with a propane heat pump as the main heating device, and with water-borne heat distribution. The building has a heated area of 2086 m<sup>2</sup>, consisting of 23 housing units.

### **3.7 BIOMASS**

There are many types of biomass, including:

- **Pulp and paper operation residues.** The by-products of forestry and processing operations.
- **Forest residues.** Wood from forest thinning operations that reduce forest fire risk.
- **Agricultural residues.** Crop residues such as corn stover (stalks) and processing residues such as nut hulls.
- **Urban wood waste.** Lawn and tree trimmings, wood pallets, construction and demolition wastes.
- **Animal waste.** Cattle, chicken and pig waste converted to gas or burned directly for heat and power.
- **Municipal Organic Waste.**
- **Landfill gas.** The natural by-product of bacterial digestion of organic garbage.
- **Energy crops.** Trees or herbaceous biomass grown specifically for energy.

This plant and animal matter can go through a number of types of energy conversion processes to yield power, heat, steam and fuel.

## Power

- **Co-firing.** Woody and herbaceous biomass such as poplar, willow and switchgrass can fuel a small portion of an existing coal power plant. This process, known as co-firing, entails biomass that represents between 1% and 15% of the energy of the coal plant, with the remainder consisting of coal.
- **Conventional steam boiler.** Burning biomass in a conventional power plant (that is, one with a conventional boiler to produce steam that runs through a turbine) built solely for the biomass is another option.
- **Biomass gasification.** Solid biomass can be converted into a gaseous form. The gas can then run through “combined-cycle” gas turbine or another power conversion technology such as a coal power plant. Many experts hope that gasification can yield more efficient biomass power plants. At this stage, gasification is still in the “demonstration” phase as projects slowly come online.
- **Anaerobic digestion.** Bacteria can decompose animal matter and landfill garbage in an airless environment to yield usable methane. The methane can then run through a number of power generation technologies such as gas turbines or even fuel cells.

## Heat and Steam

The same power plants that produce power also yield useful steam and heat in a process called combined heat-and-power (CHP). Taking advantage of these products can improve the efficiency of the operation by over 35%. Pulp and paper mills in the Southeast, Northeast and Great Lakes region of the U.S.A. already generate power, steam and heat from biomass. Finland hosts CHP operations that heat homes and businesses.

The cost of bioenergy is as varied as the technologies and forms of biomass under consideration. In short, since there are different combinations of biomass feedstocks and biomass conversion technologies, the range of cost estimates will equal the number of different feedstock-technology combinations.

Overall, biomass plants have higher capital costs and O&M costs than fossil fuel plants and, traditionally, their power output efficiencies are poor (an average of 20% nationwide), so fuel costs are higher than those for more efficient fossil fuel plants. Observers expect more efficient technologies such as gasifiers to have electrical output efficiencies of 25% to 35%:

- The cost of power from conventional biomass combustion can range from 4 pence to 8 pence per kilowatt-hour.
- Co-firing biomass with coal is much cheaper, since the power plant is already built and costs are limited to the biomass fuel and its preparation at the plant site. Costs can range from almost nothing to 3 pence per kilowatt-hour for a

project where biomass is 10% to 15% of the total fuel input of the power plant.

- The cost of power from landfill gas can range from 3 – 6 pence per kilowatt-hour, depending on the size of landfill, financing available, distance from the grid or local application, and other factors.

### **Supply infrastructure**

If bioenergy is to play a larger role, energy generators will require a steady supply of biomass. However, this is not a small task—essentially, a new industry must be formed to harvest, transport and prepare biomass into a useable form. If biomass power plant operators must supply steady power year-round, there must be enough biomass available throughout the year to fulfil their obligations.

However, suppliers of biomass do not sell just to the energy market. For example, wood chips can go into mulch or animal bedding. Other wood waste can be recycled into new products. Thus bioenergy operators must compete with other industries for biomass. This means that they must pay enough money consistently to secure the supplies they need.

### **Technology challenges**

There are still a number of challenges to mass commercialization of bioenergy. For example, co-firing can be difficult if the coal power plant has selective catalytic reduction (SCR) to comply with new, more stringent limits of nitrogen oxide emissions. The alkali content of biomass fuels may contaminate SCR technologies. Up to 70% of coal-fired power plants potentially capable of biomass co-firing are likely candidates for SCR retrofits.

### **Danish Hotel entirely fuelled by biomass**

At the Danish hotel Norrevang, situated in the town of Marienlyst, the heating supply system has been changed from electricity and oil, to biomass in the form of wood pellets. The new heating system consists of two wood-pellet-fired boilers with a total capacity of 580 kW.

### **National Waste Strategy (NMS)**

The Area Waste Plan for Highland Council area has identified organic waste streams as potential raw materials for composting in particular. However, there are opportunities for the use of these materials as fuel sources through Energy from Waste (EfW) plants. In this context EfW excludes incinerators which are deemed unacceptable by the UK public at large.

Alternative EfW plants are relatively novel in the UK and although deemed by the waste sector to be a proven technology the UK has not developed this area

yet. There are plants being built in England and sites have been identified in Scotland.

It is likely however, that economies of scale will be the determining factor in the locations of these plants and that large municipal plants will be required to make this option viable.

### 3.8 COMBINED HEAT AND POWER (CHP) OR CO-GENERATION

CHP or Co-generation is an energy conversion process, where electricity and useful heat are produced simultaneously in one process. CHP heat can be used either for district heating or for industrial processes. The CHP process may be based on the use of steam or gas turbines or combustion engines. The primary energy source can be based on a wide range of fuels, including biomass and fossil fuels, as well as geothermal or solar energy.

#### **CHP for district heating**

District heating means a system supplying heat produced centrally in one or several locations to a non-restricted number of customers. It is distributed on a commercial basis by means of a distribution network using hot water or steam as a medium. CHP power plants can be divided into five types:

#### ➤ **Backpressure power plant**

The simplest cogeneration power plant is the so-called backpressure power plant, where CHP electricity and heat is generated in a steam turbine. Another main component of the backpressure power plant is the steam boiler, which can be designed to fire solid, liquid or gaseous fuels.

#### ➤ **Extraction condensing power plant**

A condensing power plant is generating only electricity. However, in an extraction condensing power plant some part of the steam is extracted from the turbine to also generate heat.

#### ➤ **Gas turbine heat recovery boiler power plants**

In gas turbine heat recovery boiler power plants heat is generated with hot flue gases of the turbine. The fuel used in most cases is natural gas, oil, or a combination of these. Gas turbines can even be fired with gasified solid or liquid fuels.

#### ➤ **Combined cycle power plants**

Recently, natural gas fired combined cycle power plants consisting of one or more gas turbines, heat recovery boilers, and a steam turbine have become common.

➤ **Reciprocating engine power plant**

Instead of a gas turbine, a reciprocating engine, such as a diesel engine, can be combined with a heat recovery boiler, which in some applications supplies steam to a steam turbine to generate both electricity and heat.

CHP can provide a secure and highly efficient method of generating electricity and heat at the point of use. Due to the use of heat from electricity generation and the avoidance of transmission losses because electricity is generated on site, CHP typically achieves a 35 per cent reduction in primary energy usage compared with power stations and heat only boilers. This can allow the host organisation to make savings where there is a suitable balance between the heat and power loads.

### 3.9 HYDROGEN AND FUEL CELLS

Hydrogen is the most abundant element known to man, and the supply is virtually limitless. Hydrogen can be made from fresh or salt water by electrolysis, which splits the water molecule into hydrogen and oxygen.

Hydrogen's potential use in fuel and energy applications includes powering vehicles, running turbines or fuel cells to produce electricity, and generating heat and electricity for buildings. The current focus is on hydrogen's use in fuel cells. Fuel cells are basically electrochemical engines that produce electricity by harnessing the reaction of hydrogen and oxygen. The only by-products of the cell itself are clean water and useful heat.

Hydrogen is fed into a fuel cell, a battery-like device that generates DC current. It supplies electricity by combining hydrogen and oxygen electrochemically without combustion. Unlike a battery a fuel cell does not run down or require lengthy recharging. It will produce electricity and heat as long as hydrogen and oxygen are supplied. The oxygen is typically derived from ambient air, but the hydrogen comes from a reformer, which produces the gas by breaking down a fossil fuel. Reformers do release pollutants as they break down the hydrocarbons to release hydrogen.

The primary fuel cell technologies under development are:

➤ **Phosphoric Acid Fuel Cells**

A phosphoric acid fuel cell (PAFC) consists of an anode and a cathode made of a finely dispersed platinum catalyst on carbon paper, and a silicon carbide matrix that holds the phosphoric acid electrolyte. This is the most commercially developed type of fuel cell and is being used in hotels, hospitals,

and office buildings. The phosphoric acid fuel cell can also be used in large vehicles, such as buses.

➤ **Proton-Exchange Membrane Fuel Cells**

The proton-exchange membrane (PEM) fuel cell uses a fluorocarbon ion exchange with a polymeric membrane as the electrolyte. The PEM cell appears to be more adaptable to automobile use than the PAFC type of cell. These cells operate at relatively low temperatures and can vary their output to meet shifting power demands. These cells are the best candidates for light-duty vehicles, for buildings, and much smaller applications.

➤ **Solid Oxide Fuel Cells**

Solid oxide fuel cells (SOFC) currently under development use a thin layer of zirconium oxide as a solid ceramic electrolyte, and include a lanthanum manganate cathode and a nickel-zirconia anode. This is a promising option for high-powered applications, such as industrial uses or central electricity generating stations.

➤ **Direct-Methanol Fuel Cells**

A relatively new member of the fuel-cell family, the direct-methanol fuel cell (DMFC) is similar to the PEM cell in that it uses a polymer membrane as an electrolyte. However, a catalyst on the DMFC anode draws hydrogen from liquid methanol, eliminating the need for a fuel reformer.

➤ **Molten Carbonate Fuel Cells**

The molten carbonate fuel cell uses a molten carbonate salt as the electrolyte. It has the potential to be fuelled with coal-derived fuel gases or natural gas.

➤ **Alkaline Fuel Cells**

The alkaline fuel cell uses an alkaline electrolyte such as potassium hydroxide. Originally used by NASA on space missions, it is now finding applications in hydrogen-powered vehicles.

➤ **Regenerative or reversible Fuel Cells**

This special class of fuel cells produces electricity from hydrogen and oxygen, but can be reversed and powered with electricity to produce hydrogen and oxygen.

### 3.10 ASSESSMENT FRAMEWORK

In this section we undertake an assessment of the various technologies and their applicability and potential in the context of the characteristics and circumstances prevailing at Durness. This is undertaken in **Table 3.3** where the potential of Durness is compared against published technology characteristics.

<b>TABLE 3.3: COMPARISON OF POTENTIAL AT DURNESS AGAINST PUBLISHED TECHNOLOGY CHARACTERISTICS</b>				
<b>Technology</b>	<b>Key resource/siting requirements</b>	<b>Pros</b>	<b>Cons</b>	<b>Potential at Durness</b>
<b>Wind</b>  <i>Electricity for lighting, appliances and grid connection</i>	-Good site, consistent wind speeds averaging at least 4-5m/s for small wind systems	-No fuel costs -No polluting emissions -Maintenance costs low -Good UK wind resource, very good generation potential -Proven technology -Storage potential through battery banks -Connecting to grid allows balancing out peaks and troughs of supply -Some DIY potential	-Site constraints -Good sites often very visible -Planning permission can be difficult -Intermittent supply -Minimal industry standards for small scale applications -High capital costs -Stand alone systems require batteries – higher maintenance -Grid connection can be complex	-Geography and wind is very good -Interest already indicated in the general area -Community must ensure they negotiate community benefit -Landowner and rental income 2%-4.5% -Provides access to national grid -Scale vs. visitor/tourism impact -Objections of MOD -Potential for smaller and micro schemes – 70w
<b>Solar PV</b>  <i>Electricity for lighting, appliances and grid connection</i>	-Good site, facing SW-SE, 20 <sup>o</sup> -50 <sup>o</sup> degree tilt, unshaded -Optimised load or grid connection above 1kW -For domestic grid connection need approximately 8m <sup>2</sup> of roof area or more	-No fuel costs -No polluting emissions -Maintenance costs low -Proven technology -Minimal local environmental impact -Straightforward planning -Storage potential through battery banks -Grid potential for incorporating high levels of intermittent supply -Good industry standards	-Site constraints -High but falling capital costs -Intermittent supply -Stand alone systems require batteries – higher maintenance	-Constraints on sunlight hours in winter and angle of sun. -In summer long days but low sun -Potential for shadowing from higher ground to south -Technology is not sufficiently efficient -Expensive option with present technology in northern latitudes

Technology	Key resource/siting requirements	Pros	Cons	Potential at Durness
<b>Solar hot water</b>  <i>Domestic hot water supply and swimming pool heating</i>	-As for solar PV. Good site, unshaded with good orientation and tilt, optimised load -Need space for storage tank -Difficult to use in conjunction with combi boilers	-Low fuel costs -No polluting emissions -Maintenance costs very low -Proven technology -Minimal local environmental impact -Straightforward planning -Good DIY potential -Straightforward integration into existing hot water systems -Extensive indigenous industry for manufacture, supply and installation -Good industry standards	-High capital costs -Site constraints -Environmental and cost impact of electricity consumption for pumps an important consideration	As with PV
<b>Hydro</b>  <i>Electricity for lighting, appliances and grid connection</i>	-Good site with nearby water course and appropriate balance of head/ flow rate with minimal seasonal variations -For low head, head should be > 1.5m and need existing weir structure -For medium/high head, steep gradient to reduce pipe costs (e.g. > 1:25) -Optimised load or grid connection above 10/15kW	-Reliable and constant energy supply -No fuel costs -No polluting emissions -Good hydro resource at specific sites, very good generation potential -Proven technology -Some DIY potential -Long lifetime for plant	-High capital costs -Site constraints -Local environmental impacts need to be addressed -Planning permission required -Significant maintenance required -Grid connection -Licenses required from Environment Agency	-Issue over sufficient gradient/head of water -Involvement of power company preferable and they may well have their own targeted site for future development -Consider lessons from Assynt

Technology	Key resource/siting requirements	Pros	Cons	Potential at Durness
<b>Ground Source Heat Pumps</b>  <i>Space and water heating</i>	-Requires external land area for ground loops, particularly for horizontal pipework -Replacing electrical space heating is more economic -Best performance with underfloor heating	-Reliable and constant energy supply -Competitive running costs compared to electricity, marginal compared to gas -Good industry standards -Low maintenance -Little or no planning requirements	-High capital costs -Limited UK industry, both manufacturers and installers. Long travel distances for installation can make it uneconomic	-Should be considered for individual/clusters of properties or community buildings -Role as 'experimental' technology in Durness context
<b>Domestic wood stoves and boilers</b>  <i>Space and water heating</i>	-Consistent and economic supply of wood fuel, not in a controlled zone, with space for storage	-Reliable and constant energy supply -Potentially free fuel or competitive fuel prices compared to conventional supply -Competitive capital costs as compared to conventional supply -Almost carbon neutral, low NOx and SOx emissions -Extensive indigenous industry for manufacture, supply and installation	-Storage space required -Some polluting emissions -Fuel supply restrictions -Supply of pellets infrastructure still not well established in UK -Relies on a constant solid fuel supply	-Potential developments in relation to potential Caithness/Wick CHP and wood burning facilities -Forestry Enterprise interest in wood chippings -Issue of fuel supply



Technology	Key resource/siting requirements	Pros	Cons	Potential at Durness
<p><b>Larger scale biomass combustion</b></p> <p><i>Electricity for grid connection and heat for district heating/industrial demands</i></p>	<ul style="list-style-type: none"> <li>-Proximity to fuel supply at reasonable cost</li> <li>-Accessibility to transport links for fuel delivery</li> <li>-Access to grid connection</li> <li>-Opportunity to supply power or heat locally</li> </ul>	<ul style="list-style-type: none"> <li>-Reliable and constant energy supply</li> <li>-Potentially competitive fuel supply prices compared to conventional supply</li> <li>-Almost carbon neutral, low NOx and SOx emissions</li> <li>-Significant local benefits in developing local supply chains</li> <li>-Grants available for installation and crop establishment</li> </ul>	<ul style="list-style-type: none"> <li>-Storage space required</li> <li>-Need to have good access to burner plant for automatic fuel handling</li> <li>-Siting constraints</li> <li>-High capital costs</li> <li>-Some polluting emissions</li> <li>-Local environmental impacts need to be addressed</li> <li>-Planning permissions can be difficult</li> </ul>	<ul style="list-style-type: none"> <li>-Municipal waste arisings from LA area</li> <li>-Tie in with National Waste Strategy</li> <li>-Economies of Scale</li> <li>-£230m strategic waste fund bids via Area Waste Group (SEPA) via LA</li> <li>-Possible support from LA &amp; National Waste Strategy</li> </ul>
<p><b>Anaerobic digestion</b></p> <p><i>Electricity for grid connection and heat for district heating/industrial demands</i></p>	<ul style="list-style-type: none"> <li>-Proximity to good quality fuel source at reasonable costs and with consistent supply</li> <li>-Accessibility to transport links for fuel delivery</li> <li>-Access to grid connection</li> <li>-The opportunity to supply power or heat locally</li> </ul>	<ul style="list-style-type: none"> <li>-Reliable and constant energy supply</li> <li>-Marginal fuel supply prices compared to conventional supply</li> <li>-Almost carbon neutral, low NOx and SOx emissions</li> <li>-Significant local benefits in developing local supply chains</li> <li>-Waste management</li> <li>-Reduces methane gas emissions</li> </ul>	<ul style="list-style-type: none"> <li>-Storage space required</li> <li>-Siting constraints</li> <li>-High capital costs</li> <li>-Some polluting emissions</li> <li>-Local environmental impacts need to be addressed</li> <li>-Planning permission can be difficult</li> <li>-Not suited to domestic scale – except for district heating</li> </ul>	<ul style="list-style-type: none"> <li>-Trial facility option</li> <li>-Agricultural crofting wastes</li> <li>-Economies of scale.</li> <li>-Sutherland wide issue</li> <li>-Collection methodology</li> <li>-Link with LA</li> <li>-NWS funding potential via LA</li> </ul>

Table 3.4 provides indicative costs per kw for the range of renewable energy options.

The provider of these costings has stated that the costings that the consultants have reported in Table 3.4 are very approximate and these figures should be treated with great caution and used on an indicative basis only. Renewable energy projects are highly site specific and costs need to be worked out taking into account the local situation.

TABLE 3.4: INSTALLED COSTS PER kW					
	Up to 1kW	5kW	60kW	600kW	2MW
Wind	£7,200	£3,000	£1,500	£650	£700
Solar PV	£10,000	£6,000	£5,000 <sup>1</sup>	n/a	n/a
Solar Water Heating	£6,000-£8,200 <sup>2</sup>	n/a	n/a	n/a	n/a
Micro Hydro	£10-15,000	£3,000	£1,000	n/a	n/a
Ground Source Heat Pump	n/a	V <sup>3</sup> £1,700 H <sup>3</sup> £1,400	£1,500 £1,200	£1,200 (200kW) n/a	n/a n/a
Domestic Wood Stoves and Boilers	n/a	£500-600	£300-400	n/a	n/a
Larger Scale Biomass Combustion	n/a	n/a	n/a	n/a	Boiler £1,200 Gasifier £1,500
Anaerobic Digestion	n/a	£7,000			£3,000

**Note 1:** For 20kW modules. Larger schemes are too site specific to provide figures.

**Note 2:** Commercial flat plate £6,000 (typical 0.4kW, 4m<sup>2</sup>, £2,400). Evacuated tube £8,200 (typical 0.45kW, 3m<sup>2</sup>, £3,700).

**Note 3:** V = vertical, H= horizontal.

Finally, the technologies are assessed in terms of the extent to which they could potentially address DDG objectives/criteria regarding renewable energy.

**Creation of jobs**

- Biomass
- CHP

**Income**

- Wind
- Hydro
- Wave/Tidal

**Attract visitors/tourists**

- Wave/Tidal

**More energy being produced locally for local consumption**

- Wind (small)
- Geothermal
- Biomass
- CHP

**Develop reputation of Durness as a 'green' community in the same way Unst is promoting itself as 'Green Island'**

- Geothermal
- Biomass
- CHP
- Wave/Tidal

### **3.11 RECOMMENDED SHORTLIST**

Based on the relative performance of the different technologies in the context of Durness and the views expressed by DDG and the community at a public meeting, the following technologies were shortlisted for further consideration by the community:

- Wind power;
- Wave power;
- Biomass.

This does not preclude the further exploration and introduction of any of the other technologies if and when opportunities arise.

## REFERENCES AND SOURCES

1. The Alternative Energy Institute, USA [www.altenergy.org](http://www.altenergy.org)
2. Alternative Energy Project (Transnational Education Project under Socrates  
[www.energy-project.net](http://www.energy-project.net))
3. British Photovoltaic Association [www.pv-uk.org.uk](http://www.pv-uk.org.uk)
4. Centre for Alternative Technology [www.cat.org.uk](http://www.cat.org.uk)
5. Centre for the Analysis & Dissemination Of Demonstrated Energy Technologies  
[www.caddet-re.org](http://www.caddet-re.org)
6. Centre for Renewable Energy & Sustainable Technology, USA  
[www.solstice.crest.org](http://www.solstice.crest.org)
7. Combined Heat and Power Association [www.chpa.co.uk](http://www.chpa.co.uk)
8. Department of Trade and Industry [www.dti.gov.uk](http://www.dti.gov.uk)
9. Energy Efficiency [www.saveenergy.co.uk](http://www.saveenergy.co.uk)
10. The Energy & Resource Institute [www.teriin.org](http://www.teriin.org)
11. Energy Saving Trust [www.est.co.uk](http://www.est.co.uk)
12. The Engineering Business Ltd [www.engb.com](http://www.engb.com)
13. Euroheat and Power (CHP) [www.chp-info.org](http://www.chp-info.org)
14. European Union [www.europa.eu.int](http://www.europa.eu.int)
15. Fuel Cells UK [www.fuelcellsuk.org](http://www.fuelcellsuk.org)
16. The Global Environment Facility [www.gefweb.org](http://www.gefweb.org)
17. Greater London Authority [www.london.gov.uk](http://www.london.gov.uk)
18. Highland Light and Power Ltd [www.highlandlightandpower.co.uk](http://www.highlandlightandpower.co.uk)
19. Ocean Power Delivery Ltd [www.oceanpd.com](http://www.oceanpd.com)
20. Shetland Renewable Energy Forum [www.sref.co.uk](http://www.sref.co.uk)
21. UK Participation in the International Agency's Photovoltaic Power Systems Programme  
[www.iea-pvpsuk.org.uk](http://www.iea-pvpsuk.org.uk)
22. US Department of Energy [www.doe.gov](http://www.doe.gov)
23. US Department of Energy - Energy Efficiency & Renewable Energy  
[www.eere.energy.gov](http://www.eere.energy.gov)

## Assessment of Shortlisted Technologies

### 4.1 INTRODUCTION

This Chapter considers the way forward and next steps for the community to explore the shortlisted technologies. These are discussed in turn.

### 4.2 WIND POWER

Given the local topography and wind characteristics, the North Coast is particularly suitable as a location for windfarms. The key issues relate to:

- Connection to grid;
- Transport of turbines and towers to the site; and
- Planning and community objectives.

Wind farms are the most commercially likely options available to Durness and this is borne out by the recent enquiries and interest by AMEC in installing around 30 turbines on Durness Estate land, as well as at Keodale.

The advantages of such a project is that not only will it generate an income for DDG through whatever agreement for community benefit is reached with AMEC, or indeed other operators who may be interested, but it will also require the installation of suitably rated power cables to connect into the grid. This opens up the possibility of the community being able to export electricity to the grid from any other renewable energy projects they may wish to consider in the future.

The key issues for the community relates to:

- Whether they are supportive of the scheme;
- How the scheme could impact on the natural environment;
- Whether the scheme would adversely affect the tourist industry;
- How the community want to control and adapt the scheme to ensure it fits with the community and not vice versa; and
- General strategies to minimise the negative impacts and maximise the benefits.

Such a scheme could require anywhere up to 50 or 60 people working on the site at the peak periods during construction. This may create some local employment opportunities e.g. road building, civil engineering etc. Depending on the number of workers brought in from outside the Durness area, the project will create

opportunities for providing accommodation for these workers. However, the period when accommodation is required may conflict with the demands of tourists.

### **4.3 WAVE POWER**

The coast around Durness appears to be a suitable environment for wave and tidal power schemes. Compared to wind power, tidal/wave power would be more speculative and will probably depend on the availability of government funding to support the project.

However, one of the factors that makes a wave/tidal scheme more attractive now is the potential availability of a suitable power connection to the grid if the wind farm project proceeds.

Such a scheme could provide some employment opportunities during the construction phase, and perhaps in the longer term during the operational phase. Generation of power through wave energy could also be an attractor for tourists and other interested visitors as these facilities are not generally easily accessible to the public.

### **4.4 BIOMASS**

The third option relates to some form of biomass or anaerobic digestion scheme that would provide electricity and heat for the local community as well as exporting electricity to the grid depending on the scale of the project.

This project would depend on access to suitable local 'fuels' including agricultural crofting and municipal wastes.

This type of project, where heat is an important output of the process, will be particularly suitable to community projects like the village hall, sheltered housing/care home, new housing developments etc where the infrastructure can be put in place at the time of construction and feed into a group of buildings.

Finally, a biomass type project could possibly access funding support via Local Authority and National Waste Strategy.

## Conclusions

### 5.1 INTRODUCTION

This Chapter reports the main conclusions of the study.

### 5.2 CONCLUSIONS

The main conclusions of the study are:

- Over the next 15 to 20 years renewable energy sources will become increasingly important for the generation of power within the UK. Given the availability of the right conditions, much of the pressure for development of renewable energy is going to fall within Scotland, in particular the Highlands and Islands.
- Scotland is going to be the focus for much activity by the main generating companies in terms of building up alternative energy generating capacity. In addition, finding alternative uses for waste are central to the development and implementation of the National Waste Strategies.
- Many projects do not get through the planning stage and it is estimated that in Scotland about 10% of renewable energy planning applications are refused compared with around 50% in England.
- In the case of the Durness area, any renewables projects are going to need to be especially sensitive to issues of visual intrusion. The area is largely dependent on the tourism/visitor market and the community needs to be sensitive to the potential negative impacts of a number of the renewable energy options. The potential negative impacts on the visitor market needs to be balanced against potential community benefits and employment opportunities.
- Overall, the community need to consider whether they are supportive of wind farms, or perhaps more importantly how they would like windfarms to be developed and controlled.
- Renewables projects face a number of risks to their commercial viability that need to be considered by potential investors in any projects in the Durness area.
- The relevance of renewable energy resources to a community like Durness is increasing both with the availability of grants and funding to undertake such activities and in greater accessibility to small scale energy systems. The

community recognise that there is an opportunity to benefit economically and socially from exploiting renewable energy within the area.

- To exploit the renewables resources effectively the Durness community has a number of choices to make in terms of achieving their optimum balance between maximising income and employment through the export of electricity to the grid or maximising the production of local power for the local community. These choices are not mutually exclusive.
- The **community objectives** in relation to renewable energy options include:
  - Creation of jobs;
  - Income;
  - Attract visitors/tourists;
  - More energy being produced locally for local consumption; and
  - Develop reputation of Durness as a 'green' community in the same way Unst is promoting itself as 'Green Island'.
- The following technologies were reviewed:
  - Wind;
  - Solar;
  - Hydro;
  - Tidal and ocean Thermal;
  - Geothermal;
  - Biomass;
  - CHP; and
  - Hydrogen and Fuel Cells.
- The technologies that best meet individual community objectives are:
  - **Creation of jobs**
    - Biomass
    - CHP
  - **Income**
    - Wind
    - Hydro
    - Wave/Tidal
  - **Attract visitors/tourists**
    - Wave/Tidal
  - **More energy being produced locally for local consumption**
    - Wind (small)
    - Geothermal
    - Biomass
    - CHP

- **Develop reputation of Durness as a ‘green’ community in the same way Unst is promoting itself as ‘Green Island’**
  - Geothermal
  - Biomass
  - CHP
  - Wave/Tidal
  
- Based on the relative performance of the different technologies in the context of Durness and the views expressed by DDG and the community at a public meeting, the following technologies were shortlisted for further consideration by the community:
  - Wind power;
  - Wave power;
  - Biomass.
  
- Wind farms are the most commercially likely options available to Durness and this is borne out by the recent enquiries and interest by AMEC in installing around 30 turbines on Durness Estate land, as well as at Keodale.
  
- The advantages of such a project is that not only will it generate an income for DDG but opens up the possibility of the community being able to export electricity to the grid from any other renewable energy projects they may wish to consider in the future.
  
- The coast around Durness appears to be a suitable environment for wave and tidal power schemes. Compared to wind power, tidal/wave power would be more speculative and will probably depend on the availability of government funding to support the project.
  
- The third option relates to some form of biomass or anaerobic digestion scheme that would provide electricity and heat for the local community as well as exporting electricity to the grid depending on the scale of the project. This project would depend on access to suitable local ‘fuels’ including agricultural crofting and municipal wastes.