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Executive summary

This report sets out and summarises work undertaken by AEA Energy & Environment as a contribution to the development of an Energy Policy for the States of Jersey.

Our work has addressed two out of five specific Tasks originally defined by the States of Jersey within a comprehensive brief drawn up by the Environment Department. For this reason the report is not intended to provide an overall summary and picture of energy questions across the island, but rather provides data and conclusions relevant to the two Tasks that we were assigned, these being;

- ***Task 1: Exploiting and marketing the natural resources of the Channel Islands (wind and marine energy)***
- ***Task 2: Biofuels and biogas production***

For both of these Tasks we have undertaken a scoping study to identify possible resources, and the opportunities and barriers to using that resource. Our report essentially summarises our findings by technology and/or resource type, for:

- Wind Energy
- Marine Power
- Biofuels
- Biogas

Our key conclusions are as follows:

- On Jersey there is an excellent *onshore wind* resource which could be harnessed to generate significant quantities of renewable electricity. However, as with all wind developments there are also many issues that need to be resolved. If these can be overcome then there is the potential for a small number of utility scale turbines. The next step would be to engage the most relevant stakeholders starting with:
  - Jersey Airport, where a radar study needs to be commissioned
  - Radio communication operators (mobile phones, fixed links etc)
  - States of Jersey Environment and Planning Department (conservation, heritage, other planning constraints).

- *Offshore wind farms* are more difficult to develop than onshore with many more interested stakeholders. Owing to the increased development, construction and operational costs, offshore wind farms tend to be very large in terms of installed capacity to help reduce the overall cost through economies of scale. In light of this, and given the relatively low power demand of the island, offshore wind farms may be unsuitable for Jersey. However co-developing with the other Channel Islands and/or France may make offshore wind farms a more realistic proposition.

- *Wave and tidal technologies* are still in their infancy, which is a relevant factor when considering the scope for projects. There is a good *tidal energy resource* in Jersey, but some other areas of the Channel Islands and the UK have a better resource. Currently the Jersey tidal resource would be marginal for development. In the longer term, when the technology is established and farms in the faster tidal current areas have been installed, developers may turn to areas of Jersey for tidal stream exploitation. The *wave energy resource* is more limited in Jersey mainly due to sheltering effects of France. For all of these marine technologies, proximity to robust grid infrastructure as well as environmental issues relevant to marine energy deployment would need to be considered.

- There are a number of potential sites for the development of *wind and marine* power that appear unlikely to be approved for this purpose due to their sensitive nature and designation as Ramsar sites, Sites of Special Interest or other sites in planning zones with development restrictions. Investigations into the feasibility and possible location of wind and marine *energy* generating capacity would benefit from *high-level strategic environmental assessment (SEA).* SEA can make valuable contributions to:

- ♦ Early identification of areas with presumptions for/against development;
- ♦ Identification of environmentally preferred option(s);
- ♦ Production of development guidelines for project design, siting construction and operational management practices in relation to a preferred option and/or specific areas, thus assisting the development process for both industry and government;
- ♦ Providing information that can be used in subsequent project-level EIAs, which are also helped by the earlier identification of environmentally preferred options;
- ♦ Assessment of cumulative impacts of possible individual projects or actions.

- Deployment of renewable energy generation on Jersey at a low level of penetration (energy share) will have a smaller effect on electricity supply and generate less of an intermittency impact, and in this regard will therefore be more manageable than large scale deployment of renewable energy. There are factors suggesting that a low level of renewable energy is more likely, including:
    - ♦ *Jersey and Guernsey pay relatively little for their electricity.* It is not foreseeable that unsubsidised indigenous generation of any sort (renewable or non renewable) will be cheaper than French grid electricity.
    - ♦ It is envisaged by JEC that *within two years the terms of the interconnector contract will include penalties for not using agreed levels of electricity.* In addition, an indirect form of this penalty already exists: Jersey pays a fixed element in the interconnector usage charges, meaning that these costs are spread more efficiently if more electricity is imported.
    - ♦ *A substantial amount of renewable generation probably requires a large offshore wind project, of around 20 large wind turbines* (or more).

- There are a variety of renewable energy support mechanisms available. In the Jersey context, where there is potential for relatively few renewable energy projects and few players, any such mechanisms would need to be adapted and simplified. The *feed-in tariff* or the *tendering process* – or a combination of both – would probably the easiest to implement.

- Much of the agricultural land on Jersey, apart from that growing grass and forage crops, is planted with high value crops of potatoes, fruit or vegetables all returning gross margins (GM) approximately 10 times larger than the potential returns of crops grown for *biofuels.* Given this large disparity, we do not consider replacing these valuable crops with biofuel crops to be a viable option.

- There are a number of possible scenarios for producing biodiesel and bioethanol in Jersey, by growing oilseed rape, wheat and barley. Waste cooking oil and waste potatoes are also potential biofuel feedstocks.

- The scenarios we investigated could produce a maximum 5% share of biodiesel and an 8% share of bioethanol, by weight.

- There is a potential market for *biofuels* on the island. In particular, biofuel blends of up to 5% can be used in conventional vehicles, provided that they meet appropriate quality standards.

- *On-farm anaerobic digestion (AD)* is the simplest approach to this technology. It involves small-scale digestion, on-farm use of heat and power and export of any unwanted power to the grid. Our analysis indicates that avoided costs of heat and power for the farm, and income from surplus sales of electricity, are not sufficient to cover capital and operating costs and therefore such schemes would not be economic.

- We also considered the feasibility of a *centralised AD* plant co-digesting cattle and poultry slurry, waste potatoes, other vegetable packing waste and dairy wastes. Our analysis indicated that the plant would not economically viable for energy production alone under prevailing commercial conditions. A Government grant of just over £1.5 million would be needed to generate an Internal Rate of Return of 15%, assuming that all the electricity and/or heat could be sold at retail prices.

- *Anaerobic digestion schemes* can perform a number of *other important environmental functions* that may be relevant to the Jersey context.

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Appendices

1 Introduction

The States of Jersey has outlined a number of areas where it requires the provision of assistance in the development of an Energy Policy. In particular the States of Jersey has sought assistance with the development of optimal policies that:

- lead to the energy policy contributing to enhancing environmental policy;
- will meet the objectives of the energy policy in ways that minimise the total economic costs of achieving those objectives;
- ensure that the main export industries in the economy remain internationally competitive;
- ensure that the distribution of the costs and benefits of any energy policy are equitable.

The Environment Division is currently developing Policy with assistance from the political arena, stakeholders and representatives from industry. The box below shows the current perspective on Energy Policy development.

BOX 1 – States of Jersey approach to Energy Policy

Policy Goal: To develop a framework for the delivery of **secure, affordable and sustainable** energy for the Island into the long-term.

Policy Rationale: Jersey's reliance on imported energy means we are particularly vulnerable to the trend of increasing global energy prices. This highlights the need for a comprehensive energy policy that provides a long-term framework for the secure and equitable distribution, and efficient use of a resource, which has been generated sustainably and to the highest environmental standards.

Perspectives: The need for an Energy Policy is driven from five different perspectives:

Economic efficiency
Social equity
Security of supply
International reputation
Environmental

Timeframe for the policy: A 25 year vision with policies being implemented or evolving throughout the time period as appropriate

Workflows: A green paper is being developed in house with the consultation of the Energy Policy Steering Group which comprises the Minister for Economic Development, The Minister for Planning and Environment and The Minister for Health and Social Services. In addition, policy development has been informed by a Stakeholder Steering Group comprising of industry representatives, States of Jersey Officers and representatives from the NGO sector. The green paper is due to go out to the Environment Scrutiny Panel and also for public consultation in the first quarter of 2007.

This report outlines AEA Energy & Environment's contributions to the development of an Energy Policy for Jersey in the two key areas that we have been asked to explore. These are;

- ***Task 1: Exploiting and marketing the natural resources of the Channel Islands (wind and marine energy)***
- ***Task 2: Biofuels and biogas production***

The report sets out our findings and recommendations in these key areas. In undertaking these analyses we have sought to answer the following key sub-Task descriptions as set out within the original project brief.

<u>Task 1</u>

1.1 Examine the options for Jersey or Guernsey to exploit their indigenous energy resources at the large scale e.g. tidal stream, tidal barrier, wind to meet on-island needs and/or for sale to larger grid systems e.g. Continental / Inter-Island.

1.2 Address issues of intermittency and how the Islands would cope with these and how they might impact on existing electricity contracts in terms of demand profiles etc

1.3 Consider the opportunities and barriers to potential schemes e.g. legislative, economic, environmental impact and technological.

1.4 Recommend possible mechanisms to encourage potential schemes and indicate levels of capital investment and levels of risk as well as indicating alternative funding options such as public-private partnerships.

1.5 Examine whether the Channel Islands have a funding route into the exploitation of its indigenous energy sources through investment via the Joint Implementation arrangement under the Kyoto Protocol or other external funding mechanisms.

<u>Task 2</u>

2.1 Investigate options for the production of energy crops on-Island taking into account their agricultural husbandry requirements and the environmental and economic impact of these in comparison to existing agricultural use that they might displace.

2.2 Examine potential yields of energy crops and the land area required for their production. Examine the level (if any) of Government support necessary to assist the uptake of energy crops if this becomes a political priority.

2.3 Examine potential markets for biofuel / biofuel blends with respect to successful schemes elsewhere – for example a national bus fleet run on biodiesel / bio-diesel blends

2.4 Investigate the effects of the displacement of traditional fuels with greater use of biofuels e.g. the impact on the revenue stream currently collected from fuel duty. In addition investigate how fuel duty might be applied to biofuels.

2.5 Inform on the feasibility of importing biofuels such as bio-diesel and alcohol/ petrol blends to comply with UK referenced targets for biodiesel / alcohols in petrol.

2.6 Investigate options for the production of biogas production from Anaerobic Digestion Plants that utilise slurry, farm waste, sewage sludge etc.

2.7 Estimate potential annual yields of biogas given existing feedstock and suggest viable end uses of product with respect to successful schemes elsewhere – for example a national bus fleet run on biogas.

2.8 Estimate the capital expenditure on infrastructure necessary to produce biogas locally and indicate possible funding mechanisms with reference to successful schemes elsewhere – e.g. public-private funding initiatives, government subsidy

2 Wind resources

This section addresses the following sub-tasks relevant to wind energy:

Examine the options for Jersey to exploit its indigenous energy resources at the large scale e.g. tidal stream, tidal barrier, wind to meet on-island needs and/or for sale to larger grid systems e.g. Continental / Inter-Island;
Consider the opportunities and barriers to potential schemes e.g. legislative, economic, environmental impact and technological.

2.1.1 Wind turbines

Wind turbines produce electricity by capturing the natural power of the wind to drive a generator. There are many sizes of turbine ranging from micro turbines for battery charging to large utility scale machines up 120m tall (to the tip), and more. Turbine sizes have increased dramatically since modern wind turbines were first developed in the early 1980's and today, around the world, most machines being installed onshore are of 1-2MW capacity with 2MW turbines most common. These typically have a hub height of 60 to 80m and rotor diameters of 80m. The technology itself has matured greatly over the last 15 years with modern turbines having a design life of 20-25 years, with a 5MW design being tested and certified currently.

The worldwide trend is for larger and larger turbines although many of these are aimed at the offshore market. Onshore large scale turbines range from 600kW to 3MW with the turbine choice being a balance of wind regime, environmental impact and economics. At good onshore sites wind turbines commonly achieve capacity factors of 30% or more and windier areas of the UK achieve greater energy yields. In general, in the UK capacity factors vary from 20 to 40% with the record being 57.9% on Shetland.

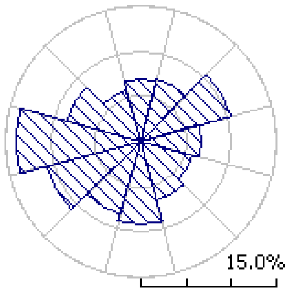
Onshore wind power is the most established of the current renewable energy technologies and is regarded by many as the cheapest large scale renewable energy technology to install. Typical installation costs onshore range from £750 to £1000 per kW depending on the number of turbines in the farm, their rating, the grid connection costs and the difficulty of construction. There are approximately 1733 turbines operating in 136 wind farms in the UK with around 60,000 operational turbines worldwide. The wind industry is expanding rapidly because wind power is one of the cheapest large scale renewable energy technologies available. There are currently no large wind turbines operating on Jersey or in the Channel Islands.

2.1.2 Onshore wind resource in Jersey

In order to assess the potential wind resource on Jersey we analysed the existing meteorological and topographic data.

Data has been obtained from the States of Jersey Meteorological Department for the met mast at Jersey Airport. The airport is on a plateau near to the west coast and is well exposed to the prevailing wind direction. The measurement height is 24m although due to sheltering effects of buildings and other obstacles this is more representative of the 10-12m wind speed. The wind rose below shows the long term wind distribution at the airport, which is considered to be typical of the island as a whole.

Figure 1: Wind rose for wind distribution at Jersey Airport

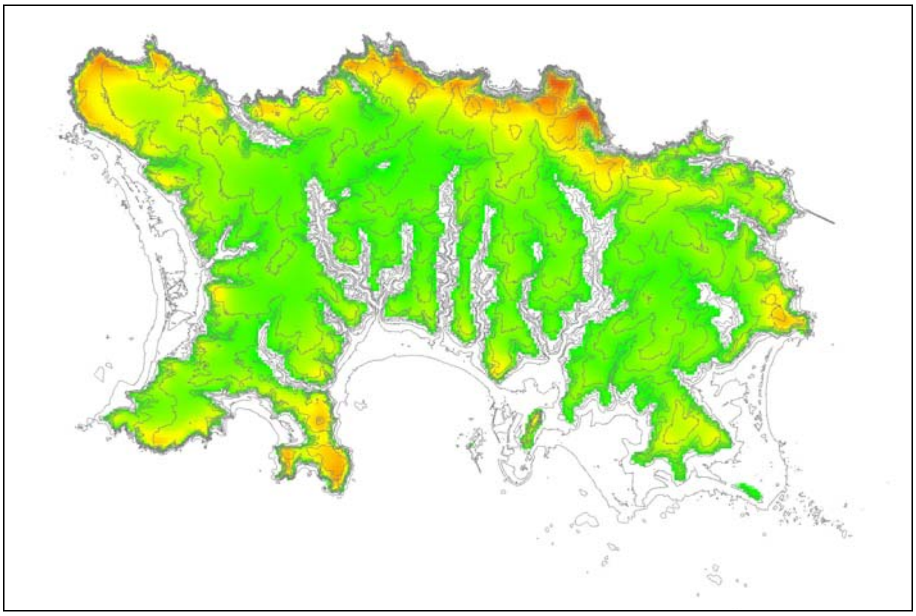


The prevailing wind direction is westerly which is the most exposed coast and corresponds to prevailing wind direction in the UK. The long term average mean wind speed is 11.3 knots which is 5.8m/s at ~10-12m above ground level (agl). Typically most modern turbines have a hub height of 60m and the airport wind speed of 5.8m/s shears up to 7.5m/s at this height[1]. This is considered an economically attractive wind speed in most countries, although this does depend on the fiscal support mechanisms in place. In the UK the development threshold is generally 7m/s at hub height.

To better understand the distribution of the wind across the island, we have produced a wind map. Using the data from Jersey airport, which has a long term record between 1989 and 2006, and a 10m contour map of the island, the wind resource has been modelled. Using the digital elevation model and wind modelling software[2] the average mean wind speed has been mapped. In the absence of surface roughness data, for example buildings, trees the variation in wind speed across the island closely matches the topography.

The highest areas of the island to the north and the raised coastal areas have the best resource. Figure 2 shows areas with sufficient resource in green, yellow and red with resource level increasing in that order. Areas under 7m/s at 45m agl have been shown in white as this is below the optimum hub height wind speed of most modern turbines.

Figure 2: Average mean wind speeds on Jersey, with white areas below the 7m/s threshold and increasing wind speed from green to red



[1] Assuming an average surface roughness of 0.03, which is typical of open countryside
[2] Wind Analysis Software Package (WAsP)

If the placement of wind turbines was only dependent upon the wind resource then best area for a small wind farm would be the northwest peninsula, which is well exposed to the prevailing winds and relatively flat. Other goods areas are the north coast and southwest peninsulas.

Separation distances between turbines vary depending on the size of the turbine however, typically 3 to 5 rotor diameters is required to reduce energy and turbulence losses for turbines in the wake of an upwind turbine. So in the case of the large 2MW turbines the ideal separation distances would be 400m.

Overall, the island has an excellent wind resource and therefore the energy extracted by the wind farm would be high. Most locations, those shown in green, yellow or red on the map, would be sufficiently windy to facilitate development under the right funding regime and would be considered good sites in the UK.

To give an indication of what might be possible in Jersey in terms of large scale wind power generation and a comparison with current electricity consumption, we looked at the possible deployment of wind turbines in the windiest parts of the island as indicated in Figure 2, being the strip of land along the north coast marked in red and yellow.

Avoiding the main settlements in this northern area, being St John's Village to Le Mont Mado and Les Croix, and using a separation distance of 400 metres between turbines, allows for at least ten 2MW wind turbines to be deployed in the area. However it must be emphasised that this does not take into account planning considerations (including environmentally sensitive areas), separation distances from other dwellings that are scattered throughout the area, or potential radar interference and grid connection issues. Thus this scenario is purely for illustrative purposes and no suggestion is made about the likelihood of it proceeding.

Assuming an average capacity factor of 35%, which is considered achievable on Jersey given the good wind resource, a 20MW wind farm would generate a total of 61.32 GWh p.a. This represents around 10% of the total Jersey consumption (603 GWh in 2005). At peak output (20MW) such a wind farm would generate around two-thirds of Jersey's minimum summer demand (32MW) and 14% of peak winter demand (140MW).

2.1.3 Practical issues

Wind resource is one of the limiting factors in siting wind farms. However, there are numerous other constraining factors which also need consideration, namely:

- Aviation impacts (including radar)
- Environmental impacts
  - Visual impacts
  - Noise emissions from turbines
  - Nature conservation issues
  - Heritage impacts
- Planning restrictions, as covered in section 4.1.

It was beyond the scope and timescale of this work to analyse all these issues in detail. However, background information is provided below. In all cases further work is required to fully scope and understand local issues.

Aviation impacts
In some circumstances, the presence and operation of wind turbines is cause for concern to civil and military airport operators and associated 'technical sites' (e.g. air traffic control relay stations). In particular, wind turbines can appear on radar scans and/or present ground obstacles. Aerodrome safeguarding is thus an important issue for wind farm developers. In the UK this issue has come to prominence in recent years with the formation of an aviation working group, comprising members of the wind power industry, the Civil Aviation Authority (CAA), National Air Traffic Services (NATS) and the Ministry of Defence (MoD).

The air traffic control (ATC) radar on Jersey is perhaps the main constraint on large scale wind energy development. To assess whether wind development was possible without compromising aircraft safety, contact was made with the Airport and the following information ascertained.

There are two types of radar, primary and secondary and the island's primary radar is located at Les Platons, the highest point, providing 360 degree radar coverage. The island also has two secondary radars, one at the Les Platons and one at the airport and these radars are also used by Guernsey Airport. Discussions with Jersey Airport (Jeremy Snowdon) highlighted that there may be areas which could be developed but due to the small size of the island, the potential for large onshore wind farms of say 20-30 turbines is limited. It is more likely that single large MW scale turbines or clusters of large turbines could be possible without significantly impacting the ATC radar. The Airport is keen to work collaboratively with wind farm developers or the States of Jersey to locate turbines where their impact on operations and aircraft safety are minimised. They did suggest that there was a realistic possibility of "living with a few turbines". The airport objected strongly to the offshore wind farm proposed by EOLORES; a copy of their objection letter is appended to this report (Appendix 1).

Weather radar
The weather radar on Jersey forms part of the UK Weather Radar Network and is seen by the UK as an important site in the network due to its southerly position. Situated in the South west corner of Jersey, the radar scans through a full 360 degree azimuth to a range of approximately 200km. However, because of the slope of the Island towards the north, there is an effective topographical shielding to the north through northeast to the east.

Environmental impacts

Visual impact
Wind turbines of the 600 kW to 2 MW range are necessarily large structures. Given their size, the visual impact of turbines on the landscape is sometimes cited as detrimental to the environment. However, views of visual impact are subjective and, conversely, some people believe wind turbines are attractive in their own right. Often, wind turbines may be no more visible than other (essential) parts of the electricity infrastructure (pylons, cooling towers etc).

In order to assess the visual impact of wind farm developments, developers commonly undertake Visual Impact Assessments (VIA). A VIA usually entails:

- Taking photographs from a number of key locations around a site (e.g. on top of a prominent nearby hill), and (electronically) superimposing wind turbine images, correctly scaled for perspective and coloured for natural lighting conditions. These are referred to as photomontages.
- Mapping the 'zone of visual influence' of the turbines using a digitised contour map.

Noise
After visual impact, the most commonly cited environmental impact from wind farms is noise. Due to the aerodynamic characteristics, it should be recognised that it is possible to hear a 'swish' of blades as they turn through the wind at short distances away from turbine towers. However, this noise quickly decreases with increasing separation distance and, to some extent, will be masked by background noise.

In 1993 the UK Department of Trade and Industry (DTI) set-up the Noise Working Group (NWG) to establish a methodology for assessing the noise output of wind turbines. The NWG suggest that noise limits at residential properties should be between 35-43dB(A) depending on the time of day, or 5dB(A) above the prevailing background noise level, whichever is greater. As an illustration of typical noise levels, it is perfectly possible to hold a conversation at normal volume while standing next to the tower base of a wind turbine turning at full rotational speed.

The best practice guidelines for wind turbine developments state that 500m from dwellings is usually required to meet the above NWG noise limits. The level of background noise at a number of nearby residential properties is normally monitored to assess the impact on the local population in relation to the guidelines. As with visual impact there are mitigation strategies which can be employed to limit the noise effects from a turbine such as screening and/or turning off or de-rating the turbine (restricting the turn rate of the turbine blades) when the wind blows from certain directions.

Ornithological impacts
In some circumstances the construction and operation of wind turbines can have the following detrimental effects on birds:

- Present a risk of collision. Generally, this can be avoided, or at least minimised, by locating wind turbines away from established flight paths and migration routes.
- Cause a loss of habitat(s). Although the land use requirement of turbines is small, the natural tendency of birds to avoid wind turbines may deter settlements within several hundred metres.

Whilst it is not within the scope of this study to identify particular sites, it is worth noting that some sites are unlikely to be approved for wind power development because of their designation as Sites of Special Interest or Ramsar sites. These and other planning considerations are described in section 4.1. It is usual for the RSPB to be consulted as part of the planning process for wind farms but as this study does not identify a particular site this has not been conducted.

Radio communications
In general, wireless radio communications services, including microwave links, terrestrial TV transmission/relay systems, and cellular telephony systems, operated in the vicinity of a proposed wind farm development must be carefully considered when siting wind turbines. This is to avoid temporary or permanent blockage to the services' signal paths, undue signal diffraction and other interference effects, which would be unacceptable to the service operators and cause them to object to the development.

Landscape
The impacts of wind turbines on a landscape, including visual impact, must be assessed in the context of the landscape's character. This is sometimes reflected in landscape classifications and designations, which exist to:

- Protect scientific, nature conservation or archaeological interests; and/or
- Safeguard landscapes for their amenity value and/or natural beauty.

The existence of a designation(s) at a proposed wind farm site does not necessarily prohibit development. However, the environmental benefits of a wind turbine (principally reduced carbon dioxide emissions) need to be carefully balanced against their negative environmental impacts and the objectives of the designation(s). While there are sometimes conflicts of interest, there have also been cases in the UK where development has proceeded within designated areas (e.g. Caton Moor wind farm located in an Area of Outstanding Natural Beauty).

Section 4.1 provides more information on planning considerations in Jersey.

Other feasibility issues
Consideration must also be given to grid connectivity, access including delivery of turbines to the port, road width and load bearing capacity, access track and terrain steepness. Issues of grid connectivity and intermittency are dealt with in section 4.2.

2.2 Offshore wind

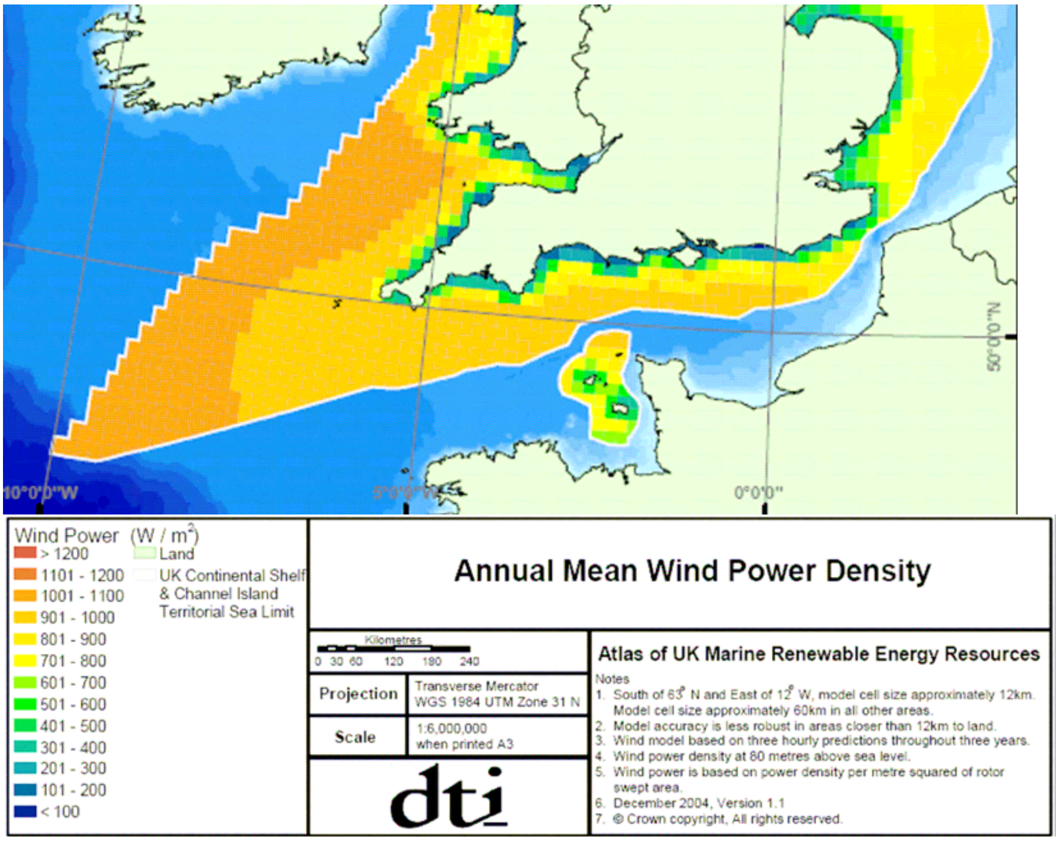
Offshore wind farms are a relatively new trend in the wind industry with four currently operating in the UK at present. Denmark and other countries have also installed offshore wind farms but the UK is leading this rapidly expanding method of installing wind turbines.

2.2.1 Wind resource

In order to assess the potential wind resource in the waters around Jersey, existing data from a variety of sources has been used:

- Meteorological data
- DTI marine energy atlas 2004

The previous section describes the onshore wind resource and suggests that this is sufficient for exploitation and the deployment of wind turbines. The same is true offshore where, despite the sheltering effects of the other Channel Islands and mainland France the resource is good. The map below from the DTI marine energy atlas shows offshore wind resource in the southern half of England and includes the Channel Islands. The resource around Jersey is somewhat lower than other Channel Islands but is still as good as other areas of the UK where offshore wind farms are being installed such as East Anglia. The map shows the wind resource in W/m^2 at 80m above sea level (asl) which is the typical hub height of offshore wind turbines. This equates to the areas around Jersey, shown in green and yellow having wind speeds of 8m/s and above (600-800 W/m^2).



2.2.2 Practical Issues

Many of the constraints that apply onshore also apply offshore and there are also new issues such as fishing, navigation, leisure (e.g. yachting) and wildlife impacts which need to be addressed. In addition, working at sea presents a multitude of difficulties which add to the cost of constructing offshore wind farms. Consequently, offshore wind farms cost between £1,500 and £1,800 per kW installed which is almost double the cost of installation onshore. For example, a 30 turbine offshore wind farm comprising 3MW turbine like those being installed in the UK costs in the region of £135-160 million. The current projects in the UK which are financed under the renewables obligation still require a capital grant of £10 million each for private developers to be able to make them economically viable. These small (30 turbine) round 1 projects are seen as a stepping stone to the larger (100-300 turbine) projects which are currently being developed in the UK.

Good offshore wind farm sites sit in shallow water, in areas of high resource with close proximity to the HV transmission grid. Typically water depths of 30m or less are desirable with many of the existing wind farms built in depths less than 20m. There are current research efforts into building deep offshore wind farms in water >50m but this is not the norm. The foundation types vary according the sea bed conditions but most offshore wind farms use monopiles.

Jersey has sufficient shallow water areas for offshore wind farms to be built and a sufficient resource for these projects to be economically viable under the right funding regime. However, the complexity of issues surrounding offshore wind makes suggesting potential areas difficult. As for onshore wind, the feasibility and site selection of offshore wind farms can only be assessed through a process of consultation with key stakeholders, followed by Strategic Environmental Assessment and/or Environmental Impact Assessment.

The issues that need to be identified in detail are:

- Aviation and navigation including radar impact
- Fisheries, leisure and tourism impacts
- Sea bed conditions (sedimentation and transportation)
- Wildlife impacts (birds and marine ecology)
- Noise impact (amenity and wildlife during construction and operation)
- Visual impact
- Identification of any significant individual or cumulative impacts which may affect other countries ('trans-boundary' impacts).

2.3 Key conclusions

1. On Jersey there is an excellent wind resource which could be harnessed to generate significant quantities of renewable electricity. However, as with all wind developments there are also many issues that need to be resolved. If these can be overcome then there is the potential for a small number of utility scale turbines. The next step would be to engage the stakeholders starting with:

- Jersey Airport, where a radar study needs to be commissioned
- Radio communication operators (mobile phones, fixed links etc)
- States of Jersey Environment and Planning Department (conservation, heritage, other planning constraints).

2. In many respects offshore wind farms are more difficult to develop than onshore with many more interested stakeholders. Owing to the increased development, construction and operational costs, offshore wind farms tend to be very large in terms of installed capacity to help reduce the overall cost through economies of scale. In light of this, and given the relatively low power demand of the island, offshore wind farms may be unsuitable for Jersey. However co-developing with the other Channel Islands and/or France may make offshore wind farms a more realistic proposition.

3 Marine resources

In order to assess the potential wave and tidal resource for Jersey, existing data from a variety of sources has been used:

- DTI marine energy atlas 2004
- Admiralty charts - which show water depth, tidal velocity and direction, underlying geology, location of sandbanks etc
- The Nautical Almanac – which shows tidal range at various major and secondary ports around the UK

For the DTI marine energy atlas, the tidal parameters of water level, current speed and current direction were calculated from a detailed model at a 1 nautical mile (approximately 1.8km) resolution.

Wind and wave resource information were sourced from models operated by the Met Office. The UK Waters Wave model which came into operation in June 2000 currently offers the best source of detailed wave information around UK waters. The resolution of wave data was 12km nearshore (including around Jersey) and 60km offshore. The wave model output has previously been verified using the available network of Marine Automatic Weather Station (MAWS) wave buoys to provide information on wave height and period which is compared directly with model output.

We have used data provided on the Admiralty Charts to check against the DTI Marine Atlas, in particular for tidal range and tidal velocity, which compare. Wave heights can only be checked using data acquired from weather buoys, which was beyond the scope of this study. There is potential for some error in the wave model particularly as we near the coast as in the case of Jersey.

Intrinsic to any discussion on energy resources are the associated resource density, bathymetric (water depth and seabed topography) and environmental issues that affect the deployment of marine technologies. These considerations have also been briefly addressed. The potential for tidal technologies in Jersey has been compared with areas in the UK, e.g. the Solent, Severn Estuary and areas of Scotland, all of which have strategic importance for marine renewables.

3.1 Potential tidal energy resource

Tides are created by the effect of gravitational forces on the oceans. These forces, created by the interaction of the earth, moon and sun, create a number of cycles within the tidal regime:

- Semi-diurnal cycle – as the moon rotates around the earth it creates our daily tides. This cycle means there are 12 hours and 25 minutes between two successive high tides.
- A 14-day cycle – this is produced by the interactions of the moon and the sun. When the sun and moon are aligned, either behind each other or on opposite sides of the Earth they exert an enhanced gravitational pull on the earth's oceans producing high energy tides (fast tidal flow) and high tidal ranges known as *springs*. When the sun and moon are at 90° to each other, some of the gravitational forces acting on the oceans cancel each other out this produces *neap* tides, which have lower speeds (tidal flows) and lower tidal ranges.

As tides flow around the world, the presence of landmass, the local plan-form of the coastline, and bathymetry of the seabed affect their path. Narrow channels, constrictions, and large volumes of water will produce high tidal energies and this affects the likely tidal ranges. Currents can be affected by density variations caused by temperature and salinity gradients. Water will flow from areas of high density to low density, potentially creating currents additional to the tidal flow. In UK waters, density gradients have little effect relative to tidal flows, but local variations in summer can occur. The pressure of the earth's atmosphere also affects tidal heights, for example changes in pressure of 1mb will cause sea level to rise or fall by 1cm.

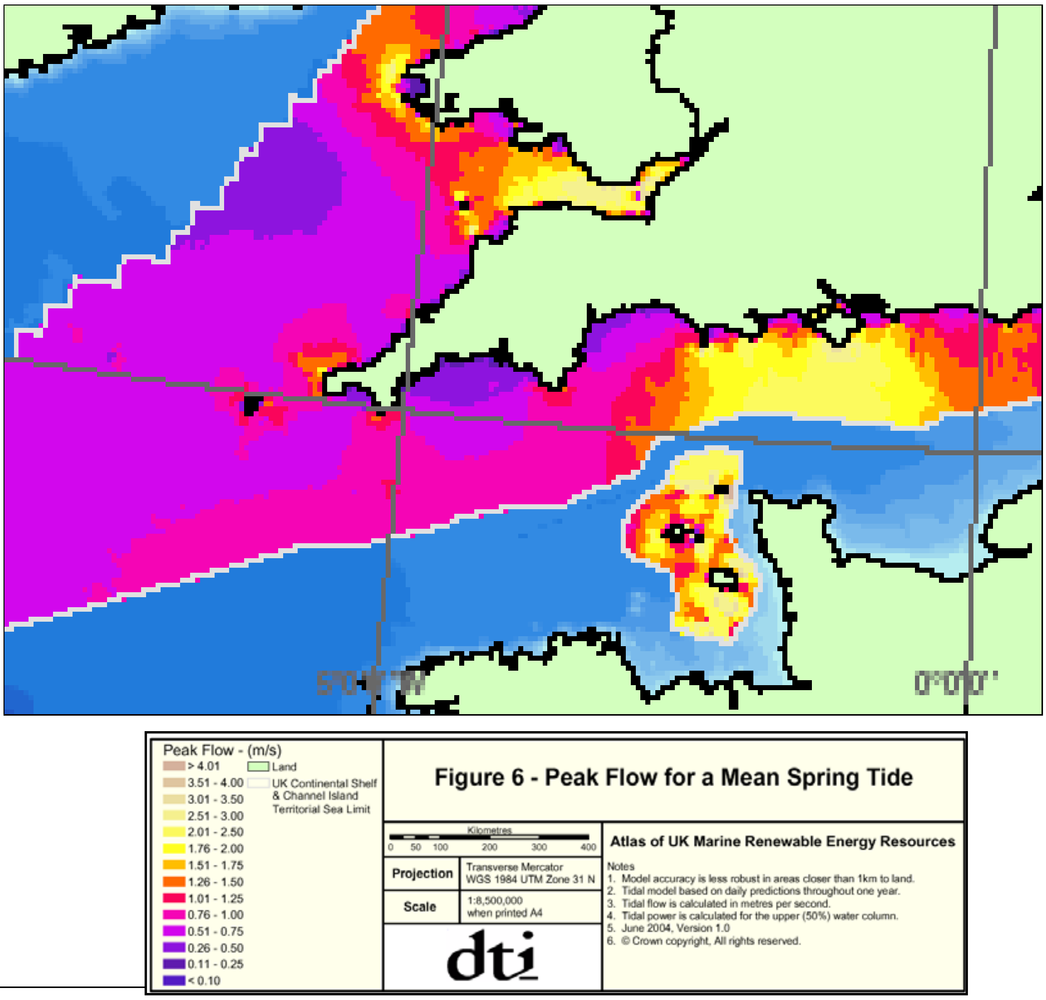
3.1.1 Tidal flows

Tides create the movement of water through channels and straits, into and out of bays and estuaries. These movements can create significant local **tidal flows** (sometimes referred to as **tidal streams**), significant tidal ranges or both. The processes by which tidal streams and local currents are formed depend on the local topography and vary widely. The combined currents and tidal streams are often referred to as **marine currents** when considering marine energy.

The potential power of a current is proportional to the cube of the current velocity. For tidal currents close to the shoreline in estuaries, and in channels between mainland and islands, the velocity varies sinusoidally with time (sinusoidal variations with periods relating to the different tidal components being multiplied). Sites of most interest for exploitation - that is, where exploitation is likely to be most economic - have a maximum current velocity in excess of 2.5 m/s[3].

The UK DTI mean spring tidal flow map in Figure 3 provides an excellent overview of the study area. It can be seen that in Jersey there is a range of tidal current speeds from 0-3.5 m/s. According to admiralty surveys the fastest tidal streams are found south of St Aubin Bay and off Grosnez Point near Desormes west cardinal marker, with tidal velocity reaching 3.5m/s and 3.1m/s respectively. The DTI marine atlas also suggests fast tidal stream can be observed in the Le Ruau channel. This represents a reasonable tidal resource although significantly lower than tidal streams around Alderney, which reach over 5m/s.

Figure 3: Mean Spring Tide Flow (m/s)[4]



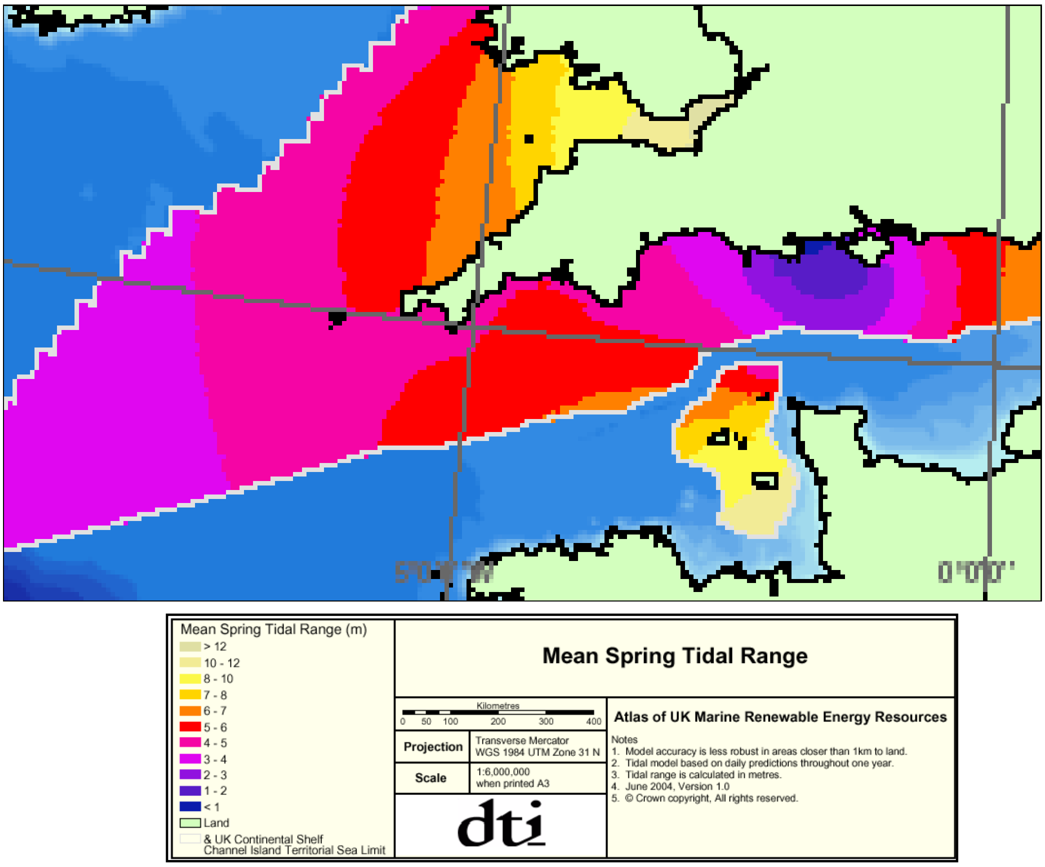
[3] 1m/s = 1.94 Knots
[4] DTI, (2004) Atlas of UK Marine Renewable Energy Resources. http://www.dti.gov.uk/energy/renewables/technologies/atlastechnicalreport.shtml

3.1.2 Tidal range

The greatest tidal ranges occur in estuaries and basins because the coastline constricts the tidal flow thus increasing its height. Certain basins can have similar natural oscillating frequencies to the tide, creating tidal resonance, which increases the amplitude of the tidal wave and therefore the height and range. As well as the morphology of the coastline, the weather affects the tide. Strong winds and low atmospheric pressure will increase the tidal height.

Owing to the constriction from the land masses of France and England the English Channel increases the tidal range significantly. The English Channel's length and average depth is similar to the natural period of the tide and therefore the tidal range is amplified. As a result of this, Jersey has the fourth highest tidal range in the world with a maximum spring range of 12 m. Figures for tidal range have been sourced from Nautical Almanac and the DTI Atlas of Marine Energy. At St Helier the mean spring tidal range is 9.7m, although the tidal range can reach up to 12m when referring to the highest and lowest astronomical tides.

Figure 4: Mean Spring Tidal Range (m)



3.2 Potential wave energy resource

Waves are formed as winds and tides create friction at the surface layers of our oceans. There are four main factors that affect the formation of waves, these are:

1. Fetch – the distance over which waves can develop; the larger the distance the more potential there is for bigger waves to be formed. The Channel Islands have a reasonable fetch towards the southwest which is the prevailing wind direction, although Jersey is somewhat sheltered by mainland France.
2. Wind strength – the strength of the wind has a direct effect on the wave height - the stronger the wind the larger the waves.
3. Wind direction – larger waves form when the prevailing wind direction is onshore.
4. Duration of wind – the longer that the wind blows the more interaction it has with the oceans surface and thus the more energy can be passed between the two creating larger waves.
5. Strength and direction of tides – if wind and tide are running in the same direction the friction between the two will be less resulting in small wave heights but often long, fast wave lengths as momentum builds up. If the wind and tide are running in opposite directions then the friction between the two is large creating a choppy sea and thus large waves.

Waves create two types of energy as they move through the water - these are kinetic and potential:

- Potential Energy – this is the energy the wave holds in its vertical movement, between the trough and crest of the wave.
- Kinetic Energy – this is the energy the wave holds in its orbital velocity; higher fetch and stronger wind create longer and higher waves that hold more kinetic energy.

The best wave climates, with annual average power levels between 20 to 70 kW/m (kilowatts per metre) of wave front or higher, are found in the temperate zones (30 to 60 degrees latitude) where strong storms occur. The opportunity that this presents is vast, as are the technical and economic challenges in developing appropriate technology capable of harvesting this abundant energy supply.

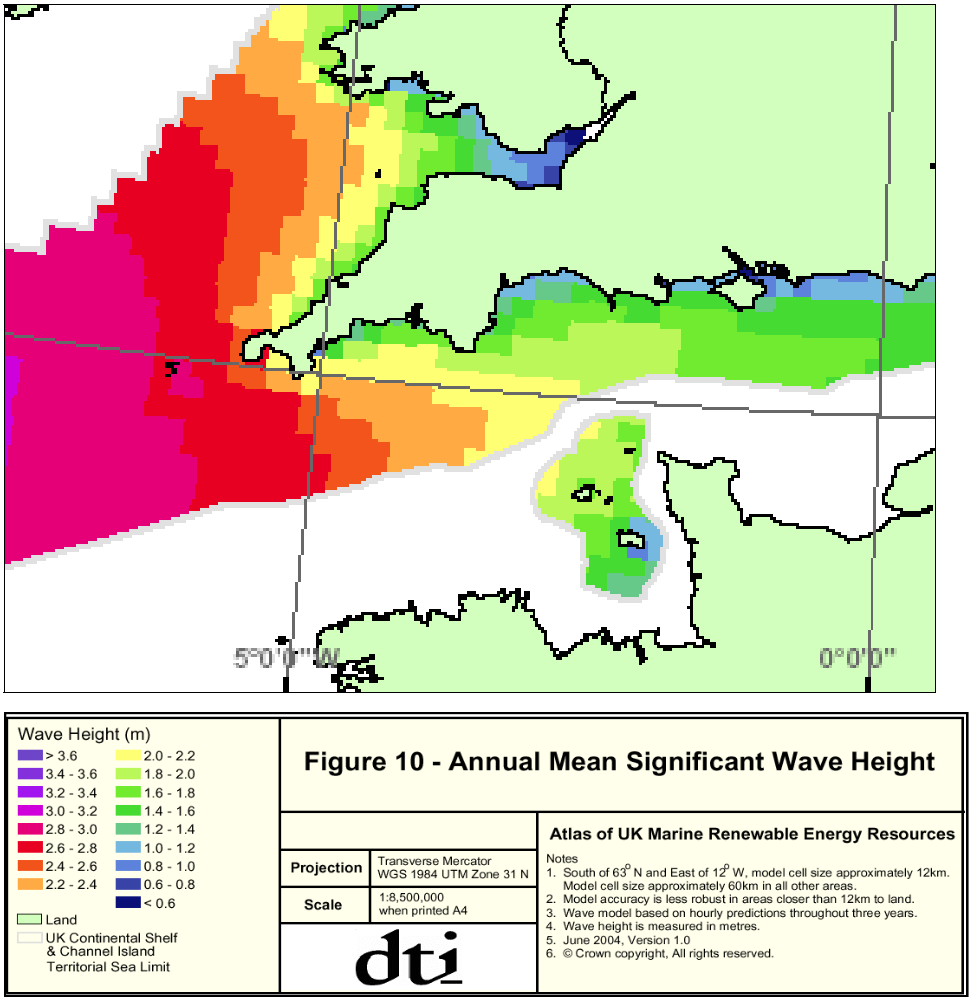
Owing to shading from France the annual average power level for Jersey ranges from 0 to 10 kW/m which suggests a low resource in comparison to other areas of the Channel Islands and the UK. For example Guernsey has a wave resource of 11 to 15 kW/m and southwest England has a resource of 26 to 30 kW/m.

3.2.1 Wave height

As waves travel around the oceans their energy levels rise and fall as the wind interacts with the surface. It is not until the wave approaches the coast that it will start to interact with the seabed and break. Waves travelling over deeper water, that becomes shallow fast, will create large breaking waves. This is in contrast to a slowly upward sloping seabed, which will produce lines of smaller breaking waves (not all breaking at the same point).

The prevailing west south-westerly wind conditions on Jersey and the relatively short fetch out across to the coastline of France means that large waves are unlikely to form other than in storm conditions. Figure 5 shows that average wave heights of around 1 to 1.8m occur in the territorial waters of Jersey. The wave heights are highest to the north and west and become larger towards Alderney, which is less sheltered from the coastline of France.

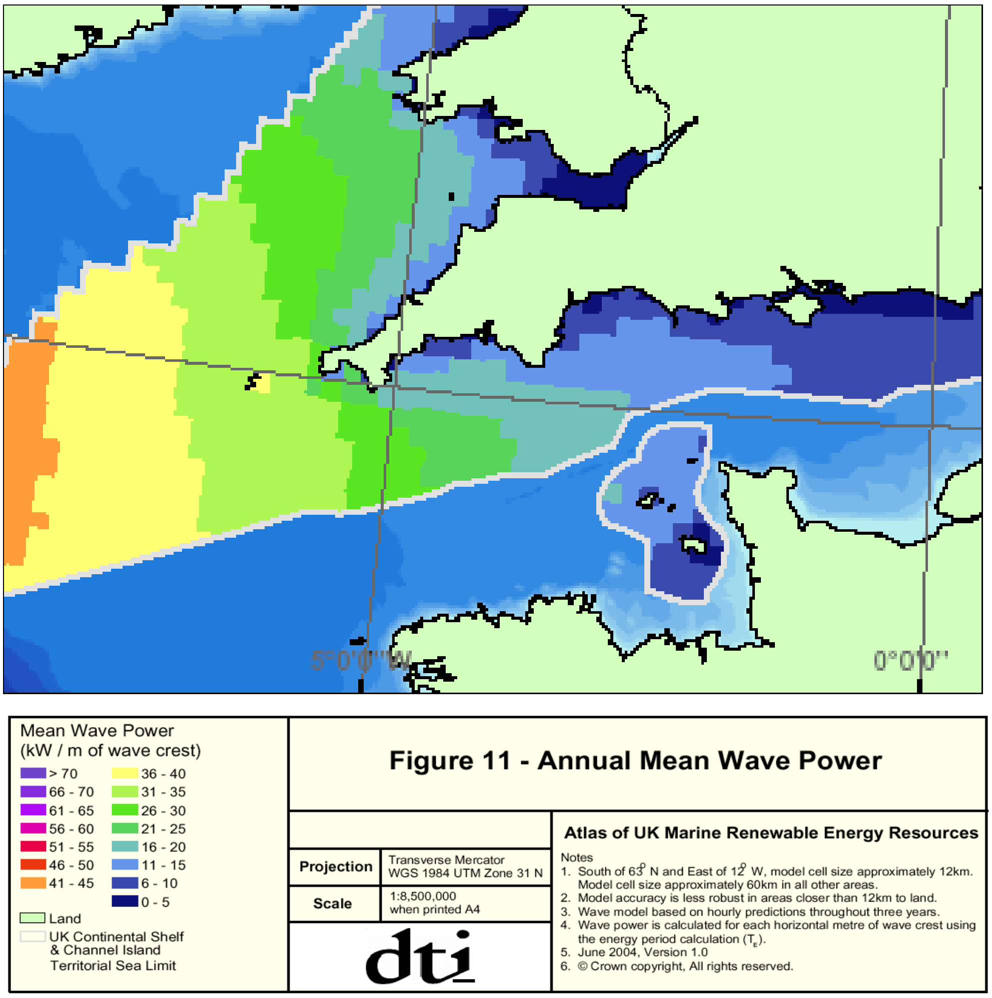
Figure 5: Annual mean significant wave height (m)



3.2.2 Wave energy

The DTI marine atlas provides data on wave power (Figure 6). Near to shore, these are low at around 0-10 kW/m. Further offshore in the northern half of the region the power levels are higher 6-10 kW/m whereas the southern region is 0-5 kW/m.

Figure 6: Annual mean wave power (kW/m)



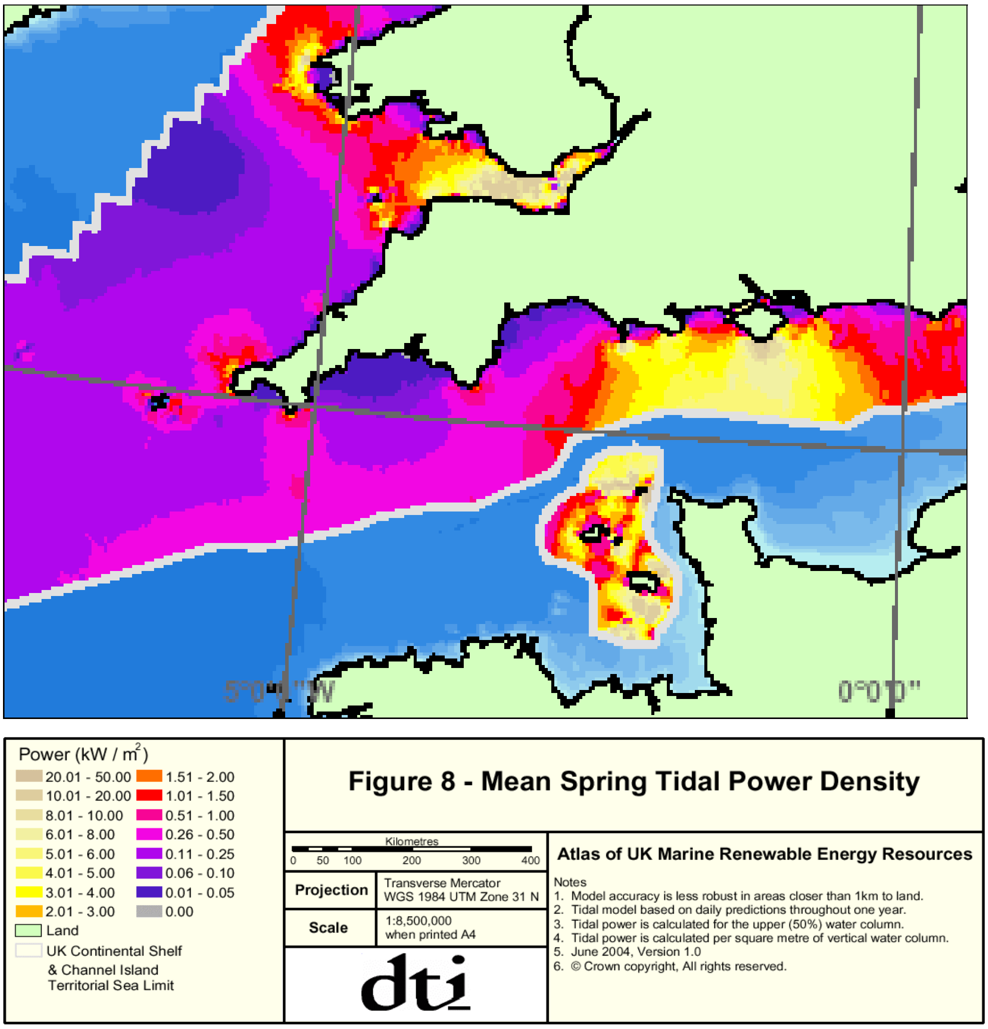
3.3 Comparison with the UK

The areas of greatest potential for tidal power in the UK are:

- Severn Estuary
- Northwest coast of Wales (around Anglesey)
- Solent
- Channel Islands in particular Alderney
- Around Islay in Scotland
- In the Pentland Firth between mainland Scotland and Shetland.

These areas are all identified in Figure 7 as having wave power densities of approximately 10-50 kW/m² or over approximately 3.0m/s tidal streams. Within the Channel Islands Alderney receives the largest stream velocities at over 5m/s, where as tidal stream around Jersey vary between 3.0 to 3.5m/s. The tidal stream resource of Jersey, although potentially commercially attractive, does not receive the highest resource and is therefore unlikely to be explored first by tidal generators – unless the market support for tidal energy compensates for the lower resource. The tidal range however is good and there are potential areas that are suitable for technologies using tidal barrages, tidal fences and tidal lagoons.

Figure 7 - Mean spring tidal power density (kW/m²)



The potential for wave energy in the region is small when compared to the southwest and western coast of the UK. Here, a long fetch combines with prevailing winds to produce the highest possible wave powers, some of the best in the world; approximately 35 kW/m off Cornwall and over 40 kW/m off the northwest coast of Scotland. This compares to a maximum in Jersey of 10 kW/m.

3.3.1 Bathymetry and seabed conditions

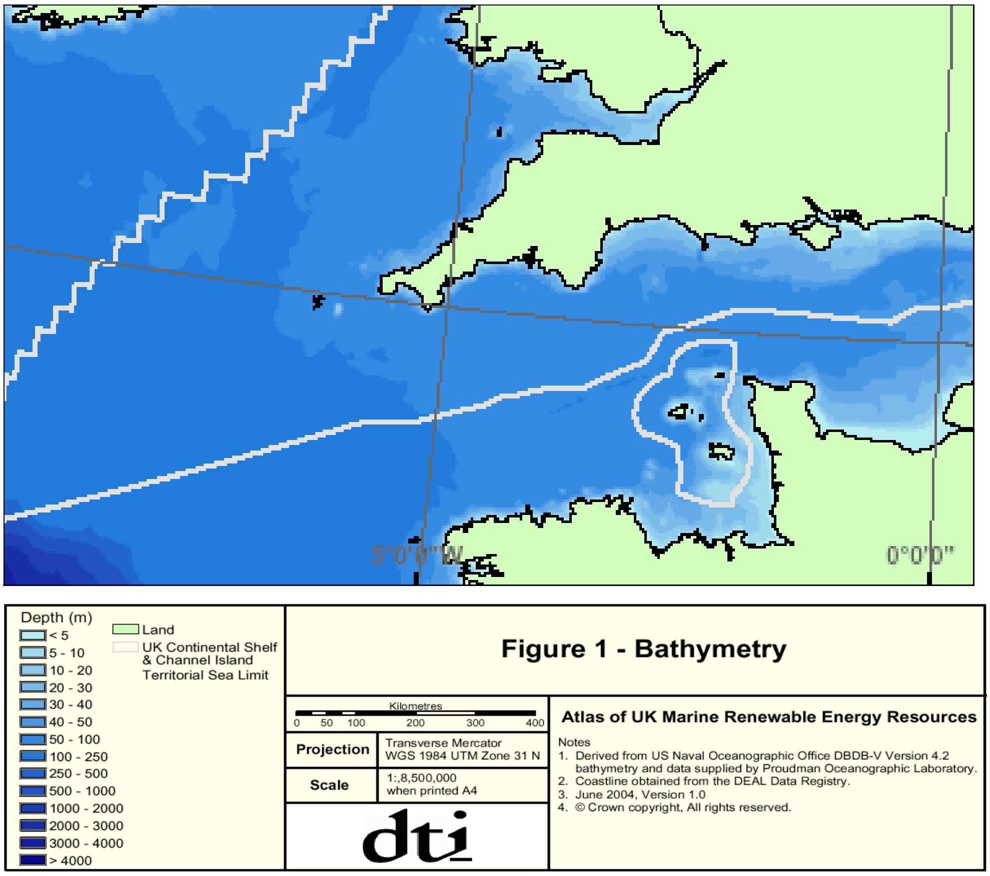
Bathymetry is the depth of water in relationship to the lowest astronomical tide (LAT), which is the minimum calculated depth possible. Tide levels must be added to this to calculate a true sea level or tidal height. Figure 8 shows the bathymetry of the Jersey, which is predominantly shallow, with water depths of between 0 to 50m. Most marine technologies currently being developed function best in the 20 to 50m water depth range due to anchorage and clearance issues, thus this area has good bathymetric properties for the deployment of marine renewables.

The nautical charts show that there are many features in the area that must be taken into consideration when deciding on suitable sites for marine renewables. These include:

- Explosives dumping areas (potentially)
- Oil and gas pipelines
- Electricity and communication cables
- Historic wrecks
- Shipping lanes

- Fishing Areas

Figure 8: Bathymetry of the study Area



3.4 Tidal technologies

3.4.1 Tidal barrages and lagoons

Tidal barrages and lagoons impound water in order to achieve a head difference between the water within the impoundment and the natural water level outside the impoundment. When sufficient head difference is achieved, water is released through hydropower turbines at a sufficient and controlled rate to generate power. The power generated is proportional to the weight of water flow and head difference. The energy yield over a tidal cycle is proportional to the impoundment basin plan area, the square of the tidal range, and a load factor. The load factor is dependent upon the flow regime, determined by the complexity of the scheme and environmental constraints.

One of the largest tidal energy projects proposed in the world is the Severn Barrage project which would have approximately 9,000MW capacity (approximately the capacity of nine coal or nuclear fired power stations), and supply 6% of current electricity demand for England and Wales. This proposal has been under assessment since 1984, and is subject to reappraisal due to greater awareness of the need to achieve significant increases in electricity generation from non-fossil fuels, and more positive economic conditions for renewable generation. However two major obstacles remain:

- The size of capital investment and commitment from both public and private funding which would be required, being incompatible with the privatised electricity supply industry regime and short term payback criteria;

- The environmental impacts of impounding such a large area of estuary, including the shoreline habitat and upstream impacts. Environmental organisations have ruled out acceptability in an area which is now selected for designation as a Special Area of Conservation (SAC) under the EU Habitats Directive.

Large operational tidal barrages include the 240MW River Rance (France), and 24MW experimental facility at Annapolis Royal (Canada). Established hydroelectricity technology is used, including low head Kaplan turbines.

The following is a brief resume of the operational history of the River Rance plant.

- The plant operated successfully for 30 years from 1967 to 1997, typically generating 600,000 MWh/yr.
- The impoundment area is 22 km2, the dam 750m long and 13m high. By comparison with the sites identified off Jersey, the Rance Barrage provides much greater energy in proportion to the size (and hence cost) of the impoundment structure.
- The capital costs of the plant have been fully recovered, giving a low long-term generation cost which is now less than conventional or nuclear power (and much less than other renewables including estimates for new tidal lagoons).
- In 1997, a 10-year refurbishment programme commenced, due for completion in 2007. The plant has continued to operate over this period.
- There has been progressive silting of the River Rance, however this has not prevented viable continued operation.
- The original scheme included 2-way generation and pumping. The operation of the plant has been modified to mitigate environmental impact, now being operated mainly with ebb generation and pumping. Ebb generation with pumping only has been considered as a refurbishment option, but the capability to operate in both ebb and flood modes has been maintained.

Different combinations of flow regimes and scheme configuration may be used, listed in order of increasing complexity and energy capture (load factor):

- Ebb generation;
- Multiple turbines for higher operating efficiency over range of operating conditions;
- Ebb generation with pumping (above the high tide level to increase working head - this generates more additional energy than is used in pumping);
- Two-way generation (on the ebb and flood tides – flood generation, especially may be restricted by environmental concerns);
- Two-or three pond / basin schemes (allows increase in load factor and more consistent power output).

It should be noted that there are other barrage arrangements that are designed for water level control and are not suitable for power generation, either because there is insufficient head difference, or there is insufficient flow permitted through the barrier over sufficient time periods for significant power generation. This includes the Thames Barrier (either in current or upgraded) form, which is intended to restrict maximum upstream water levels below flood levels, but is not intended to alter tidal levels or flows from those naturally occurring over most of the tidal range. Another example is the Cardiff Bay Barrage, which is intended to retain higher water levels in Cardiff Bay than in the tidal Bristol Channel.

Development of tidal barrages for power generation is generally precluded in Great Britain at present due to environmental concerns. The power generation element of a barrage scheme inevitably results in large environmental effects and potentially significant adverse impacts.

Tidal lagoons have recently been proposed as an alternative to tidal barrages, to eliminate the most significant adverse environmental impacts of the latter. The impoundment is constructed in shallow water encircling the area of water to be used for power generation, and clear of the shoreline. Hence there is no barrier across the estuary and the natural tidal range and tidal flows along the shoreline of the estuary and upstream are largely unaffected. Since tidal lagoons do not use the shoreline as part of the impoundment, they are constructed in any area of water where the depth of water and volume of structure required would not be cost prohibitive.

Tidal lagoons use the same turbine technology, taken from hydroelectricity, as tidal barrage schemes. The combinations of flow regimes and scheme configuration which may be used are also similar to tidal barrages, but without the environmental restrictions on flow regimes. Tidal lagoons also lend themselves to two or three pond / basin schemes.

The major cost is that of the impoundment structure, dependent upon the volume of material arsing from its length (proportional to the square root of the impoundment area), and cross-sectional area (proportional to the square of the maximum depth of water). It should be noted that any depth of water below the tidal range (low water springs) does not contribute to power generation, but significantly increases costs, so shallow water depths (minimum below chart datum) are essential. For a similar planform shape, large area schemes will have lower unit costs than small schemes since the length of the impoundment dam is less in proportion to the enclosed area.

The potential capacity of tidal lagoon schemes around Great Britain and France has been estimated at[5]:

- Severn Estuary - 4500MW;
- France – 2000MW;
- North Wales and Liverpool approaches - 1500MW;
- Thames Estuary - 150MW;
- Jersey – 60MW
- Guernsey – 50MW.

Tidal Electric Ltd has proposed tidal lagoon schemes for Swansea Bay (South Wales) and Colwyn Bay (North Wales), with indicative information given below.

Table 1 Details from studies of previously proposed tidal lagoon projects

Tidal lagoon projects proposed by Tidal Electric Ltd.					
Tidal lagoon scheme / location	Capacity (MW)	Basin area (km^2)	Tidal range (Mean springs)	Capital cost (£M)	Installed cost (£K/MW)
Swansea Bay	60	5	8.5	79	1,300
Colwyn Bay / Rhyl	432	60	6.7	480	1,100

The information from Tidal Electric indicates that tidal lagoons could be cost-competitive with offshore wind where the site characteristics are optimum for the technology (Tidal Electric, 2004). However, the predicted performance and costs have recently been reviewed under the DTI New and Renewable Energy Programme, indicating that the energy output could be 66% of that predicted, and the cost a factor of 3.6 times that predicted by Tidal Electric (Baker and Leach, 2006). In any case, for marine construction projects actual capital costs can be a factor of two or more above initial cost estimates. Revenues will be dependent upon the performance of the technology and its reliability in practice.

In appraising the likelihood of proposed projects being achieved, it should be borne in mind that despite the apparent attractiveness of tidal lagoon proposals, such as those by Tidal Electric, no projects have been taken forward to the firm planning stage. Independent of the DTI and WDA review, this raises questions on the robustness of the proposals, whether the performance and cost predictions are realistic, or whether the level of uncertainty is too great for private investors to foresee an acceptable risk-reward balance.

These projects require major capital investment and present major risks to investors due to the high levels of uncertainty on performance and costs. Hence demonstration of the successful construction, commissioning, and operation of power projects using new technologies is essential, as a prerequisite to viable commercial development, or development on a larger scale. However, this technology is not scaleable down to the size which is commonly supported by governments for demonstration projects. This presents a major barrier to implementing this technology.

[5] http://www.tidalelectric.com/Projects UK.htm

3.4.2 Tidal barrage and lagoon sites off Jersey

Environmental aspects are considered in section 3.4.4 and planning considerations in section 4.1 of this report. This section briefly considers the technical and economic potential for tidal lagoons off Jersey.

Jersey, along with nearby Guernsey and the adjacent coast of France, has the fourth highest tidal range in the world. This clearly provides good potential for extraction of tidal energy. However, compared with other locations such as the Severn Estuary, the Baie Du Saint-Michael, or the Thames Estuary, the areas of suitable depth water are much smaller.

Furthermore, the bathymetry is much more complicated, with rocky bottoms providing specific construction challenges. These are not considered within the scope of this preliminary assessment, but could substantially increase the costs such that the identified developments may not be economically viable. It should be noted that Tidal Electric show relatively low potential for tidal lagoons off Jersey, and that this may be based on more in-depth analysis of the potential sites, and more in-depth knowledge of the technology than in the following exploratory assessment. Our assessment should therefore be treated as a “best case” scenario, which being reliant on a range of successful outcomes during development of the proposals, is unlikely to be achievable in full in practice.

Potential tidal barrage and lagoon sites of Jersey have been identified and exploratory calculations undertaken by comparison with information available for the Swansea Bay proposal (Tidal Electric Ltd, 2004).

This includes the following assumptions, with performance and cost information being taken from the DTI / WDA review where this differs from the Tidal Electric information:

- The mean springs tidal range at St Helier is 9.6m, which compares with 8.5m in Swansea Bay;
- The most cost effective depth of water for construction of the impoundment is between 1 and 5m at lowest astronomical tide. However, the case of an impoundment with depths of water up to 8m has been included for a lagoon on the Plateau Des Minquiers, as this allows a much larger lagoon;
- Two-way generation similar to the Swansea Bay proposal;
- An overall energy coefficient of 0.18. This is used to estimate the average energy extracted compared with the theoretical energy available from a spring tide. It accounts for the variation in tidal ranges over the monthly lunar cycle compared with mean spring range, the effective operating periods for the turbines, and for the energy conversion efficiency through the turbine-generators. It should be noted that this has not been proven in practice.
- A power factor of 24%. This is used to estimate the capacity of the plant from the average energy yield as calculated above. It is a measure of the average energy yield compared with the energy yield if the plant could operate at its full capacity continuously. It accounts for the variation in tidal ranges over the monthly lunar cycle, the variation in tidal heights over the diurnal cycle which give variations in flow rates through the turbines, and the effective operating periods of the turbines;
- Installed costs have been extrapolated from the Swansea Bay costs by considering the difference in volume of material for the impoundment structure arsing from the length and height of the dam, and the difference in the capacity of the power generation plant and electrical connection. It should be noted that no allowance has been made for different bottom conditions or length of subsea electrical cables. It should be noted that actual costs could be a factor of 2 or more above the assumed costs;
- Environmental aspects do not preclude or constrain development.

The results of this exploratory assessment are presented below.

Table 2 Tidal barrage and lagoon sites off Jersey

Indicative information from preliminary viewing of marine charts and rough calculations							
Location	Form of impoundment	Capacity (MW)	Energy yield (MWh/yr)	Basin area (km^2)	Capital cost (£M)	Installed cost (£K/MW)	Comments
St Aubin Bay	Barrage across bay 1.2M long	50	100,000	3	160	3,300	May be precluded by conflicts with other users and environmental concerns
Banc Du Chateau	Barrage to shore 3M x 1M	180	370,000	12	400	2,200	Likely to be precluded by conflicts with tourism, leisure and fishing
La Grande Arconie (typ)	Circular lagoon 1.5M diameter	90	190,000	6	300	3,300	Similar shoal sites identified off Violet Bank, off St Aubin, and on Plateau Des Minquiers
Plateau Des Minquiers (5m)	Lagoon S of drying rocks 5M x 1.1M	290	600,000	19	700	2,400	May be precluded by Ramsar designation. Longer subsea electrical connection required
Plateau Des Minquiers (8m)	Lagoon S of drying rocks 6M x 3M	940	2,000,000	62	1,800	1,900	May be precluded by Ramsar designation. Longer subsea electrical connection required

This shows a range of potential developments, in terms of location, form of the impoundment, and scale. The largest developments give the lowest unit costs.

Projected generating costs are significantly greater than large-scale offshore wind. An additional increase in the level of economic support necessary to attract investment in tidal barrages or lagoons would be required to cover the higher level of investment risk, since the technology has not been proven in recent energy markets. Furthermore, the project developers would need to demonstrate both the technical and economic capacity to decommission the scheme. Decommissioning costs could be of similar order to the construction costs. If successful, the scheme could be refurbished periodically to operate over many decades, and the effect of decommissioning costs on the overall project economics would be low. However, if the project could not be operated successfully, decommissioning would be required soon after this was realised.

As described in the offshore wind section of this report, hitherto Jersey has not found it necessary or beneficial to provide economic support for offshore wind or other renewables. Provision of support for renewable generation on a large scale, at the levels required for tidal lagoons would be a major long-tem cost commitment for the Jersey Government, tax-payers or energy consumers.

Furthermore, as described above, one of the smaller scale tidal barrier or lagoon projects (whether off Jersey or elsewhere) will need to be successfully demonstrated, both technically and commercially, as a prerequisite for investment in larger projects. Funding such a demonstration project is a major barrier, and it would appear unlikely that the States of Jersey could fund such a project unless as a joint venture with other governments. Hence, the potential for development of any tidal lagoons off Jersey is dependent upon the funding and success of demonstration projects elsewhere. At present there are no firm plans for such projects.

Clearly the indicative exploratory results presented here rely on the validity of the Swansea Bay analysis, and the above assumptions for projects off Jersey. Should there be interest in any of the sites identified, the following next steps would be essential to give a better indication of the potential for each case:

- Further independent analysis of tidal lagoon technologies and likely costs, especially their installation on rocky seabeds;
- Further investigation of the site bathymetry, technical conditions and constraints on development;
- Analysis of the tidal heights and tidal energy profile;
- Plant sizing and design, cost-optimised to suit the tidal energy profile;
- Engineering of the structure, cost-optimised to suit the site bathymetry and conditions;
- Estimation of costs of the structures, plant, and electrical connection to the shore, including realistic contingencies;
- Environmental screening assessment.

3.4.3 Tidal Stream

'Tidal stream' or 'marine current' energy concepts operate in the free flow of the tides on the same principal as wind turbines: the extracted power is proportional to the air or water density, the cube of the flow velocity, and the efficiency of the device.

The velocity-cubed term means that:

- Due to low tidal flow velocities (usually less than 6 knots or 3.1m/s), tidal stream energy is of low power density despite the high density of water;
- The variation of tidal stream energy (sustained power) over both semidiurnal and synodic cycles is very significant. The energy extractable over a neap tide may be less than one fifth of that from a spring tide. Capacity factors over the complete tidal cycle are comparable or may be significantly less than for wind;
- Power to weight (and hence material cost) ratios tend to be low compared with wind, and orders of magnitude lower than steam or gas turbines, since pressure forces and energy which the strength of the structural elements must resist are proportional to the square of flow velocity, whilst the power is proportional to the cube;
- The economic viability of a tidal stream project is very sensitive to the tidal flow and local variations at a particular site;
- Since tidal flow velocities are approximately proportional to tidal range, it can be observed that tidal stream energy is more sensitive to tidal range and variations than tidal barrages or lagoons.

As tidal streams are a diffuse form of energy, large numbers of energy devices need to be spread over relatively large areas of seabed, for a significant amount of energy generation. Due to water being far denser than air, marine devices can be much smaller than wind turbines for the same power output, and the velocities in a good tidal stream area are a fraction of typical wind turbine cut-in speeds. Tidal streams are steadier and accurately predictable, giving marine current energy the potential for lower storage requirements and easier integration within network planning**.** Initial data analysis suggests that the highest tidal stream velocities around Jersey are 3 to 3.5m/s.

Tidal stream devices can be installed by a number of different means – either via fixture to the seabed or by deployment as a floating device to allow retrieval for maintenance. Some of the more advanced concepts are compared in Appendix 2. These are at differing stages of development and three are considered to be most applicable to Jersey:

- Marine Current Turbine - The Marine Current Turbine (MCT) requires a minimum mean spring peak flow of 2.25 m/s (4.4knt) with a depth of water 20-30m. The MCT appears to be the tidal stream concept at the most advanced stage of development in the UK at present, and is being deployed in tidal streams in excess of 5m/s.
- Lunar Energy's Concept – limited testing of a 1:20 scale prototype shows promise and has recently won DTI funding for demonstration scale project.
- SMD Hydrovison's TidEL device – is also at prototype stage and initial results show that 2.5m/s flows are economically viable. As it is not fixed to the seabed this device may be suitable for a wide range of locations.

In general, ducted (Lunar Energy) or venturi devices may offer lower cost solutions and greater potential for economic viability in low flow regimes. The potential will be dependent on the ability to install at very low cost, and/or incorporate them in other structures.

Currently, the tidal stream velocities surrounding Jersey would be marginal for development and their resource potential does not compare favourably with other areas of the UK. However longer term, when the technology is established and farms in the faster tidal current areas have been installed, developers may turn to areas of Jersey for tidal stream exploitation. However the market support for renewable generation would have to be attractive as the cost of producing electricity from renewable technologies, particular offshore devices doesn't compare well with traditional methods. The proximity to robust grid infrastructure as well as environmental issues would also need to be considered in the overall business case for deployment.

3.4.4 Environmental impacts and factors affecting offshore renewables

Wave and tidal devices have varying impacts on the environment which are strongly dependent on their mode of operation and location. As mentioned previously, tidal barrages have attracted the most concern due to significant impacts on navigation, recreation and ecology. For these and other reasons tidal barrage construction has not progressed in the UK.

At present the UK government is conducting a Strategic Environmental Assessment for marine renewables, this includes offshore wind, wave and tidal power. The purpose of this study is to identify high resource areas and investigate the likely environmental impact prior to development. The DTI Marine Energy Atlas is the start of this process and several areas have already been selected for offshore wind development.

It is likely that wave and tidal devices will be subject to similar criteria for environmental impact assessments (EIA) as offshore wind farm developments. However due the obvious differences in the technologies, additional consideration needs to be extended to the impact on sediment, marine life and hydraulics.

The location and device type determines the environmental impact and a review of each technology in this respect was beyond the scope of this report but a brief summary of the key issues is provided below. For commercial scale developments, a full environmental impact assessment (EIA) is required and in addition to the planning issues identified in section 4.1 of this report, the EIA will have to take account of the following factors:

Biological effects – The biological impact will depend on the technology, the scale of the development and the location in which the device is deployed. The main issues of concern here are habitat loss, impact on fisheries and fish spawning areas, and flora and fauna.

Historically tidal barrages have attracted criticism from environmental bodies. Tidal lagoons appear to be less environmentally damaging and are therefore more accepted by environmental groups. Large tidal lagoons would have a major effect on any sea life and habitats within the footprint of the lagoon. However developers may be able to identify sites that are sparsely populated so that the lagoon has limited environmental impact.

Physical effects – this includes the disruption of the tidal and wave regime which affects sediment processes both locally and downstream of any development. Both tidal stream and tidal lagoon developments will affect hydraulics and sediment transport therefore creating physical affects on the environment.

- The tidal lagoon concept has been developed to avoid the main adverse impacts of tidal barrages, and is currently one of the favoured routes to marine renewable energy by environmental organisations.
- Significant alteration of sedimentation patterns has the potential to affect the viability of these schemes. Lagoons and other marine current devices will affect sediment movement in a number of ways including; total sediment transport, deposition and erosion. These effects will not only impact on the scheme itself but also on the marine environment some distance away. Rigorous modelling will be required to predict and thoroughly assess the likely effects of each scheme;
- Mitigation measures can be put in place to reduce the impact of erosion and deposition and these will be site specific.

It should be noted that the two major tidal barrage schemes in the world have continued to operate successfully over a prolonged period, demonstrating that their construction is practical in certain environments where sedimentation effects can be avoided or mitigated against.

Visual impact – this depends on the device, the location, the distance offshore and where in the water column the device operates. Marine technologies that operate on the surface or close to shore will have the greatest visual impact, as well as those technologies that are large in scale or require numerous individual components or structures.

Tidal lagoons can have a significant visual impact, depending on the distance offshore, height of observer, and state of the tide. It is an economic imperative that the height of the lagoon structure above high water level is kept to the minimum and therefore so is the visual impact.

Tidal stream devices operate predominantly below the surface but certain components protrude from the sea. In most cases, associated electrical equipment (transformers, switchgears, pylons etc) is located onshore where it has a visual impact that would require assessment as part of the EIA.

Noise – Marine energy generators are mechanical devices, which emit noise either through the air or water. This could have an effect on marine life and residential amenity depending on the technology type and the proximity to shore. Noise levels are likely to be less than from ship engines, or hydroschemes (tidal lagoons) and in all cases will be subject to assessment against current noise guidelines. There will be increased noise levels for a short period during the construction process, especially where piling is necessary. Assessment of the noise effects on marine life would also be considered within the EIA.

Archaeological – any development would have take in to account archaeological sites of importance and mitigate as necessary. Appropriate consultation with relevant bodies will advise of sensitive areas and excavation processes necessary to avoid damage or disturbance to archaeological artefacts.

Navigation – With boating and fishing being a key local industry in the Channel Islands it is imperative that any impact is quantified and mitigated. Tidal lagoons are necessarily sited in shallow water and are therefore likely to have little impact on commercial shipping. The lagoons would be marked on charts and clearly identified with aids to navigation such that the risk of collision is reduced. Tidal stream technology would be similarly marked and presents no greater risk than offshore wind or oil and gas installations, although some of the devices would require larger exclusion zones due to movement around their mooring.

Decommissioning – The design life of marine energy devices varies. Structures, sub-structures or foundations may remain, unless removal is necessary to reduce navigation or environmental hazard. It would not be economic to remove tidal lagoon impoundments, although if necessary, some openings could be made in the structure to partially restore the pre-existing water flow conditions. However, such schemes would be intended to operate over many years with only replacement of the machinery and electrical cables. The environmental impact of the decommissioning process would also require consideration as new habitats and populations would establish on the lagoon structure.

Human environment - The following human factors need to be considered alongside appropriate consultation with the relevant bodies to determine the impact on: fisheries, offshore oil and gas, aggregate extraction, sub-sea cables and pipelines, leisure, tourism and military activities.

3.5 Key conclusions

1. Wave and tidal technologies are in their infancy.

2. There is a good tidal resource in Jersey, but some other areas of the Channel Islands and the UK have a better resource. Currently the Jersey tidal resource would be marginal for development. In the longer term, when the technology is established and farms in the faster tidal current areas have been installed, developers may turn to areas of Jersey for tidal stream exploitation.

3. The wave resource is more limited in Jersey mainly due to sheltering effects of France.

4. The proximity to robust grid infrastructure as well as environmental issues relevant to marine energy deployment would need to be considered.

4 General issues relevant to wind and marine

4.1 Planning issues

The following issues are particularly relevant to the deployment of wind and marine energy, and some would also apply to new plant for biofuel or biogas production.

The Island Plan 2002 sets out a number of **General Development Considerations**, including that development will "not unreasonably affect the character and amenity of the area", "not have an unreasonable impact on important open space or natural or built features", and "not have an unreasonable impact on the safe operations of the Airport". An **Environmental Impact Assessment** (EIA) is required "where there are likely to be significant impacts on the environment".

Policy NR4 of the Island Plan deals with **Renewable Energy Proposals**. It states:
"Encouragement of the development of renewable energy schemes must be weighed carefully against environmental protection policies in particular. Where such a conflict may occur, the Planning & Environment Department will need to consider both the immediate impact on the local environment and the wider contribution the proposal would make to reducing greenhouse gases.

… Proposals for renewable energy schemes will normally be permitted provided that the development:

1. *will not have an unacceptable visual impact;*
2. *will not have an unacceptable impact on the character of the immediate and wider landscape;*
3. *will not have an unreasonable impact on features of ecological, archaeological or historic interest;*
4. *will not have an unreasonable impact on neighbouring uses and the local environment by reason of noise, odour, pollution, visual intrusion or other amenity considerations, both during and after construction; and*
5. *is in accordance with other principles and policies of the Plan."*

The Plan defines a number of sites and zones with specific requirements on new development that are briefly discussed below:
- Sites of Special Interest
- Zone of Outstanding Character
- Green Zone
- Countryside Zone
- Important Open Space
- Conservation Areas
- Green Backdrop Zone
- Shoreline Zone
- Marine Protection Zone
- sites zoned for housing and other uses.

Jersey also has four sites included in the Ramsar List of Wetlands of International Importance under the Ramsar Convention on Wetlands:
- South East Coast of Jersey
- Les Écréhous & Les Dirouilles
- Les Minquiers
- Les Pierres de Lecq (the Paternosters)

It is important to note that sites covered by the above planning zones and/or Ramsar designations would be considered less favourably by the States of Jersey for renewable energy development than non-designated sites. Indeed they may be excluded from this type of development. More detail on the development requirements in each zone is provided below.

Sites of Special Interest are listed for their special zoological, ecological, botanical, geological architectural, archaeological, artistic, historical, scientific, or traditional interest. The Plan states that “there will be a presumption against development that would have an adverse impact on the special character of a Site of Special Interest”.

The **Zone of Outstanding Character** applies to “parts of the Jersey coast and countryside that are of national and international importance”, where “there will be the strongest possible presumption against new development.” The zone includes:

- the cliffs and heath land of the north coast and the south-western headlands;
- the Quennevais dune system; and
- the north-east wooded edge, backing the wide sandy bays of St. Catherine’s and Anne Port along the eastern side.

It should be noted that some of the coastal areas with highest wind speeds coincide with the Zones of Outstanding Character.

The **Green Zone** includes areas of the countryside identified as having an intact rural character and comprising an important range of environmental features needing a high level of protection. The zone includes:

- the St. Ouen’s Bay coastal plain;
- the main escarpments of St. Clement, Grouville, Ouaisné, St. Brelade’s and St. Ouen’s Bay and the wooded valleys of St. Peter’s, Waterworks, Bellozanne, Grands Vaux, Vallée des Vaux, Fern and Queen’s Valleys, amongst others; and
- the agricultural landscapes of the north coast.

The Plan recognises that “within this zone there are many buildings and established uses and that to preclude all forms of development would be unreasonable”. It lists types of development that may be permitted in the Green Zone, including “development that has been proven to be in the Island interest and that cannot practically be located elsewhere.”

The **Countryside Zone** is the area outside the Zone of Outstanding Character, the Green Zone and the built-up area. The restrictions on development are similar to those for the Green Zone.

Conservation Areas
Development within or affecting the setting of a Conservation Area will only be permitted where it would conserve or enhance the architectural or historic character or appearance of the Conservation Area.

The **Green Backdrop Zone** is important for views along the south and east coast and within the wider built environment. Amongst other criteria, development will only be permitted “where the natural landscape remains the dominant element in the scene.”

In the **Shoreline Zone** there is a presumption against development that would “fill gaps or obstruct public views to the foreshore and sea”.

Within the **Marine Protection Zone** “there is a presumption against all developments except those which are essential for navigation, access to water, fishing and fish farming and coastal defence.”

Marine Sites of Special Interest are areas being considered for protection as Sites of Special Interest. These include the Ramsar site extending from La Collette around the coast to Gorey Pier and in a south-easterly direction, and Les Écréhous and Le Plateau des Minquiers which have been identified as potential Ramsar sites or as part of a Marine Park. These sites coincide with some areas of interest for the exploitation of wind and marine energy.

In addition to the above zones, **St Ouen’s Bay** in the west of the island has its own Planning Framework, after it was recognised in 1968 as being “the only large coastal open space left in the island”. This is a potentially attractive area for wind power due to the prevailing westerly winds. The framework aims to protect and enhance the natural environment and landscape, with an inherent presumption against “significant and inappropriate development”.

We recommend that investigations into the feasibility and possible location of wind and marine energy generating capacity would benefit from high-level strategic environmental assessment (SEA). SEA can make valuable contributions to:

- Early identification of areas with presumptions for/against development;
- Identification of environmentally preferred option(s);
- Production of development guidelines for project design, siting construction and operational management practices in relation to a preferred option and/or specific areas, thus assisting the development process for both industry and government;
- Providing information that can be used in subsequent project-level EIAs, which are also helped by the earlier identification of environmentally preferred options;
- Assessment of cumulative impacts of possible individual projects or actions.

4.2 Intermittency impacts

Address issues of intermittency and how the Islands would cope with these and how they might impact on existing electricity contracts in terms of demand profiles etc

In this section, the characteristics of the Jersey electrical system are briefly discussed, followed by considerations related to the integration of intermittent generation into this system. The impacts of these considerations are very much proportional to the amount of intermittent generation connected to the grid, thus integration issues are considered in the context of two different levels of intermittent generation:

- a low penetration scenario, where intermittent sources provide for around 10% of Jersey's electrical needs; and
- a high penetration scenario where intermittent sources constitute around 33% of Jersey's needs (or more). This scenario would require a considerable amount of renewable generation – equivalent to over 20 offshore wind turbines.

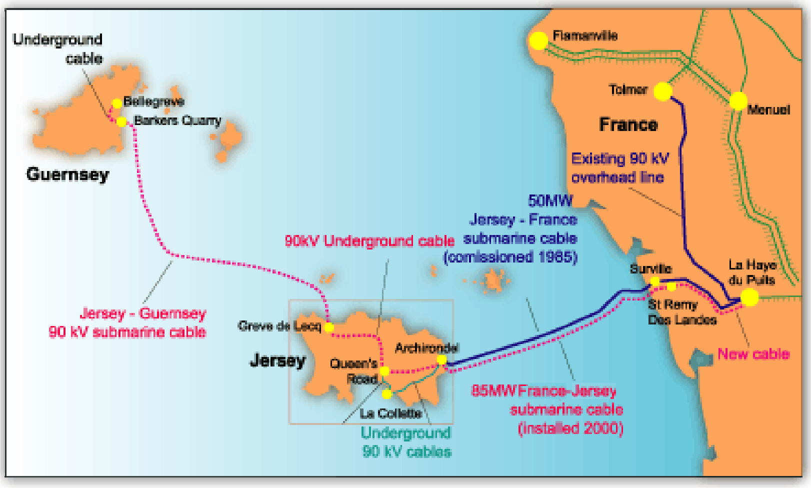
It is considered most likely that Jersey would seek to pursue only low penetration of intermittent generation, if any at all. This is mainly because renewable generation could not compete from a cost point of view with the cheap and secure electricity source provided by the interconnector system from France.

Scenarios of high penetration could only be considered if the States of Jersey sets up financial support mechanisms for renewable generation, described in section 4.3. That the electricity supply from France is (and will likely continue to be for the foreseeable future) a one way system, negates consideration of a third scenario of renewable energy integration on Jersey – one where a very large penetration of intermittent generation enables Jersey to export excess electricity to France.

4.2.1 Jersey's electricity supply system

Jersey has an unusual electricity supply system, typified by bi-directional interconnection with its neighbour Guernsey (allowing the trading of power between the islands), and twin one-way interconnection from the French mainland (allowing electricity to be transferred in only one direction – from France to Jersey), using either or both of the twin pair denoted by the unbroken blue line and dotted pink line in Figure 9.

Figure 9 – Channel Islands Electricity System



At times when electricity demand exceeds the capacity of the interconnector, Jersey injects power from its own indigenous plant, or accepts power from Guernsey's indigenous plant. The presence of generators on Jersey and Guernsey provides contingency cover for failure of the mainland interconnector.

To put the indigenous generation in perspective, Jersey obtains 95% of its total electricity consumption from the mainland interconnector system. In fact, the 145MW maximum capacity of the French interconnector provides for all of Jersey and Guernsey's summertime load – it is only in winter (or at other times, if either leg of the twin mainland interconnector fails) that the islands need to call on indigenous plant. The availability of cheap power from the French electricity grid allows citizens of Jersey to experience electricity costs around 30% lower than those typical for the UK.

A third mainland interconnector is due to be installed in 2012-13, (also uni-directional), reflecting the economic preference of utilizing French electricity. This 100MW interconnector is being considered primarily to allow the decommissioning of steam generating plant at La Collette, Jersey, which effectively supports the loss of one of the existing submarine cables at the moment. It will in addition, mitigate the risk that known metallurgical defects in the 55MW submarine cable installed 21 years ago, cause it to fail irreparably.

Demand

Electricity demand in Jersey has grown steadily over the past 14 years, by an average of about 2.2% per year. In 2005 around 603,200 MWh were consumed compared to 446,000 in 1991 – and the reliance on the interconnector system has risen consistently. Consumption is projected to continue rising, and Figure 10 below shows the Jersey Electricity Company's projections for electricity demand up to 2030.

Figure 10 – Load profile, actual & predicted: 1984 – 2029

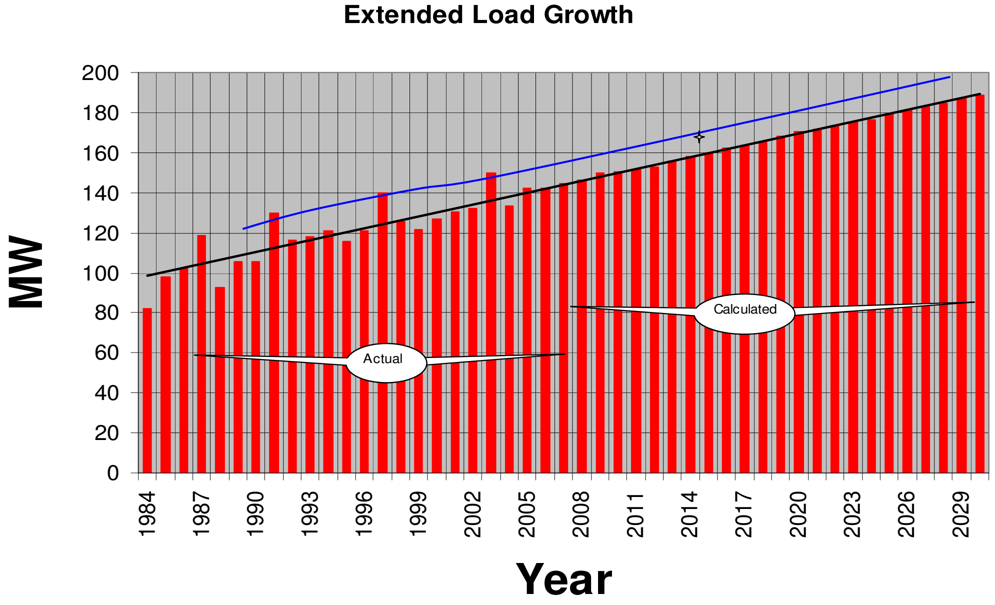


Table 3, based on current (2006) statistics obtained from JEC, shows (unsurprisingly) that Jersey's power consumption exhibits a high degree of seasonality – with a peak winter demand some 4.4 x greater than the summertime minimum. (This compares to a winter:summer peak ratio of around 2.5 for the UK).

Table 3 - Key data (maximum excursions)

Peak winter demand	140 MW
Maximum local generation capacity	199 MW
Minimum summer demand	32 MW

Seasonality effects also affect diurnal variations in power consumption – it is seen in **Figures 11 & 12** below that typical consumption follows a distinctly different pattern between summer and winter. In wintertime, consumption scarcely drops below 80MW, whereas in summer a typical minimum is 50% of this. This pattern is influenced by the high incidence of electric heating systems on Jersey.

JEC has been extremely successful in promoting heat pump and other high efficiency applications for the commercial sector - which consumes 50% of the electrical energy supplied on the Island. It has developed with manufacturers, domestic space and water heating applications for wet and dry systems and tailored off-peak tariffs to shape demand profiles on the Jersey Electricity network.

A statutory limit of 145MW capacity to Jersey and Guernsey is afforded by the mainland interconnector. Contractually Guernsey is entitled to at least 16MW of this but in practice it typically draws up to 50 MW of this capacity, with the remainder supplied by its on-island thermal generation plants powered by diesel and gas. In order for the sharing arrangements to work and to avoid relying on additional expensive and environmentally deleterious indigenous thermal generation, it is seen that care needs to be taken to avoid large peaks in consumption on Jersey. 'Demand side management' is effected through a variety of tariffs which discourage peak period consumption either through Maximum Demand charges for larger electricity users, or through favourable off-peak tariff rates for domestic and other smaller users.

In addition, load management arrangements are available for larger customers able to reduce load significantly on request, providing seasonal relief from the 145MW maximum interconnector demand limit. Currently only the Water Utility has taken up the Load Management arrangements and interruption has been requested only twice in three years.

Figure 11 – Diurnal load profile for typical winter day

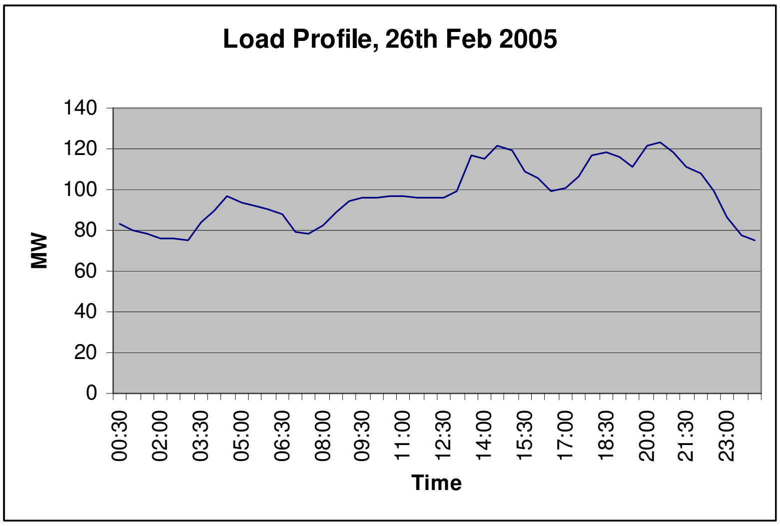
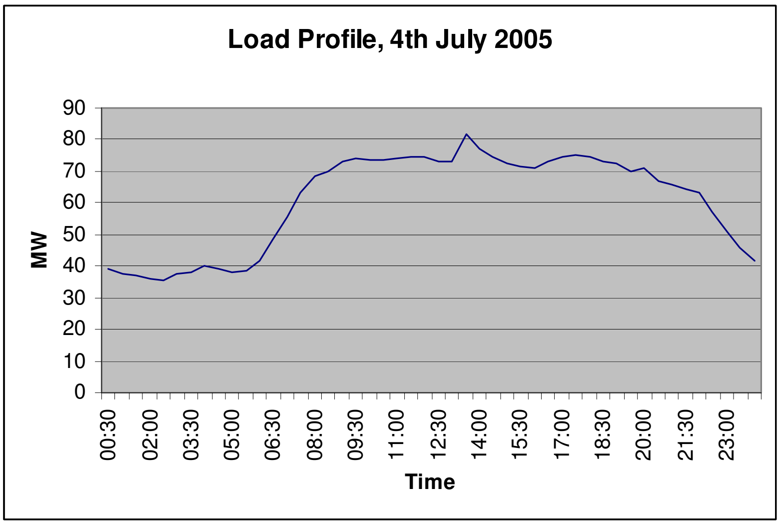


Figure 12 – Load profile for typical summer day



Indigenous Generation

In addition to the substantial capacity of the interconnector, Jersey maintains a portfolio of 209MW of generation, (gradually being mothballed) allowing for mitigation of interconnector failure, and for consumption above the maximum capacity of the interconnector. However we note that in practice, indigenous plant at Guernsey is used in preference to the Jersey plant due to its higher flexibility, lower operating costs, and the greater annual availability of plant at Guernsey due to its more prolonged seasonal use of indigenous generating capacity (economically and environmentally it is preferable to make heavier use of plant that is already running, than it is to start up 'cold' plant, especially if only required for a short period of time). Guernsey maintains a portfolio of 113MW of indigenous generation.

4.2.2 Integrating intermittent generation sources into Jersey's electrical system

The impacts of integrating renewable generation to Jersey's electrical system are directly proportional to the amount of renewable generation employed. This analysis focuses on wind generation as this is likely to be the most intermittent source of renewable energy.

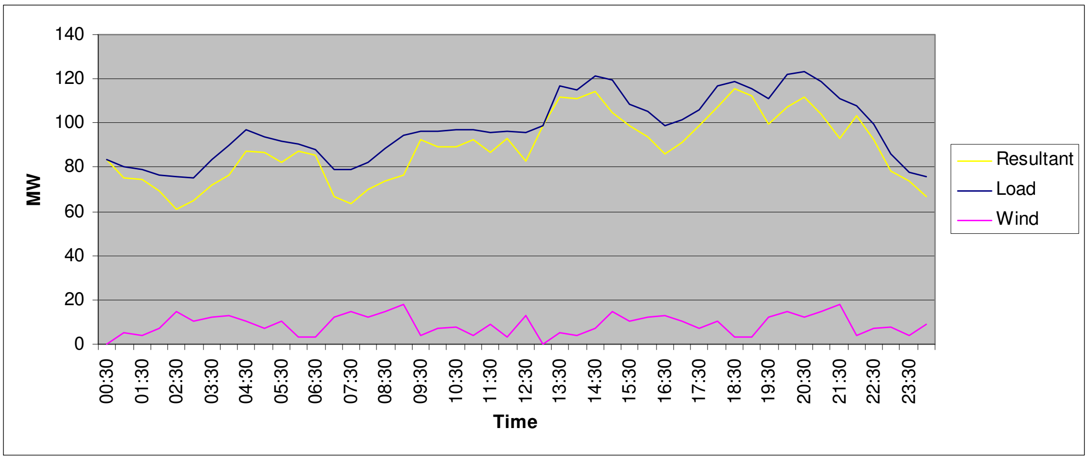
Whilst a detailed investigation of the precise cost impacts and/or modifications potentially required necessitates a thorough engineering study based on comprehensive network parameters, it is possible here to outline the likely effects of intermittent generation and to make recommendations accordingly.

The 'negative load' effect

When a generation source is connected to an electrical network, the network 'sees' the intermittent generator as a 'negative load' – whatever is being generated from the generator at that time, is taken away from whatever the load demand is, leaving a resultant effective demand that is lower.

Figure 13 shows the resultant load when 20MW of semi-randomly varying wind is connected to the Jersey electrical system on a typical winter day.

Figure 13 – Load profile under a low wind penetration scenario (wintertime)



It is seen that the variability of the wind does not add significantly to the variability of the load in this case, because the penetration (renewable amount/total load) is small.

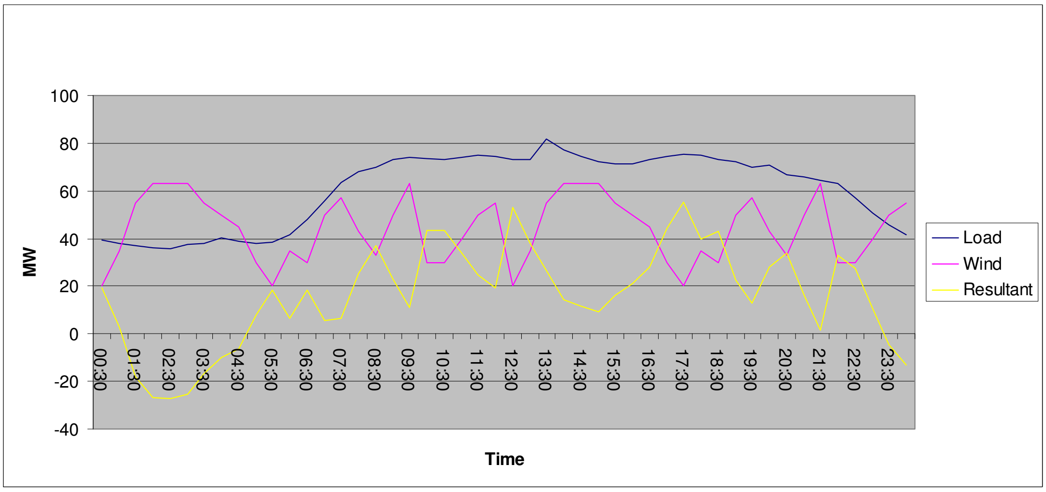
In the summer though, one would expect greater resulting variability in the total electrical load (resultant). Because the total load will be considerably smaller in the summer, this effectively makes the effective intermittent penetration larger.

Less electricity would be taken from the French interconnector in situations where there is good windspeed and the demand of Jersey and Guernsey is less than 145MW (i.e. most of the time). However, if the period under examination is one where Jersey and Guernsey are calling on indigenous generation as well as the French interconnector (e.g. in the depths of winter), the effect is that less energy is required from thermal plant – though in a high wind penetration scenario (with a worse case in summer, due to the minimum network load occurring in this time), the extra variability demanded of this thermal plant (in rapidly adjusting its output in sympathy with the injected wind contribution) at high penetration of intermittents (20%+) could reach a point where significant environmental and economic costs in increased start up/shut down of thermal plant are incurred. Some 'standby' thermal plant would need to be kept on line to allow for sudden unanticipated drops in windspeed.

It is important though to consider Jersey's electrical system after 2012-13, when the extra 100MW of interconnector capacity that will be made available to the channel islands will effectively displace all thermal plant – meaning that when the wind blows in a high intermittent penetration scenario, its effect will be solely on displacing interconnector consumption accordingly – meaning that the economic and environmental penalties attached to making erratic use of thermal plant will not apply in the future.

A high penetration of intermittent generation on Jersey (for example, by integrating a 60MW offshore windfarm that can provide for ~45% of electricity needs) will mean that in the summertime when Jersey's load is relatively small, there will be occasions where the electricity produced from this source will exceed the requirements of the island, and Jersey can then sell excess electricity to Guernsey. This scenario is depicted in **Figure 14** below.

Figure 14 – Load profile under a high intermittent penetration scenario (summertime)



Note that in this example between the hours of 01:30 and 04:30, and from 23:30 to around 00:00 Jersey is producing so much renewable electricity in relation to its demand at these hours, that the consumption is negative – meaning that Jersey could export some energy to Guernsey (displacing Guernsey's use of interconnector capacity) as well as displacing all of Jersey's demand on the interconnector.

However, for the reasons below (technical integration constraints excepted, and dealt with later), this scenario is considered unlikely:

- Jersey and Guernsey pay relatively little for their electricity. It is not foreseeable that unsubsidised indigenous generation of any sort (renewable or non renewable) will be cheaper than French grid electricity. (Unless, for example Guernsey and Jersey agree between them a premium for displacing the interconnector, in recognition of environmental benefits).

- Whilst the contracts associated with the mainland interconnection system do not currently have a statutory minimum consumption level attached to them (for example, allowing Jersey and Guernsey to have periods of time where no electricity is taken from the interconnector, due to a high renewable penetration), it is envisaged by JEC that within two years the terms of the contract will include penalties for not using agreed levels of electricity. In addition, an indirect form of this penalty already exists: Jersey pays a fixed element in the interconnector usage charges, meaning that these costs are spread more efficiently if more electricity is imported.

- Such a substantial amount of renewable generation requires a large offshore wind project, of around 20 large wind turbines (or more). It is not considered likely that Jersey will opt for this, especially in light of the above two points.

4.2.3 Technical implications for a high intermittency scenario

It is worth keeping in mind that prior to establishing a renewable generation project on Jersey, the liaison between the renewable energy developer and JEC, and/or any electrical engineering specialists called in by the developing consortium in relation to the proposal, would address all the points identified here through conducting an in-depth analysis using modelling software and detailed site specific network parameters. However, the overview provided herein allows the States of Jersey to familiarize themselves with the technical considerations of incorporating intermittent sources of generation, which would certainly be a useful process prior to commissioning any renewable electricity projects, and together with the non-technical points introduced earlier allows for an enhanced understanding of the related issues.

The following then, provides an overview of technical issues that would need to be considered in relation to a renewable electricity project of a substantial size. These same principles are relevant to a lesser degree in integrating a smaller amount of renewables to the grid.

- Large **power/voltage flows** stemming from the precise points at which any future intermittent generation is connected to the **electricity grid** require investigation. The results of investigation could necessitate reinforcement of the electrical network, if the excursions in power could take existing equipment outside its design ratings. This requires investigation by JEC and any proposed developer, making use of the comprehensive database of network parameters available. For a small penetration of intermittents, the costs involved in reinforcing the network will not likely be significant, but will be highly site specific, so can only be approximated when decisions have been made regarding potential generation sites. For a scenario involving large penetration of intermittent generation sources, network reinforcement costs could be substantial.

- The environmental and economic costs of increased **'cycling' (start/stop)** of thermal plant would require investigation, in a scenario where a large amount of intermittent generation is employed. However, if renewable generation is to be employed after 2012-13, when a third French interconnector is deployed, this issue would not require consideration. Instead any future economic **penalties** imposed for under-consuming agreed amounts of power as introduced earlier would require consideration.

- The impact of the new generation needs to be assessed in terms of its effect on the quality and security of the overall system supply as tested against the **operational codes and standards** in force. This would require a detailed study by JEC, but again for a small proportion of renewable generation this is not likely to be significant.

- Any intermittent generation employing electronic power converters must adhere to **power harmonics standards** (e.g. UK standards), to preserve power quality. The issue of harmonics concerns injecting malicious voltage components onto the network, and can result in very undesirable characteristics, such as over heating of transformers, substations, mal-operation of consumer equipment, electromagnetic interference.

- **Fault level management**. 'Fault levels' are a measure of the strength of the network at any particular point – i.e. its ability to absorb extra generation capacity without causing the network characteristics (for example, power flow and voltage flow as introduced above) to vary unacceptably. Any proposed generation must not cause local fault levels to rise above their design values. Switchgear and other equipment may be 'reinforced' to take account of increased fault levels. Similarly, the point of connection of the intermittent source must be sufficiently 'strong' that the lowering or absence of generation from the intermittent source will not cause a significant dip in local fault levels. Fault level management will need to be visited on a case by case basis.

As described earlier, the fact that two current interconnector cables are uni-directional (with electrical flow from France to Jersey) negates consideration of a scenario in which Jersey exports electricity to France. JEC has advised that the third interconnector due to be installed in 2012-13 is also planned to be uni-directional. However if the States of Jersey is seriously considering a large deployment of renewable energy generating capacity then it may be prudent to examine the economics of a bi-directional third interconnector. Subject to agreement with the French energy provider (currently EDF) a bi-directional system may allow Jersey to sell renewable electricity to the continental grid and then buy electricity back at some negotiated rate, in order to cushion the difficulties associated with intermittency.

Another possibility would be for the States of Jersey to negotiate with the French energy provider a certain percentage of the electricity to be sourced from renewable energy sources such as wind and hydroelectricity. This option would avoid the intermittency issues of indigenous renewable energy production on Jersey.

4.2.4 Key conclusions

Deployment of renewable energy generation at a low level of penetration (energy share) will have a smaller effect on electricity supply and generate less of an intermittency impact, and in this regard will therefore be more manageable than large scale deployment of renewable energy.

4.3 Support mechanisms

Recommend possible mechanisms to encourage potential schemes and indicate levels of capital investment and levels of risk as well as indicating alternative funding options such as public-private partnerships.

In this section we describe a range of support mechanisms used in the UK and other EU countries, each with its advantages and disadvantages. We recommend that the States of Jersey consider how each of these might fit within its current taxation and support regime. It is clear that support mechanisms do not operate in isolation; a suite of measures is required to encourage investment in renewables and to successfully integrate renewables into energy systems. Based on our experiences in managing a number of UK Government support schemes from the 1970s to the present day[6] as well as observing developments in other countries, we draw together the following conclusions about the requirements for successful integration of renewables into energy systems:

1. A clear Government high level policy statement – to provide a clear signal to industry and establish confidence in the market, as well as to recognise different benefits that can be derived from renewables, e.g. reductions in greenhouse gases, diversity and security of supply, contribution to rural development and employment.

2. Commitment to a long term support policy with targets. Clear targets for the contribution of renewable energy give clarity and confidence to industry and investors, and provide a clear benchmark against which to measure progress. In setting targets, States of Jersey would need to take account of the available renewable resource and the feasibility of utilising the resource.

3. Legal requirements on a party (e.g. electricity supplier, network owner) to meet the target or face some form of penalty. Considerations for Government include: on whom the requirement should be placed, the legal foundation for the requirement, and which technologies should be included. On Jersey this mechanism might be used to require a party to procure all the renewable energy produced on the island.

4. Financial support mechanisms to provide predictable support, ideally over 10+ years. This is less of an issue where governments use a tendering process plus contract for a fixed number of years, like the UK Non Fossil Fuel Obligation (NFFO) which operated from 1990 to 1998. Future policies can change but contracted projects are guaranteed their income via the contract and any inflation increase (if written in).

5. Addressing barriers to the development of renewables, which may include:

- Connection to the grid – renewables can be confronted with a lack of sufficient grid capacity and/or may be denied access (- consider putting in place transparent rules for bearing and sharing the costs of grid investments, and for ensuring grid access at a reasonable and transparent price).

[6] AEA Energy & Environment has managed the UK's Emerging Energy Technologies Programme on behalf of the Department of Trade and Industry (DTI) from its start in 1970s to the present day, we managed the Non Fossil Fuel Obligation (NFFO) process on behalf of DTI, and we currently manage the DTI's Wave and Tidal Stream Energy Demonstration Scheme, Offshore Wind and Biomass Capital Grant Programme and PV Domestic Field Trials.

- Land use planning approvals
- Regulatory barriers
- Access to finance
- Small fragmented industry
- Lack of co-ordination between government agencies (- consider setting up or identifying an agency responsible for coordinating activities) or between government and industry (consider establishing an Industry/Government Working Group)
- Unfair competition from conventional energy (review price setting mechanisms and ensure that externalities are incorporated into conventional energy prices).

6. Providing associated support for renewable energy industries, which may include:

- Support R&D and technology demonstration to build up technical experience
- Establish a policy framework that encourages private investment
- Encourage joint ventures and international cooperation
- Provide access to resource data and market information
- Initiate training programmes
- Disseminate information on benefits to opinion formers and the wider population.

It is clear that the level of risk to investors in renewable energies will vary according to the extent to which Jersey is able to address the above requirements, as well as the type of support mechanism/s adopted.

There are five main types of financial support mechanisms for renewable energy in the UK and other EU countries:

Feed-in tariffs exist in most of the EU Member States. These systems are characterised by a specific price, normally set for a period of several years, that must be paid by electricity companies, usually distributors, to producers of renewable electricity. The additional costs of these schemes are paid by suppliers in proportion to their sales volume and are passed through to the power consumers.

A variant of the feed-in tariff scheme is the fixed-premium mechanism currently implemented in Denmark and partially in Spain. Under this system, the government sets a fixed premium or an environmental bonus, paid above the normal or spot electricity price to renewable electricity generators.

Pure **tendering** procedures existed in three Member States (UK, Ireland and France). However, France has recently changed its system to a feed-in tariff combined with tendering system in some cases and Ireland has announced a similar move. The UK's Non Fossil Fuel Obligation (NFFO) which operated from 1990 to 1998 has been replaced by an energy obligation with Renewables Obligation Certificates (ROCs). Under a tendering procedure, the state places a series of tenders for the supply of renewable electricity, which is then supplied on a contract basis at the price resulting from the tender. The additional costs generated by the purchase of renewable electricity are passed on to the end-consumer of electricity through a specific levy.

Under the **renewable certificate** system, currently existing in five Member States, renewable electricity is sold at conventional power-market prices. In order to finance the additional cost of producing renewable electricity, and to ensure that the desired renewable electricity is generated, all consumers (or in some countries producers) are obliged to purchase a certain number of renewable certificates from renewable electricity producers according to a fixed percentage, or quota, of their total electricity consumption/production. Since producers/consumers wish to buy these certificates as cheaply as possible, a secondary market of certificates develops where renewable electricity producers compete with one another to sell renewable certificates.

In the UK these are called Renewables Obligation Certificates (ROCs). This system may be more expensive than others in terms of increased price passed on to the consumer, as investors seek high returns early in the project due to a lack of certainty about future ROC prices. In addition, cheaper well-developed technologies are favoured as all types of renewable technologies generate the same number of ROCs. In order to encourage promising but less well-developed and more expensive renewables, the UK is considering moving to a banded renewables obligation system where different renewable technologies would receive varying numbers of ROCs depending on the degree of development of the technology, with less developed technologies receiving more ROCs per MWh.

Capital grants are provided by the state, usually following a competitive bidding process of some form. These provide the developer with additional funds at the construction phase and therefore help meet capital costs that are often relatively high for renewable energy technologies. The drawback of capital grants alone is that they do not provide any incentive to operate and maintain the project. They are used in combination with renewable certificates and also with feed-in tariffs to ensure less commercially developed technologies, such as offshore wind, wave and tidal and biomass can come forward alongside the more developed technologies.

Systems based only on **tax incentives** are applied in Malta and Finland. In most cases (e.g. Cyprus, UK and the Czech Republic), however, this instrument is used in combination with other policy tools.

In the UK the Enhanced Capital Allowance (ECA) scheme allows a greater proportion of the capital spend to qualify for tax relief against profits made during the period of investment. This can provide a modest cash-flow boost to profitable businesses. ECAs in this context are a business tax relief for spending on designated energy technologies. Businesses are able to claim 100% first year capital allowances on investments, meaning that the whole cost of the investment can be written off against future taxable profits.

Table 4 summarises some advantages and disadvantages of the five main types of support mechanisms.

Table 4: Advantages (+) and disadvantages (-) of the main financial support mechanisms

	Feed-in tariffs	**Tendering**	**Renewable certificates**	**Capital grants**	**Tax incentives**
+	Technology specific, can target promising but less developed technologies. Successful in delivering installed capacity. Certainty about prices to be paid for renewables.	Deliver low cost renewables.	Market mechanism. Targets attained: financial penalty (eg need to purchase ROCs) incentivises compliance.	Promote construction, but…	Administratively simple.
–	May be expensive (e.g. Germany). Targets not necessarily attained (vs penalty/ purchase of ROCs).	Administratively onerous (e.g. UK NFFO 1990-1998, Ireland). Likely to be less of an issue in Jersey.	May be expensive. One price-incentive fits all: under-rewards less developed technologies.	…don't promote production.	Provide little support to start-up companies/schemes without profit.

In the Jersey context, where there is potential for relatively few renewable energy projects and few players, we consider that some of the above mechanisms would need to be adapted and simplified. The feed-in tariff or the tendering process – or a combination of both – would probably the easiest to implement. The tendering process is often considered to be administratively onerous but given the relatively limited number of potential projects in Jersey this is likely to be less of an issue. Feed-in tariffs alone do not ensure a target is reached in that there is no penalty (unlike the obligation) for not producing or purchasing renewable energy. The States of Jersey may wish to consider the possibility of combining a feed-in tariff with an obligation on a party to purchase a set percentage of renewable energy..

We again stress the importance of the other requirements for the successful integration of renewables into Jersey's energy system. Regardless of support mechanisms or incentives offered by the States of Jersey, any barriers such as grid access, planning and lack of stakeholder support will need to be addressed in order to stimulate the installation and uptake of renewable energy.

4.4 External funding

Examine whether Jersey has a funding route into the exploitation of its indigenous energy sources through investment via the Joint Implementation arrangement under the Kyoto Protocol or other external funding mechanisms.

4.4.1 Joint Implementation under the Kyoto Protocol

The States of Jersey has not yet ratified the Kyoto Protocol. However in April 2006 the States made a decision (MD-PE-2006-0047) to support the UK's request that ratification of the Kyoto Protocol be extended to Jersey, with any obligation upon Jersey to reduce emissions to be determined by the Government of Jersey in conjunction with the UK Government. The UK is an Annex 1 Party under the Kyoto Protocol.

Set out in Article 6 of the Protocol, Joint Implementation (JI) refers to climate change mitigation projects implemented between two Annex 1 countries. JI allows for the creation, acquisition and transfer of "emission reduction units" or ERUs.

Article 6 states that: "*For the purpose of meeting its commitments …, any Party included in Annex I may transfer to, or acquire from, any other such Party emission reduction units resulting from projects aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy*", provided that certain eligibility requirements are fulfilled.

For example, if another Annex 1 country were to invest in renewable energy projects in Jersey, the ERUs generated by that project would count towards that country's emission reduction commitment. The main attraction for funding such projects is where the same emissions reductions can be delivered at a lower cost than an equivalent in-country project. To date most JI projects have been implemented in Eastern European countries. Jersey would therefore need to offer comparably low-cost renewable projects in order to attract investment through JI.

4.4.2 Potential UK funding sources

The States of Jersey is not part of the UK and therefore would not be eligible to receive UK funding directly. However we understand that Alderney Renewable Energy (ARE) have been in discussions with the UK Department of Trade and Industry (DTI) about application of the Marine Renewables Deployment Fund to the testing of tidal stream prototypes by UK technology developers in Alderney's waters. If this comes to fruition, Jersey may also be able to take advantage of such an arrangement.

The two main sources of UK Government funding for wind and marine energy are the Technology Programme which supports R&D and the Marine Renewables Deployment Fund which supports deployment. Both schemes are funded by the DTI.

The **Technology Programme**, previously the New and Renewable Energy Programme, supports industry-led, shared-cost, pre-competitive R&D.

Projects funded under the Programme must be "based on research conducted in the UK." Additional criteria for wind and wave and tidal stream R&D include:

- Wind: Funding is available for innovative technologies and approaches which offer significant reductions in capital and operating costs of offshore wind farms. Technologies that will reduce the radar cross-section of wind turbines through new materials and designs are prioritised.
- Wave and tidal Stream: Funding is available for projects that will further develop, evaluate and test wave and tidal stream device concepts and components. Proposals will be assessed on the basis of the long-term economic prospects.

Note that funding is only available for tidal stream technologies, not tidal impoundments (barrages and lagoons) which have far greater potential in Jersey. For comparison Alderney has a much greater potential for the development of tidal stream energy.

The Wave and Tidal Stream Energy Demonstration Scheme under the **Marine Renewables Deployment Fund** (MRDF) provides support towards the construction, deployment and operation of wave and tidal stream energy arrays that are connected to the UK grid. It is aimed at technologies that have completed their R&D and are ready to begin early-stage commercial operation, but are not yet economical enough to be competitive in the energy market.

Like the Technology Programme, the MRDF does not provide funding support for tidal impoundments. The other criterion is UK-grid connection, although as mentioned Alderney is seeking an exception to this with the DTI.

In summary, unless a special agreement can be negotiated with the DTI, these sources of funding are only available for projects carried out in the UK. We note that the States of Jersey is at an early stage in scoping the potential for wind and wind and marine energy. If further investigations and consultation result in any firmer plans for deployment then that may be an opportune time for Jersey to approach the DTI and/or to review Alderney's experiences in this regard.

4.4.3 Other external funding sources

If renewable electricity produced by Jersey could be sent to France though the interconnector (see section 4.2 for a discussion of this issue) then Jersey may be able to take advantage of France's feed-in tariffs for renewably-produced electricity. However this would be contingent upon EDF accepting the electricity from Jersey, which it may be reluctant to do particularly for intermittent wind-generated power.

We have not investigated the possible application of European capital investment programmes or funds to the deployment of wind or marine energy in Jersey as there is an existing mechanism for European investment though the Joint Implementation process described above. This is perhaps the most likely route for any European investment as it allows the investing country (for example France) to take advantage of the ERUs generated.

We are not aware of other external funding mechanisms relevant to the States of Jersey, as it seems unlikely that an affluent country such as Jersey would qualify for schemes funded by the World Bank and International Monetary Fund. Instead, we recommend that Jersey look to establish favourable conditions in the six factors described in section 4.3, so as to encourage inward investment in renewable energy on the island.

5 Biofuels production

The term "biofuels" is commonly used to refer to liquid transport fuels, biodiesel and bioethanol, derived from biomass. Biodiesel may be produced from feedstocks such as used cooking oils and oilseed rape (OSR). In temperate climates bioethanol is most commonly produced from cereals or sugarbeet, although potatoes are another possible feedstock. Biofuels are used at a blend of up to 5% with fossil-derived transport fuels for use in conventional vehicle engines, while 100% biofuel use is possible with engines designed or modified for this purpose.

Growing biofuel crops on land currently in arable production is not likely to have a significant impact on the environment, while replacing grassland by biofuel crops is likely to have significant adverse impacts on the local environment. Estimates of savings of greenhouse gas emissions from biofuels are in the range of 50-65% for bioethanol and 55-80% for biodiesel from OSR (Mortimer et al., 2002; Woods and Bauden, 2003).

We investigated a number of scenarios that may be feasible in Jersey, based on:
- biofuels produced from feedstocks grown in Jersey;
- biodiesel produced from waste cooking oil in Jersey;
- imported biofuels.

We then calculated the amounts of biodiesel and bioethanol that could be produced, expressed as a percentage of Jersey's annual diesel and petrol consumption, being 11,105 and 27,956 tonnes respectively in 2005.

5.1 Options for biofuel production in Jersey

Investigate options for the production of energy crops on-Island taking into account their agricultural husbandry requirements and the environmental and economic impact of these in comparison to existing agricultural use that they might displace.

5.1.1 Existing uses of agricultural land in Jersey

The total area of the island of Jersey is 11,800 ha. Of this area, *c.* 6000 ha are currently in agricultural use. The largest agricultural areas are used for growing potatoes (*c.* 2700 ha) and permanent grass for the livestock (*c.* 2200 ha). There is no set aside on the island.

The following tables show the areas, gross margins (GM) and total current value for first crops (Jersey Royal potatoes) and permanent crops, and for second crops grown after Jersey Royal potatoes are lifted. Information on GM for most crops has been provided by the States of Jersey; for those crops for which no specific data were available the figures quoted by Nix (2005) were used.

Table 5: Area, GM and total value of first and permanent crops

Crop	Area (ha)	GM (£/ha)	Total value (£)
Jersey Royal potatoes	2553.48	2900	7405092
Main crop potatoes	154.98	2900	449442
Outdoor flowers	177.12	2500	442800
Outdoor fruit and vegetables	395.1	2800	1106280
Glasshouses, polytunnel	62.28	NA	NA
Winter wheat	32.22	445	14338
Permanent grass	2197.26	180	395981
Redundant/uncultivated	287.28	0	0
Total area	*5859.72*		

Table 6: Area, GM and total value of second crops

Crop	Area (ha)	GM (£/ha)	Total value (£)
Green manure crops	1938.60	0	0
Barley	193.64	67	12974
Oats	3.24	67	217
Cereals grown for straw only	30.39	0	0
Forage maize	273.84	572	156634
Other stock feed	16.36	350	5727

Thus, from the information available, potatoes make the dominant contribution to the Island's economy from cropping.

5.1.2 Potential biodiesel feedstocks in Jersey

Oilseed rape (OSR)
Oilseed rape is not currently grown on Jersey, but there is no reason to suppose it could not be, as it is grown successfully in SE England and northern France. Standard practice is to grow the crop in rotation, but not with other *brassicae*. The three key diseases of club root, light leaf spot and sclerotinia can quickly become established and increase year on year under short rotations. Hence the crop is usually grown every 5 years, although some farmers grow a crop every 4 years. Hence, assuming a standard 5-year rotation is practised, the maximum area of winter OSR (WOSR) that could be grown on Jersey would be 20% of the island's cultivable area, *c.* 1500 ha. It should be pointed out that this scenario is unlikely as it would displace other more valuable crops.

WOSR yields on good soils in southern England average *c.* 3.5 t/ha. Yields of spring oilseed rape (SOSR), which could be planted as a second crop in between Jersey Royal potato crops, will be lower and less reliable as yield will greatly depend on how early the crop is sown and on subsequent weather. Yields are likely to be *c.* 2.5 t/ha from crops sown at the optimum time (early April) and 2.0 t/ha for sowings up to early May.

For the purposes of this report we have assumed yields of 3.5 t/ha for WOSR and 2 t/ha of SOSR in Jersey.

The average conversion ratio of oil feedstock to biodiesel is 97.5%. Each tonne of feedstock oil requires 2.84 t of rapeseed to be harvested, hence 2.77 t of rapeseed can be used to produce 1 t of biodiesel.

Nix (2005) suggests prices for OSR as a biofuel feedstock would be similar to that of the 'normal commercial' price for food purposes. This equates to a GM of around £230/ha for WOSR at a yield of 3.5 t/ha and £130/ha for SOSR at a yield of 2 t/ha.

Used vegetable oil
Each year 220,000 litres (*c.* 200 tonnes) of used vegetable oil is produced on the island. At as February 2007 this is sent to the UK, at a cost to Jersey, to be converted to biodiesel for sale in the UK. However we understand that the States of Jersey is currently negotiating a tender to process the waste oil on island, to produce biodiesel. With the addition of an oilseed crushing facility and extra biodiesel processing modules, it would be possible to also produce biodiesel from OSR in such a plant.

5.1.3 Potential bioethanol feedstocks in Jersey

Wheat and barley
Wheat is regarded as the most appropriate feedstock for bioethanol production in the UK. At a yield of 9 t/ha in Jersey, 3.2 t bioethanol/ha could be produced.

Wheat grown in Jersey for food purposes generates a GM of up to £445/ha. In this study we have used a more conservative figure of £300/ha, considered more likely for wheat as a bioethanol feedstock.

Barley can also be used as a bioethanol feedstock. It is currently grown in Jersey at a lower GM of £67/ha.

Potatoes
Waste potatoes may also be used as a feedstock for bioethanol production. The yield of ethanol ranges from *c*. 35 L/t from waste produced during processing to *c*.75 L/t from whole potatoes (Easson et al, 2004). The States of Jersey (Iain Norris, pers comm) reports that between 4500 and 8000 t/year of whole waste potatoes may be available from pack houses.

5.1.4 Scenarios for the production of biofuels in Jersey

Maximum agricultural area available
Given the gross margins (GM) of fruit and vegetables including potatoes (£2500 to £3000), which are substantially greater than the GM likely to be realised for OSR or cereals, we would not envisage any of these areas being replaced by biofuel feedstock crops. However, the cultivation of SOSR instead of green manure after growing Jersey Royal potatoes is an option that is considered here. There is also the option of replacing some of the area currently given over to grass by WOSR and wheat.

Following is a description of the scenarios for biofuel crop production that are considered most viable in Jersey, with table xx depicting the changes in land use if all scenarios were adopted. For most crop areas we considered a 'low' and a 'high' scenario which depend on the availability of suitable land.

1. All cereals for bioethanol production
In this option all of the current first crop wheat as well as the second crop cereals would be used for bioethanol production. It is assumed that the area currently given over to second crop barley and oats would be entirely planted to second crop barley. The area currently planted for second crop straw has been excluded from the calculations as this may be suitable for late planting only, without sufficient time to give a yield of grain.

2. Green manure – SOSR after Jersey Royal potatoes
Since green manures are sown immediately after the potato harvest and only occupy the ground for one winter, growing WOSR on this land is not an option. An alternative would be to grow SOSR after the earliest lifted Jersey Royal potatoes.

Around 400 ha of potatoes are lifted by mid May, but up to 20% of this land may be too steep or otherwise unsuitable for growing SOSR (Iain Norris, pers comm.). The maximum amount of SOSR that could be grown, which we have called the 'high' scenario, would be the remaining 320 ha – but only if the area in which potatoes are lifted early is in different plots of land from year to year to allow the 1 in 5 year OSR rotation. The 'low' scenario assumes that the area of early-lifted potatoes may be the same from year to year, and hence only 20% of that land (*c*. 64 ha) can be sown to SOSR.

Achieving the above levels of SOSR would depend upon being able to sow the crop by early May at the latest and subsequent weather supplying enough moisture for rapid germination and good growing conditions to achieve the modest yield potential. Delays in sowing and/or subsequent dry weather could substantially reduce crop yield and require feedstock to be imported in order to maintain biodiesel production. The longer growing season on Jersey, compared with the UK, might not help as the crucial factor is having enough moisture to ensure rapid germination and vigorous growth in the early vegetative phase.

It may be a concern that replacing green manures will affect the land as green manures 'rest' the ground, whereas any crop continues to deplete it and this may be an issue in the long term. However, the main benefits of using a green manure, eg recovery of nutrients not taken up by the potato crop, suppression of weeds and returns of organic matter to soil, may also be obtained by growing SOSR. The traditional function of green manures is primarily to provide a source of nitrogen to subsequent crops. The other advantages of green cover, as opposed to bare fallow, are that a growing crop will help maintain soil organic matter, both by returning above-ground plant residues to the soil and also by supplying organic matter to the soil via root exudates, while effectively competing with weeds and hence reducing the risk of serious weed infestation in the following cash crop. In addition, green manures will reduce overwinter leaching of nitrate and increase N availability in Spring. SOSR will also fulfil the functions of returning organic matter to the soil and suppressing weeds. The harvest of

SOSR in the autumn may appear to pose a problem, but there is always some spillage of rapeseed during harvest and if those seeds are allowed to germinate and grow over winter they will form a useful green manure.

3. Redundant land
Redundant land is land that has dropped out of agricultural production and is currently uncultivated. In its reconciliation of the 2005 Agricultural Statistics, the States of Jersey identified 1596 vergees (287 ha) of uncultivated land. It was beyond the scope of this study to assess the suitability of the various parcels of land for growing OSR and wheat. However based on the advice of the States of Jersey (John Jackson pers. comm.) that a sizeable proportion of the 1596 vergees is marginal land that has not been cultivated for some time and/or may be too steep or otherwise unsuitable for OSR cultivation, we chose a 'high' scenario of 1200 vergees (216 ha) and 'low' scenario of 600 vergees (108 ha). The scenarios assume that these areas would be planted to WOSR for 1 in 5 years and wheat for 4 in 5 years.

4. Grassland
To meet a nominal biofuel target of 5% of Jersey's current consumption we investigated displacing some permanent grassland with WOSR for 1 in 5 years and wheat for 4 in 5 years. This would require 300 ha of grassland (60 ha for WOSR, 240 ha for wheat), which represents just under 14% of the current area of grass.

Reducing the area of grassland would impact on livestock production. The impacts on the dairy industry and hence the potential for energy generation by anaerobic digestion (largely reliant on cattle slurry) would need to be quantified and weighed up against the use of grassland for biofuel production.

5. Waste vegetable oil and **waste potatoes** were added to the relevant biodiesel and bioethanol scenarios above.

The use of waste potatoes assumes current practices only, ie packing waste that is already collected. Any more than the 'high' scenario of 8000 t would require a change in farming practices to collect waste potatoes from the field. It should be noted that the waste potato feedstock for bioethanol production would potentially be in competition with an anaerobic digestion plant if built.

Table 7 shows the changes in land use in Jersey if all of the above scenarios were adopted. All other crops including forage crops and potatoes stay the same. The use of waste vegetable oil and waste potatoes does not impact on current landuse. The potential biofuel yields from these scenarios and a comparison of GMs for current landuse versus biofuel crops are described in the following section.

Table 7: Changes in landuse with the introduction of biofuel crops

Current crop/land use	Change with biofuels scenarios	Current (ha)	With biofuels (ha)
Wheat	Same main crop area plus additional area displacing redundant land and grass	32.2	358.5(L), 444.8(H)*
Barley	All barley	193.6	196.9
Oats		3.2	0.0
Green manure	Some displaced by SOSR	1938.6	1874.6(L), 1618.6 (H)
SOSR	New crop. Second crop after JR potatoes, displaying green manure	0.0	64 (L), 320 (H)
WOSR	New crop	0.0	81.6 (L), 103.2 (H)
Redundant land	Some displaced by WOSR (1 in 5 yr) and wheat (4 in 5 yr)	287.0	179.1 (L), 71.2 (H)
Grass	Some displaced by WOSR (1 in 5 yr) and wheat (4 in 5 yr)	2194.8	1894.8

* consists of 32.2 ha existing main crop plus scenarios of low/high redundant land and grass.
L = low, H = high area of biofuel crops / utilisation of green manure and redundant land.

5.1.5 Potential yields and financial returns

Examine potential yields of energy crops and the land area required for their production. Examine the level (if any) of Government support necessary to assist the uptake of energy crops if this becomes a political priority.

The following tables show the amounts of biodiesel and bioethanol that could be produced from energy crops and wastes in Jersey. For biodiesel, both the ‘low’ and ‘high’ scenarios include waste cooking oil, and similarly for bioethanol, both ‘low and ‘high’ include all current cereals being used for bioethanol production. The scenario involving displacement of grassland is treated separately as it may be viewed less favourably than other options due to the disruption caused to the dairy industry.

These amounts have then been compared with Jersey’s current fuel consumption (2005 figures), as a percentage by weight and by energy value. More biofuels must be used than their fossil fuel equivalents as biodiesel contains only around 88% of the energy content of diesel and bioethanol around 61% of the energy of petrol.

In summary, the amount of biodiesel that could be produced under these scenarios ranges from 2.46 to 5.06% of current Jersey diesel consumption (2.17 to 4.45% by energy value), and for bioethanol from 3.63 to 8.05% of current Jersey petrol consumption (2.20 to 4.89% by energy value). If the waste potatoes were unavailable as a feedstock, for example if they were instead used in an anaerobic digestion plant, the figures for bioethanol drop to 2.73 to 6.47% (1.66 to 3.93% by energy value).

Table 8 a, b, c: Production of biodiesel and bioethanol as a percentage of Jersey’s current fuel consumption, by weight and by energy value

(a) Biodiesel scenarios

Scenario	Fuel produced, t	% by weight	% by energy value
SOSR displacing green manure - low	46	0.42	0.37
SOSR displacing green manure - high	231	2.08	1.83
WSOR on redundant – low	27	0.25	0.22
WSOR on redundant – high	55	0.49	0.43
WOSR displacing grass	76	0.68	0.60
Waste cooking oil	200	1.80	0.02
Total Low	**273**	**2.46**	**2.17**
Total High	**486**	**4.37**	**3.85**
Total Low including grass	**349**	**3.15**	**2.77**
Total High including grass	**561**	**5.06**	**4.45**

(b) Bioethanol scenarios

Scenario	Fuel produced, t	% by weight	% by energy value
All current cereals (1st wheat, 2nd crop barley)	488	1.75	1.06
Wheat on redundant – low	276	0.99	0.60
Wheat on redundant – high	552	1.98	1.20
Wheat displacing grass	768	2.75	1.67
Waste potatoes – low	249	0.89	0.54
Waste potatoes – high	443	1.59	0.96
Total Low	**1013**	**3.63**	**2.20**
Total High	**1483**	**5.31**	**3.22**
Total Low including grass	**1781**	**6.37**	**3.87**
Total High including grass	**2251**	**8.05**	**4.89**

(c) Bioethanol scenarios without waste potatoes

Scenario	Fuel produced, t	% by weight	% by energy value

Total Low	764	2.73	1.66
Total High	1040	3.72	2.26
Total Low including grass	1532	5.48	3.33
Total High including grass	1808	6.47	3.93

Table 9 compares the potential return from biofuel crops with the return from current land uses that would be displaced. 'Low' and 'high' refer to the different scenarios using a small or large area of biofuel crops (displacing small or large areas of green manure and redundant land).

Table 9: Potential return from biofuel crops in comparison with displaced crops in Jersey

Current crops/ land use	Current (ha)	With biofuels (ha)	GM/ha	Return	Biofuel crops	Ha	GM/ha	Return	Difference
Wheat	32.2	32.2	445	£14,321.97	Wheat	32.2	300	£9,655.26	-£4,666.71
Barley	193.6	196.9	67	£12,974.19	Barley	196.9	67	£13,191.03	£216.84
Oats	3.2	0.0	67	£216.84	Barley	0.00		£0.00	-£216.84
Green manure low	1938.6	1874.6	0	£0	SOSR	64	130	£8,320.00	£8,320.00
Green manure high	1938.6	1618.6	0	£0	SOSR	320	130	£41,600.00	£41,600.00
Redundant low	287.0	179.1	0	£0	WOSR	21.58	230	£4,962.48	£4,962.48
					Wheat	86.30	300	£25,891.20	£25,891.20
Redundant high	287.0	71.2	0	£0.00	WOSR	43.15	230	£9,924.96	£9,924.96
					Wheat	172.61	300	£51,782.40	£51,782.40
Grass	2194.8	1894.8	180	£395,067.35	WOSR	60	230	£13,800.00	£3,000.00
					Wheat	240	300	£72,000.00	£28,800.00

The table demonstrates that growing biofuel crops would generally be financially advantageous, delivering the following returns in comparison to current production:

- Reduced return: wheat produced for bioethanol would give a lower return (by around a total of £4700), based on a lower GM of £300/ha;
- Same return: for barley, on land currently grown to barley and oats. Return could be increased by growing wheat instead of barley, but there may be good reasons why farmers are not already growing wheat;
- Additional return: for SOSR displacing green manure crops (£8,320 to £41,600), WOSR and wheat grown on redundant land (£30,850 to £61,700), WOSR and wheat grown instead of grassland (£31,800), and waste cooking oil.

The use of waste potatoes for biofuel production would represent additional income if sold to a bioethanol producer, or the same if supplied free of charge.

5.1.6 Fertiliser and pesticide use on biofuel crops

The following text focuses on the agricultural husbandry needs of oilseed rape, as the other potential biofuel crops (wheat and barley) are well established in Jersey and their needs will be well known.

Oilseed rape cultivation
Early weed control is essential. Pre-emergence herbicides that are usually recommended include metazachlor with trifluralin or metazachlor with quinmerac. Post-emergence herbicides may be needed for grass weeds. These may be less of a problem on Jersey where populations of herbicide resistant species such as blackgrass are unlikely to have established. However, one of the following may be needed if the OSR is sown after a grass crop: fluazifop, tepraloxydim, cycloxydim, propaquizafop, propyzamide, carbetamide or quizapfop ethyl. Broad-leaved weeds may be controlled by clopyralid, cloryralid and picloram, cyanazine, propyzamine and carbetamide. Propyzamide is the

most commonly used post-emergence residual herbicide applied after the crop reaches the 3-leaf stage.

Crops will need to be inspected to assess damage from cabbage stem flea beetle. If more than 50% of petioles are damaged a pyrethroid spray will need to be applied. A pyrethroid spray may also be needed to control aphid vectors of virus diseases such as beet western yellows virus.

Fungal diseases also need to be controlled. Since the crop is not currently grown on Jersey the need may not be immediate, especially for light leaf spot which tends to be a problem in the north of Britain. However, Phoma may need to be controlled as without treatment, yields may be reduced by 0.5-0.7 t/ha. Treatment is with difenoconazole or flusilazole. Later in the season crops will need to be monitored for infection by Sclerotinia and Alternaria.

A number of pests attack the crop in the period leading up to harvest. Infestation by pollen beetles, cabbage aphids, brassica pod midge and cabbage seed weevil may require treatment with pyrethroid or primicarb if treatment thresholds are exceeded.

Care needs to be taken at harvest to minimise the risk of the seed pods shattering and scattering seed. Pre-treatment with a dessicant may be needed.

Spring oilseed rape
Spring oilseed rape actually receives few chemical applications compared with most other crops. The proportion of the area treated varies substantially from year to year depending on weather and other factors. The main ingredients applied are trifluralin as a weed killer, glyphosate as a dessicant and Cypermethrin as an insecticide against pollen beetle. There are various recommendations for fertiliser, typically 75 to 150 kg/ha N (less for *Brassica rapa*) and a treatment of P_2O_5, both applied around sowing.

Nitrate leaching

Table 10 compares the typical nitrogen (N) fertiliser application and nitrate leaching rates of biofuel crops and current land uses. The 25kg/ha leaching from green manure crops is estimated from 50 kg/ha uptake on N residues following potatoes. Nitrate leaching from redundant land can be assumed to be negligible. Grass land used for grazing has higher rates of N fertiliser application and nitrate leaching than grass used for silage.

Thus, on the area currently sown to green manure crops that would be displaced by SOSR for 1 in 5 years, nitrate leaching might be expected to increase by around 50 kg/ha. Nitrate leaching from redundant land sown to WOSR (1 in 5 years) and wheat (4 in 5 years) would increase by around 45kg/ha overall. WOSR (0.2*60 = 12) + wheat (0.8*40 = 32) = 44

On the grass lands, ploughing out grass to sow WOSR and wheat would cause an initial peak of nitrate leaching (2-5 years). It is not possible to be exact about the amount of leaching as it depends on factors such as how long the land has been in grass, the soil type and over-winter rainfall. However, the peak could be reduced if WOSR is planted as the first crop after grass (because it takes up much N over the winter) and if the N fertiliser applied to the WOSR and the subsequent two cereal crops is reduced to take account of the extra N present, released from the breakdown of grass. In the longer term the level of nitrate leaching from WOSR and wheat would be expected to be similar or slightly higher than from silage grass land, and reduced compared with grazing grass land.

Table 10: N fertiliser application and typical nitrate leaching rates of biofuel crops and current land uses

Crop	Typical N fertiliser application kg/ha/year	Typical nitrate leaching (kg/ha/year)
Winter oilseed rape	190	60
Winter wheat	200	40
Spring oilseed rape	150	75
Green manure	0	25
Redundant land	0	0

Grass land - grazing	220	75
Grass land - silage	190	45

5.1.7 Economics of producing biofuels in Jersey

The previous sections investigated the potential yields and financial returns from biofuel feedstock crops, as required by the project brief. It is clear that with the exception of a small amount of first crop wheat, which would give a lower return as a bioethanol feedstock, it should be economic for farmers to produce biofuel feedstock crops (assuming that combine harvestors are available).

In addition we provide here an initial indication of the economics of producing biofuels in plants on Jersey.

Biodiesel
A recent study tour of biodiesel plants in the EU reported plants with capacities to produce 12,000 to 250,000 tonnes of biodiesel per year. However small plants are also available, including farm-scale plants producing as little as 40 l/day.

The States of Jersey commissioned an economic analysis of a biodiesel plant producing 240,000 l/year of biodiesel from waste cooking oil. Annual fixed costs were calculated at 23.2 p/l, with a total production cost including the fixed costs and consumables of 42.8 p/l. If biodiesel is sold at 85.9 p/l (5 p/l cheaper than the current diesel pump price), this gives a profit margin of 43.1 p/l. Thus the plant would be profitable using waste cooking oil only.

The calculations assume that waste cooking oil is collected on 3 days per week and processed in the biodiesel plant for 2 days per week. It would therefore be possible to produce biodiesel from OSR on the other 3 days per week. The design of most plants is modular so that extra capacity can be added if required.

The introduction of OSR would change the economics of the plant: the purchase of OSR feedstock is an additional cost not reflected in the calculations, while the additional biodiesel produced would provide extra revenue and achieve economies of scale by offsetting the fixed costs of the plant.

Bioethanol
Most EU bioethanol plants have a capacity of 20,000 to 150,000 tonnes per year. While there are many small biodiesel kits on the market, we did not find similar scale bioethanol plants in our enquiries to a number of UK suppliers. However we understand that Green Fuels Ltd is developing a prototype farm-scale bioethanol plant to produce from as little as 4.5 l/hour, which can be scaled up as required. Such a plant may be suitable for Jersey where bioethanol production in the lowest scenario would be just 760 tonnes (1 million litres) per year. The prototype uses wheat as a feedstock but also would be capable of processing the other feedstocks considered in this study (barley and potatoes). The aim is to produce bioethanol that complies with European fuel standards. If successful, sales of small-scale plants would commence later in 2007.

5.1.8 Government support for biofuels

A range of support mechanisms for renewable energy generation, that could also be applied to stimulating the biofuels industry, is described in section 4.3.

The States of Jersey currently funds three support mechanisms that are relevant to biofuels production:

- Single area payment: £35 per vergee per year
- Rural Initiative Scheme: grant-based for rural enterprise; up to 50% of up-front costs
- Countryside Renewal Scheme: capital grants where an environmental benefit can be demonstrated.

For comparison, the UK also provides support for the growing of biofuels crops, in a two-tiered system depending on whether the crops are grown on set-aside or non set-aside land:

- the Single Payment Scheme under the EU Common Agricultural Policy applies to energy crops grown on grown on set-aside land. The amount of payment depends on the number of ‘entitlements’ each farmer has according to EU rules (flat rate plus an addition based on any historic reference amount);
- the Energy Aid Payments Scheme which started in 2004 enables aid to be claimed for crops where the main use is for the production of energy (for heat, electricity or transport fuels) on non set-aside land. The payment in 2006 was 45 euros per hectare.

Our economic analysis for growing biofuel crops in Jersey as summarised in table x found that with the exception of a small amount of first crop wheat (32 ha), farmers would receive the same or additional income for biofuel crops. On this basis it would appear that government support is not needed for growing these crops (except perhaps for the first crop wheat).

However access to suitable agricultural machinery for harvesting biofuel crops may be a significant barrier. There is no requirement for harvesting of green manure and it is not known whether potato farmers could gain access to combine harvesters (they would be unlikely to have their own unless on larger mixed farms) - a level of detail not possible in this study. If additional combine harvesters were required, the States of Jersey may need to consider offering financial support for the capital cost of acquisition.

There is an additional need for investment in biofuel manufacturing capacity, which may require government support.

Finally, the States of Jersey could support the development of a biofuels industry on the island by facilitating discussions with the fuel companies about forecourt biofuel sales and/or by setting obligatory sales quotas, similar to the Renewable Transport Fuel Obligation in the UK.

5.1.9 Potential markets for biofuels

Examine potential markets for biofuel / biofuel blends with respect to successful schemes elsewhere – for example a national bus fleet run on biodiesel / bio-diesel blends

The cost of production of crop-derived biofuels is greater than that of mineral fuels and biofuels will not compete without some form of financial support. EU-produced biodiesel breaks even at oil prices around €60 per barrel, while bioethanol becomes competitive with oil prices of about €90 per barrel (European Commission, 2006). Bioethanol produced from sugar cane in Brazil is cost competitive with petrol (by volume – but not by energy content). Sweden, the leading European consumer of bioethanol in 2004, imported around 70% of this from Brazil.

Leaving cost to one side, the technical aspects to consider in the question of potential markets include fuel standards and vehicle requirements/warranties.

In the EU diesel vehicles are generally warranted to use EN590 fuel, which can contain up to 5% biodiesel by volume (where the biodiesel meets EN14214 specification). Petrol vehicles are warranted to use EN228 fuel, which can contain up to 5% bioethanol by volume. These 5% blends can be used in conventional vehicles without any engine modifications, so the potential market in Jersey is all petrol and diesel vehicles.

Use of biofuel at more than the 5% blend generally requires engine modifications (biodiesel) or a different engine system (bioethanol). Pure bioethanol is difficult to vaporise at low temperatures. For this reason the fuel is usually blended with a small amount of petrol to improve ignition. E85, 85% bioethanol, is the common high percentage blend. Several car manufacturers including Ford, Saab, Volvo and Toyota produce ‘Flex-Fuel Vehicles’ (FFVs) capable of running on any percentage petrol-ethanol blend (up to E85) or on conventional petrol – the engine management system automatically detects which fuel is being used and adjusts the timing accordingly making the vehicles fuel-flexible. Pure biodiesel fuel conforming to the EN14214 standard can be used in many heavy-duty vehicles and agricultural machinery, a potential market in Jersey. In addition, a growing number of vehicle manufacturers have endorsed the use of 100% biodiesel fuel provided it meets the EN14214 standard.

The use of bioethanol as a vehicle fuel is being promoted through the European 'BEST' Project (Bioethanol for Sustainable Transport). As part of the project more than 10,000 bioethanol cars and 160 bioethanol buses are being introduced across the EU. As an example of what can be achieved on a small scale, Somerset County Council and Avon and Somerset Constabulary became the first UK Council and Constabulary to include FFVs in their fleets. Somerset County Council and its partners also received BEST funding to establish a network of refuelling stations selling E85.

In the UK sales of biofuel blends are on the increase with Tesco converting all of its filling stations in the SE and NW to 5% biodiesel and bioethanol blends. Morrisons have become the first UK retailer to offer E85. With regards to infrastructure at Jersey's refuelling stations, biofuels could be blended at up to 5% by volume and sold as 'regular' fuel complying with the relevant standards. The sale of biofuels at higher than 5% blends would require additional infrastructure, unless some of the existing tanks and bowsers could be switched over to biofuel.

5.1.10 Importing biofuels

Inform on the feasibility of importing biofuels such as bio-diesel and alcohol/ petrol blends to comply with UK referenced targets for biodiesel / alcohols in petrol.

The 2003 EU Biofuels Directive required Member States to set national targets in line with a recommended target of 2% (by energy content) share of biofuels within transport fuels by December 2005, increasing to 5.75% by 2010. In 2005 the share of biofuels in the UK was just 0.24%, well short of the 2% national target. In response, the UK's Renewable Transport Fuel Obligation introduced in 2005 requires forecourt sales of 5% biofuel *by volume* by 2010.

It should be noted that this 5% target *by volume* falls far short of the indicative target of 5.75% *by energy* as set down by the EU Biofuels Directive. The UK Government recently announced in the Energy Review that is considering increasing the level of the RTFO to 10% by 2015, subject to "three critical factors" being met:

- development of robust sustainability and carbon standards for biofuels to ensure that they are delivering high levels of carbon savings without leading to biodiversity loss or endangering sensitive habitats – which is particularly relevant to palm oil plantations in SE Asia and may be an important consideration for Jersey in its sourcing of imported biofuels;
- development of new fuel quality standards at EU level to ensure existing and new vehicles can run on biofuel blends higher than 5%; and
- costs to consumers being acceptable.

Both France and the UK present possible sources of biofuel for importation to Jersey. In 2004 France was the second largest producer of biodiesel and bioethanol in the EU, producing 348,000 and 102,000 tonnes respectively (EC, 2006). In 2004 the UK produced only 9,000 tonnes of biodiesel but the industry has expanded significantly since the introduction of the RTFO. Production capacity for biodiesel now exceeds 450,000 t/year, and four plants are being constructed for bioethanol production from wheat and/or sugar beet feedstocks, with a total capacity of 325,000 t/year from 2008 (NNFCC, 2006). Currently the UK imports all of its bioethanol and it may be feasible to import a small additional amount for export to Jersey. However as noted above, there is a degree of uncertainty about future obligations for supplying biofuel to the UK market which is likely to be the prime concern of the UK industry.

In 2004 Spain was the largest producer of bioethanol in the EU (194,000 tonnes), and may also be a possible source of bioethanol for importation to Jersey.

5.1.11 Fuel duty revenue

Investigate the effects of the displacement of traditional fuels with greater use of biofuels e.g. the impact on the revenue stream currently collected from fuel duty. In addition investigate how fuel duty might be applied to biofuels.

In the UK the main support mechanism to achieve a 5% share of biofuels under the Renewable Transport Fuel Obligation is a 20p/l duty break for biofuels. This has had some success in encouraging the expansion of the biofuel industry with several new plants being built.

Here we examine the effect of a similar duty break in Jersey. This is a hypothetical situation for 2007, if the volumes of petrol and diesel were the same as in 2005 (the last full year of data), with fuel duties applied at the new 2007 rates.

We have chosen a range of possible scenarios of indigenously produced and/or imported biofuels to achieve a range of percentage share targets, as shown in Table 11. The analysis in section 5.1 indicates that both a 5% and 8% share of bioethanol (by volume) could be produced indigenously while only a 5% share of biodiesel is feasible. Obviously the scenarios for indigenously produced and imported biofuels could be combined, for example 5% indigenously produced with 15% imported biofuels to give a total market share of 20%.

It is important to note that the calculations are by volume rather than by energy share – biofuels deliver between 20-50% less energy than mineral petrol and diesel. In the last few years fuel consumption in Jersey has been trending down slightly, so using the 2005 figures is conservative and partly compensates for the additional fuel volumes that would be needed with the introduction of biofuels.

The GST calculations are dependent upon the price of biofuels. In the UK, biofuel blends are being sold at slightly less than their mineral equivalents (in part due to government support mechanisms), and a proposal for biodiesel production submitted to the States of Jersey on 31 July 2006 also proposed that biodiesel would be sold cheaper than mineral diesel. For the motorist these cheaper prices help to compensate for the increased volume of fuel required. For this exercise it is assumed that biofuel blends are retailed at 10% less than their mineral equivalents, so around 70p/l for a bioethanol blend and 78 p/l for a biodiesel blend. If biofuels were sold at higher prices then more GST would be collected than is indicated in Table 11 and hence less revenue would be foregone, thus these figures are conservative.

For the purposes of this exercise we have investigated the effects of a duty break of 20p/l for imported biofuels, which would give a rate of 19.35p/l for both bioethanol and biodiesel. In an alternative scenario without this duty break there would be no reduction in duty revenue.

Table 11: Foregone fuel duty revenue under scenarios of 5%, 8% and 15% share of biofuels

	Petrol	**Diesel**
Total fuel consumption	37,852,965 litres *	13,314,835 litres
Total duty revenue	£14,992,170	£5,239,388
5% biofuels share	1,892,648 litres	665,742 litres
GST on 5% **indigenous** biofuels	£39,746	£15,578
Duty on 5% imported mineral fuels	£744,757	£261,969
Foregone revenue	*£705,011 (3.5%)*	*£246,391 (1.2%)*
Duty on 5% **imported** biofuels**	£366,227	£128,821
Duty on 5% imported mineral fuels	£744,757	£261,969
Foregone revenue	*£378,530 (1.9%)*	*£133,148 (0.7%)*
8% biofuels share	3,028,237 litres	1,062,187 litres
GST on 8% **indigenous** biofuels	£63,594	-
Duty on 8% imported mineral fuels	£1,191,611	-
Foregone revenue	*£1,128,018 (5.6%)*	-
Duty on 8% **imported** biofuels**	£585,964	£206,114
Duty on 8% imported mineral	£1,191,611	£419,151

fuels		
Foregone revenue	*£605,647 (3.0%)*	*£213,037 (1.0%)*
15% biofuels share	5,677,944 litres	1,997,226 litres
Duty on 15% **imported** biofuels**	£1,098,682	£386,463
Duty on 15% imported mineral fuels	£2,234,271	£785,908
Foregone revenue	*£1,135,589 (5.6%)*	*£399,445 (2.0%)*

* comprising 31,863,593 litres unleaded petrol and 5,989,372 litres super unleaded petrol.
** assuming a duty rate of 19.35p/l.

Thus it can be seen that the foregone revenue ranges from £133,148 (0.7% of total revenue) for a 5% share of imported biodiesel to around £1,130,000 (5.6%) for either an 8% share of indigenously produced bioethanol or 15% imported bioethanol.

5.1.12 Second generation biofuels

The biofuels crops described in this study are “first generation” feedstocks. Worldwide there is much R&D effort going into “second generation” biofuels that use the ligno-cellulosic parts of plants (stems, leaves etc). These parts are broken down by either biological or chemical means, the latter being a proven but not yet commercially viable technology.

The great advantages of second generation feedstocks is that they:
- do not compete with food crops
- deliver greater yields with lower environmental impacts, eg feedstocks include perennial crops that require less fertilisers, as well as waste vegetation.

While the present study finds limited opportunities to produce biofuels from first generation crops grown on the island (OSR and wheat), it would be worth reassessing the situation once second generation biofuels are commercially viable. There are likely to be significant opportunities to use perennial crops (eg miscanthus) as well as the 12,500 tonnes of green waste that is current composted.

5.2 Biomass crops for power generation

Any form of biomass that can be burnt can be used to generate heat and/or power. There are two main options for combusting biomass for energy generation:
- centralised generation of electricity, by using biomass as a feedstock in a conventional power plant, or of heat and electricity in a CHP (combined heat and power) plant. In many places “co-firing” of biomass with coal occurs;
- decentralised, micro-generation of heat using in-situ biomass boilers that are typically powered by wood chips or pellets. Miscanthus can also be used as a feedstock for some types of boilers. This decentralised option would involve capital outlays in terms of purchasing and installing multiple biomass boilers (which are different to conventional fossil fuel powered boilers). Micro-CHP would be another option. We understand that micro-generation options for Jersey are being investigated in another project.

While not part of the brief for this project, we provide the following information about the use of Miscanthus grass and short rotation coppice (SRC) to assist the States of Jersey should it wish to explore these options further.

A 44 MW dedicated biomass power plant at Lockerbie will require 220,000 oven dry tonnes (odt) of fuel. The plant is expected to 'meet the needs of 70,000 homes' and will hence require *c.* 22,000 ha of short rotation coppice (SRC). (http://www.renewablefuels.co.uk/news_full.php?NewsItem=19)

The population of Jersey is *c*. 87,000. Assuming an average household size of 2.3, the number of households is likely to be *c*. 38,000. Hence a biomass power plant to supply all household energy needs would require *c*. 120,000 odt, and 12,000 ha of SRC. This area is greater than that of the Island. Yields of Miscanthus are similar to those of SRC and hence a similar area would be needed. Therefore it would not be possible to supply all household electricity requirements from biomass produced on Jersey.

Miscanthus

Miscanthus is a perennial grass, indigenous to Africa and Asia, that can be used as an energy crop. Harvesting can begin in the second year after planting, giving 4-10 t/ha. By the third year yields are 10-13 oven dry tons (odt)/ha, and the crop can be harvested annually for 15 years.

Most agricultural sites should be suitable as Miscanthus tolerates a wide range of soil types and pH between 5.5 and 7.5. In practice, crops seem most likely to thrive within the areas which are currently best-suited to maize production. However, once established Miscanthus can grow to 3.5 m and it may be important to consider the visual impact.

Due to efficient nutrient use and effective re-cycling nutrient removal at harvest is moderate and hence relatively little fertilizer is needed. Nutrient requirements of an established crop are expected to be at most 75 kg nitrogen, 20 kg phosphate and 100 kg potash per ha annually. Nix (2005) considers that, once established, there is no need for any further fertilizer application.

Miscanthus has a net calorific value, on a dry matter basis, of 17 MJ/kg, with a 2.7% ash content. The energy value of 20 t dry Miscanthus is equivalent to 12 t coal. Establishment costs are around £2500/ha (Nix, 2005).

The economics for Miscanthus production are specific to each situation and BICAL provides detailed information for growers about each project. However, in general terms Miscanthus offers the following benefits to UK farmers:

- Low variable costs and establishment grant
- Following establishment no application of sprays or chemical fertilisers
- Annual harvest, and income from year 2 onwards
- Harvesting with conventional farm machinery possible
- Dedicated machinery developed for large scale production
- Harvesting can be done internally or by contractor to maximize profitability
- Long term crop contracts (10 years) with index linking for power contracts
- Multiple end uses, power, animal bedding and composites

(http://www.bical.net/economics.htm)
Nix (2005) quotes a price for power generation of £25-30/t. Thus the crop should realise £250 to £400/ha. No figure is quoted for harvest costs, but since this may be carried out using standard farm machinery a cost of £40/ha, i.e. that quoted for cereal harvesting on Jersey, may be applicable. If the establishment costs are averaged over 15 years, using an amortization factor of 0.109, based on an interest rate of 7%, over the 15 years of the Miscanthus plantation the annualised cost of establishment would be £275/ha. Thus the profitability of this crop is critically dependent upon the yield achieved and the price paid per odt. At 10 odt/ha a price of *c*. £35/odt would be required, greater than the range quoted by Nix (2005). *These are preliminary estimates and would need to be assessed for each individual site.*

Short rotation coppice (SRC)

For SRC willow is harvested on a three-year rotation. Plantations are expected to last 15-25 years. An annual yield of 10-12 oven dry tons (odt)/ha average per year (30-36 t at each 3-year harvest) should be achievable.

Establishment costs are £1200- £1850 per hectare with £550 for plant material. Estimates of profitability range from £300/ha (£30/odt, 6 odt/ha/yr) to £2960/ha (£40/odt, 12 odt/ha/yr). The following table provides profit margins according to chip price and yield:

Yield odt/ha/yr	£30	£35 price	£40
6	297	640	980
8	730	1180	1640
10	1160	1730	2300
12	1590	2270	2960

(source http://www.dti.gov.uk/files/file20821.pdf), although a NI website (http://www.ruralni.gov.uk/biomassmk2.pdf) suggests £1200/ha at 10 t/yr. Again, such projections should be assessed for any proposed site.

5.3 Key conclusions

1. Much of the agricultural land on Jersey, apart from that growing grass and forage crops, is planted with high value crops of potatoes, fruit or vegetables all returning gross margins (GM) approximately 10 times larger than the potential returns of crops grown for *biofuels*. Given this large disparity, we do not consider replacing these valuable crops with biofuel crops to be a viable option.

2. There are a number of possible scenarios for achieving a 5% share of indigenously produced biodiesel and bioethanol. These rely to a greater or lesser extent on growing oilseed rape and wheat on redundant agricultural land that is currently uncultivated, and on land currently used for green manure crops and grass. In general the gross margins of biofuel crops are greater than those land uses being displaced. However the profitability of growing biofuel crops would depend on the amount of additional agricultural machinery to be purchased.

3. The use of waste oil for biodiesel production is an attractive option as it does not displace any crops or require any changes in farming practices, and it is currently sent to the UK, at Jersey's expense, for conversion to biodiesel.

4. The scenarios we investigated could produce a maximum 5% share of biodiesel and an 8% share of bioethanol, by weight.

3. There is a market for biofuels on Jersey, as biofuels at up to a 5% blend (provided they meet quality standards) can be used in conventional vehicles. Pure biodiesel can be used in many heavy-duty vehicles and farm machinery. Use of high bioethanol blends would require the acquisition of 'Flex-Fuel Vehicles'. Biofuels could potentially be imported from France, the UK or perhaps Spain.

4. There would be a modest reduction in Jersey's fuel duty revenue if biofuels were imported (assuming a duty break), and a larger reduction in duty revenue if biofuels were indigenously produced.

6 Biogas production

6.1 Biogas production by anaerobic digestion

Anaerobic digestion (AD) is a process by which anaerobic bacteria convert biomass into biogas and 'digestate' by-products.

Biogas is composed mainly of methane and carbon dioxide (CO_2). It is the methane portion, commonly comprising 40-70% depending on the feedstock, that is used to generate energy. Biogas is usually saturated with water vapour, ammonia is often also present and feedstocks high in sulphur produce H_2S. Methane and nitrous oxide, which are far more potent greenhouse gases than CO_2, are diminished through the anaerobic process.

The digestate is comprised of a solid fraction known as 'fibre' that can be applied to land as a soil conditioner, and 'liquor', a liquid fraction that is high in nutrients and can be used as a fertiliser.

Biogas production is proportional to the volatile solids (organic matter) content of the feedstock, but to a good approximation may be considered proportional to the dry solids (DS) content. 1tDS of feedstock may be conservatively estimated to produce biogas containing about 200m^3 of methane, with an energy content of about 2000kWh (1m^3 methane equates to 9.98 kWh). Converting this to useful energy is usually by combustion in a gas engine for combined heat and power (CHP). Electricity generation from biogas can be 30-35% efficient and up to 50% of the remainder of this energy is available as heat. Typically around 15% of the electricity and half of the heat generated is used in operating the AD plant.

In AD plants all materials are pasteurised prior to the digestion process. In the EU, the Animal By-Products Regulation (EC 1774/2002) in force since May 2003 permits AD plants to treat low risk animal by-products and catering waste as long as they are treated to at least 70^{o}C for 1 hour in a closed system.

The following sections address the sub-task: ***Investigate options for the production of biogas production from Anaerobic Digestion Plants that utilise slurry, farm waste, sewage sludge etc.***

6.2 Current waste management practices in Jersey

St Helier Bellozanne Waste Facility
Jersey generates around 100,000 tonnes per year of non-inert waste. Approximately 79,000 tonnes of this were burnt in the Bellozanne incinerator (energy from waste plant) in 2004. The plant generates 3MW, which powers the Bellozanne site. However this plant is old and inefficient and is due to be replaced by a new energy from waste mass-burn incinerator at La Collette, expected to produce 8MW.

The Bellozanne facility treats sewage through an anaerobic digestion system. Each year it produces approximately 1,200,000 m^3 of biogas and between 70,000 and 80,000 tonnes of digested sewage sludge. The sludge is dewatered and treated to produce a residue that is classed as Enhanced Treated Sludge in the 'Safe Sludge Matrix' shown in Figure15[7]. The preferred method of residue disposal is application to land, although this has been made more difficult by the policy of two supermarket chains not to purchase food crops from fields where residue has been applied. The alternative method of disposal is incineration.

In investigating the potential for biogas production in Jersey we have assumed that anaerobic digestion of sewage sludge will continue at Bellozanne.

[7] UK retailers, Water UK and ADAS have come together to develop a "Safe Sludge Matrix" for the UK. In this they have agreed to a voluntary arrangement for guaranteed standards in the treatment of sewage in the UK and in pathogen kill numbers for sludge spread on land. Details include the type of sludge that can be applied to land used for crops and how long must be left between the sludge application and harvesting of food crops. The retailers are a powerful lobby in the UK and suppliers into the UK market are likely to have to meet these "voluntary" standards. For more details see: http://www.adas.co.uk/news/publications.html?podlet_id=42&article_id=52

Figure 15: The Safe Sludge Matrix (courtesy ADAS)

THE SAFE SLUDGE MATRIX

CROP GROUP	UNTREATED SLUDGES	CONVENTIONALLY TREATED SLUDGES	ENHANCED TREATED SLUDGES
FRUIT	✗	✗	✓ (10 month harvest interval applies)
SALADS	✗	✗ (30 month harvest interval applies)	✓ (10 month harvest interval applies)
VEGETABLES	✗	✗ (12 month harvest interval applies)	✓ (10 month harvest interval applies)
HORTICULTURE	✗	✗	✓ (10 month harvest interval applies)
COMBINABLE & ANIMAL FEED CROPS	✗	✓	✓
GRASS & FORAGE - GRAZED	✗	✗ (Deep injected or ploughed down only) (3 week no grazing and harvest interval applies)	✓ (3 week no grazing and harvest interval applies)
GRASS & FORAGE - HARVESTED	✗	✓ (No grazing in season of application) (3 week no grazing and harvest interval applies)	✓ (3 week no grazing and harvest interval applies)

NOTE : ✓ *All applications must comply with the Sludge (Use in Agriculture) Regulations and DETR Code of Practice for Agricultural Use of Sewage Sludge (to be revised during 2001).*
✗ *Applications not allowed (except where stated conditions apply)*

Dairy farms
In farms without slurry storage, slurry is spread onto land frequently. The States of Jersey has been subsidising up to 66% of capital costs (a total of £1.5 million) for farmers to construct large slurry stores with capacity to hold up to four months of slurry. This allows for the rate and time of application to be matched to the needs of the crop/grass and to be avoided during high rainfall periods, so as to minimise water pollution.

6.3 The potential for AD in Jersey

The scenarios in this study represent the “base case” using animal manure (slurry) as feedstock. AD plants must be designed around the dominant feedstock, being of slurry of *c.* 6% dry solids. Generally the plants are able to operate at up to 12% dry solids, meaning that up to 20-25% of the feedstock may be solids that have quite a high liquid content, e.g. vegetable waste.

The efficient management of an anaerobic digestion plant, yielding maximum biogas and proper breakdown of organic feed material, is a complex process. For instance, water content of raw material must be monitored because digestion of material with total solid content lower than 5% is usually not economically viable. Temperature must be maintained relatively constant to sustain gas production. The acid-alkaline chemical balance must be controlled for efficient digestion. Similarly the ratio of carbon to nitrogen must also be closely managed. In summary the feedstocks should remain relatively constant over time.

We have examined the feasibility of installing two different types of AD on Jersey:

- On farm AD, in which individual farmers install their own systems
- Centralised AD, in which all of the farms on the Island send their slurry to a centralised facility.

6.3.1 On-farm AD

On-farm AD is the simplest option. It involves small-scale digestion, on farm use of heat and power and export of any unwanted power to the grid. The AD configuration will include pre-digestion mixing tanks, a pasteurisation stage, use of small scale CHP, with heat from generation being used to heat the tanks and post-digestion storage of digestate and biogas in one tank, prior to digestate being spread on land and the gas being used for heat and power generation.

This analysis was based on farm sizes of 72 (average) to 300 (large) dairy cows. There is variation in the slurry storage collection capacity at different farms. While the animals are on pasture fields, the manure is dropped on the field and is unavailable for collection for AD.

The yield of biogas is also dependent on the design of the digester. For this analysis we assumed that farmers will be offered simple batch/plug flow reactors, which are constructed off site from steel. Alternatively, farmers may choose to construct their own reactors from concrete. They can also build them on ground or bury most of the reactor in the ground for insulation, although such measures are probably not necessary in Jersey. In addition such reactors are more difficult to clean out and trouble-shoot.

Our analysis indicated that avoided costs of heat and power for the farm and income from surplus sales of electricity are far from being sufficient to cover capital costs and annual operating costs of individual on-farm AD plants and therefore **such schemes would not be economic**. In addition, farmers would have to spend time on operation and maintenance. Some European farmers claim up to two hours per day are spent looking after their digesters.

6.3.2 Centralised AD

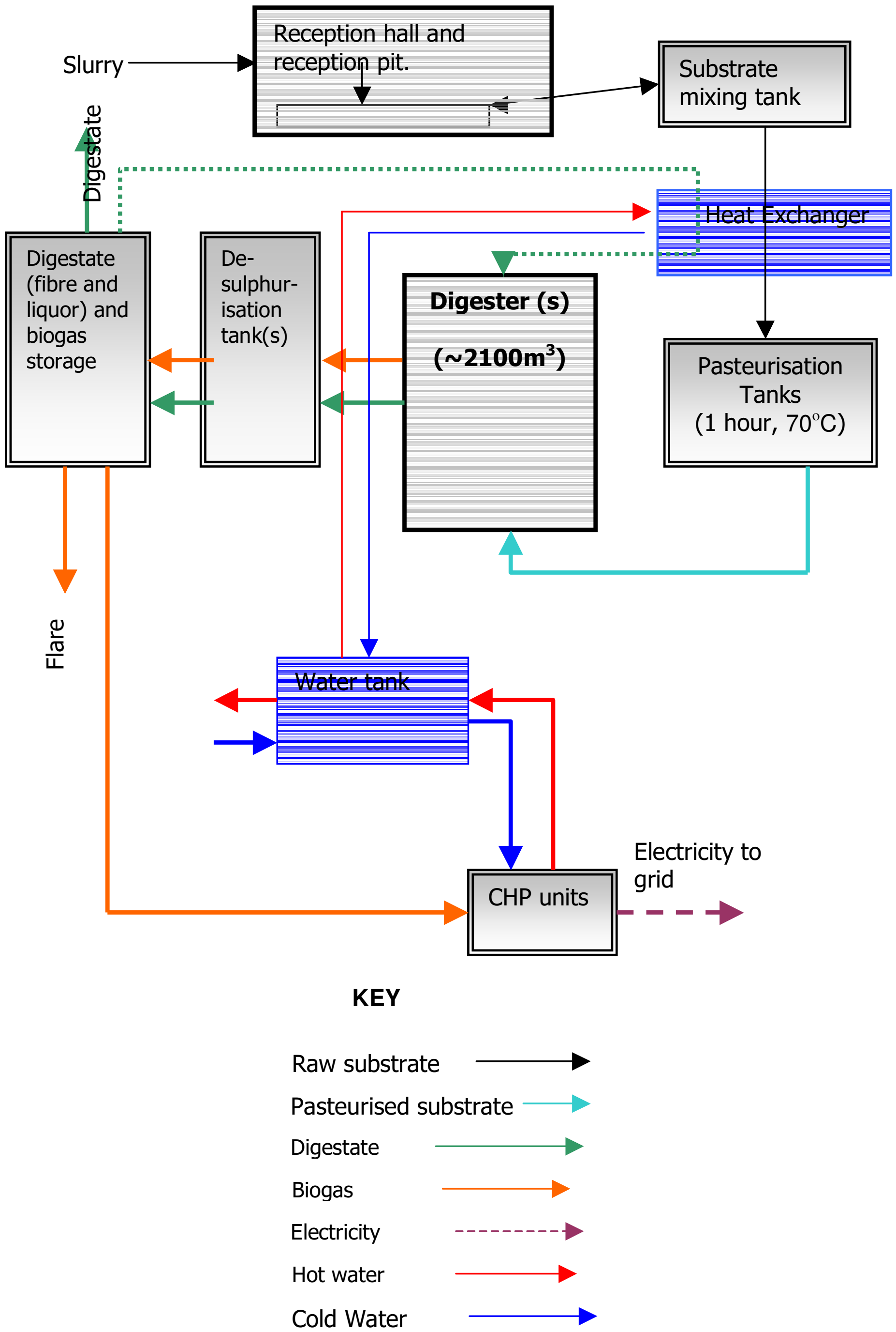
Recent analysis of AD in the UK (Mistry et al, 2005) indicated that on-farm AD is not an economic option, but with Government support and other, non-financial incentives centralised AD may be viable. Centralised AD takes advantage of economies of scale. It also allows specialist staff to be employed for routine operation and maintenance. In the right circumstances it may also enable a district heating to be established.

Around Europe there are a number of centralised AD schemes in operation, most notably in Denmark, Germany and Italy. More recently a scheme has commenced operation in Holsworthy in Devon, UK. There is much information available on Holsworthy and, should Jersey decide to investigate centralised AD further, we suggest that a visit to Holsworthy would be useful. We have used our experience of these plants in our analysis.

Figure 16 shows a typical centralised AD plant in Denmark and Figure 17shows a diagrammatic flow chart for a typical scheme. This is based on the Holsworthy scheme in Devon, UK.

Figure 16: View of a centralised AD plant at Studsgaard in Denmark.
The plant was constructed in 1996. The digester capacity is 6,000 m^3. Two persons are sufficient to run the plant. One of the main digesters may be viewed on the right. The gas collection dome may be seen on the left. The biogas is cleaned of hydrogen sulphide in the two towers next to the gas collection dome.

Figure 17: Schematic of a typical centralised AD plant, based on the configuration of the Holsworthy plant in Devon, UK.



6.3.3 Potential AD feedstocks in Jersey

Potential feedstocks for AD plant/s in Jersey include the following wastes:

- **animal manure (slurry)**
- **waste potatoes**, between 4500 and 8000 tonnes per year – from packing houses, which used to be composted but are now taken back by farmers and put back to field. The yield of biogas from potatoes through AD is excellent (Ortenblad, 2000).
- **other vegetable packing waste**, 450-500 tonnes per year – AD plants in several European countries receive a gate fee for taking in organic waste such as vegetable waste. However in Jersey the vegetable trimming and packing company, Amal-Grow, disposes of its vegetable waste free of charge to farmers who use it for animal feed.
- **dairy waste** from Jersey Dairy – In 2005 the dairy disposed of 76,774 m^3 liquid waste, mainly water, to the sewer (disposal consent: solids 200mg per litre; pH between 6 - 10). Currently the dairy does not pay a fee for disposing of its waste. The dairy advises that there are no solid dairy wastes produced in its operations.
- **green waste**, 12,500 tonnes per year – currently composted at La Collette in open windrows; may move to in-vessel composting. The States of Jersey sells the high quality compost (20%) as a soil conditioner and pays farmers to take back the remainder. Green waste would not be a suitable AD feedstock if it is woody, ie with a high ligno-cellulose content that cannot be broken down in the AD process. Non-woody green waste would be a suitable feedstock at up to 20% input, and may assist with odour management issues at the La Collette composting area. It would save the States of Jersey the money paid to farmers to take back lower grade compost (80%) but would displace income from the high-grade compost (20%).
- **household food waste** – is used as a feedstock in some European countries where it attracts a gate fee. However in the Jersey context we understand that disposal of commercial and domestic food waste has been controversial, and that the States of Jersey intends to continue incineration of food waste in the energy from waste plant.
- **abattoir wastes** – disposal of the digestate from abattoir feedstocks may be an issue. Pasteurisation of feedstocks prior to anaerobic digestion destroys most livestock diseases such as foot and mouth disease but not Bovine Spongiform Encephalopathy (BSE) which has been present in Jersey.

In addition grass can be used as an AD feedstock. The yield of biogas from grass is good, provided there are no pesticides present as these inhibit the AD process (Ortenblad, 2000). Jersey has a total area of 12,200 vg (2,200 ha) of grassland used mostly for dairy farming. Thus the use of grass in an AD plant would compete with dairy farming, and the economic impacts of growing grass for an AD plant versus for dairy farming would need to be assessed. Given the economic analysis that follows, dairy farming is likely to be far more profitable. As a general observation it seems unlikely that any grass or crop (eg green manure) would be harvested and provided to an AD plant free of charge and hence the underlying economics of the scheme would not be improved.

6.3.4 Feedstocks selected for scenarios

Animal manure (slurry)
We assumed that slurry for a centralised AD plant would come from 2500 of the dairy cattle, and the 6000 laying hens that are kept on deep litter. The Agricultural Statistics 2005 indicates that there were 3200 milking cows. Normally we would assume no slurry collection in summer when cattle are in the field. Information provided by the States of Jersey (John Jackson, Agricultural Advisor) is that slurry is collected from 2500 cows including in summer but at a lower rate - hence the lower figure for manure per day.

The hens are housed above 'deep litter' beds, which build up over the course of the year and are only removed during an annual cull of hens and clean-out of the houses. The manure from laying hens is produced at 30% dry solids but over the year this air dries to approximately 70% solids.

Table 12: Assumptions for slurry feedstocks to a centralised AD plant

Live-stock	Number	Rate of slurry production	Total slurry to AD plant
Cattle	2500 Manure collected in slurry stores for 165 d/yr when housed. Grazed for 200 d/yr.	Housed: 45kg/day per cow at 10% dry solids = 18562.5 t/y Grazing: 15kgd/cow/ at 10% dry solids = 7500 t/y	26,000 t / yr
Poultry	6000 on deep litter	0.115 kg/head/d at 30% dry solids = 250 t/year. This dries to 70% solids over the year =108 t/year.	108 t / yr

None of the pigs (478 in 2005) is housed and so pig manure cannot be readily collected for use in an AD plant. The majority of horses (465 on-farm, 700 in racing or other stables) are kept on bedding including straw, shredded paper and wood shavings. These materials are likely to become mixed in with the manure and may pose particularly problems for the AD plant as they cannot be digested and straw may become wrapped around moving parts of the plant. Also, without the same imperatives that operate on the dairy industry to collect and manage manure, we consider that the regular and free provision of horse manure to an AD plant is unlikely to be guaranteed. For all these reasons we have erred on the side of caution by not including horse manure in the analysis.

Other feedstocks
In this study we consider co-digestion of **waste potatoes**, **other vegetable packing waste** and **dairy wastes** with the cattle and poultry slurry. At first glance it appears that there should not be any cost or other barriers to their use in an AD plant, but this would need further investigation including consultation with producers of these feedstocks. The other four potential feedstocks – green waste, household waste, abattoir waste and grass, are likely to be more problematic for reasons alluded to in section 6.3.3 above.

We understand that Jersey Dairy is due to be relocated and upgraded in the near future, although final decisions are yet to be made. There is not enough space at the current site for the dairy to be upgraded. The imminent move presents a potential opportunity to co-locate the dairy and a centralised AD plant. This scenario is the basis of our analysis as it is considered to be the most feasible option, logistically and economically.

Jersey Dairy has advised that electricity and heat usage at the new plant will approximately halve, on the assumptions that the plant will be more efficient and milk powder production (with a high demand for electricity and heat) will no longer be carried out there. The new plant will also be far more water efficient, cutting water usage by up to 75%. This means that dairy wastes are likely to be reduced from the current 70,000 tonnes per year to less than 20,000 t/year.

Our other assumptions are shown in tables 12 and 13.

We have assumed that farmers agree to provide slurry free of charge and take back digestate (fibre and liquor) for land spreading free of charge. A scheme for a centralised AD plant on the Isle of Wight in the 1990s failed because farmers insisted on charging both for their slurry and for taking effluent from the plant.

The advantage to farmers in receiving the digestate back is that it is a product that has been assayed for its nutrient content and it allows for the rate and time of application to be matched to the needs of the crop receiving the liquor. The pasteurisation step prior to AD also destroys most weeds and pathogens.

An alternative scheme that would also deliver cost neutrality for provision of slurry and disposal of digestate would be to pay a small amount for slurry and charge the same amount for disposal. The advantage of this is that the digestate could be used on crops where there is likely to be more demand for fertiliser than on dairy farms.

Table 13: Assumptions for analysis of centralised AD in Jersey

Parameter	Assumption
Slurry solids content	Current mix at around 7%; could be up to 12% solids content.
Transport	Assumes that farmers are willing to bring slurry to the plant and take the digestate away free of charge.
Hygienisation stage	Pre-digester tank heating slurry to 70°C for 1 hour.
Digester tank	One stirred tank reactor type (e.g. CSTR), ~3300 m^3, constructed off site in steel.
Retention time	20 days (lower retention times may be feasible, but with less yield of methane).
Capital cost	Estimated £2 million (CHP) / £1.9 million (heat only). Includes reception hall and pit, mixing tank, digester, heat exchanger, separation tank, digestate and storage tank, generation set and electricity grid connection (for CHP) / gas boiler (for heat only).
Operation and maintenance	1.5% of capital cost.
Rates and insurance	1.5% of capital cost.
Electricity price	7.2p/kWh (equates to £20/GJ_e)
Heat Price	£8.97/GJ_t
Gas pipeline connection price	£100/m to install
Staff	Two @ £20k/year
Potential grant	£1.5M

The above electricity and heat prices are those currently paid by the dairy, with electricity provided by JEC and heat obtained from fuel oil and gas. In this analysis it is assumed that all of the electricity and heat able to be exported from the AD plant (beyond what is used by the plant itself) can be sold at the above prices. As a minimum, it is assumed that the dairy would be a guaranteed purchaser of electricity and heat in return for free waste disposal through the AD plant.

6.3.5 Yield and economic analysis

Table x presents our assumptions for the annual tonnages of incoming biomass feedstocks and their composition in terms of total, dry and volatile solids (determining methane yield). It shows that the greatest methane yields are from the cattle slurry and waste potatoes.

Table 14: Methane yields from the biomass feedstocks

Incoming biomass	t/y (~m^3/y)	% TS	t DS/y	% VS of TS	% VS of DS	tVS/y	m^3 CH_4/tVS	m^3 CH_4/y
Cattle slurry	26,000	10	2,600	65%	6.5	1,690	210	**354,900**
Poultry manure	108	70	76	75%	52.5	57	285	**16,160**
Dairy liquid waste	20,000	0.08	16	90%	0.1	14	300	**4,320**
Waste potatoes	6,000	12.5	750	80%	10.0	600	400	**240,000**
Vegetable waste	450	20	90	80%	16.0	72	400	**28,800**
Total	**53,038**		**3,532**			**2,433**		**644,180**

TS: total solids, DS: dry solids, VS: volatile solids, CH_4: methane.

To convert this methane to useful energy we investigated two scenarios for the AD plant:
1. combined heat and power (CHP), with a 300kW engine producing both heat and electricity;
2. heat only, using a gas-fired boiler.

The assumptions for the CHP and heat only scenarios are presented in Table x below.

Table 15: Conversion efficiencies and yields for CHP and heat only scenarios

	CHP		Heat only	
m3 CH4/tDS	182		182	
kWh/m3 CH4	9.98		9.98	
kWh/tDS	1816.36		1816.36	
Total Power Yield (kWeh/tDS)	636	35%	0	0%
In-house Power Load (kWeh/tDS)	91	5%	91	5%
Exported Power (kWeh/tDS)	545	30%	0	0%
Total Heat Yield (kWth/tDS)	908	50%	1,453	80%
In-house Heat Load (kWth/tDS)	545	30%	545	30%
Exported Heat (kWth/tDS)	363	20%	908	50%
Loss	272	15%	363	20%

It can be seen that the CHP scenario, a small amount (14%) of the generated electricity is consumed by the AD plant itself. Without a CHP unit in the heat only option, the in-house power demand must be met by buying electricity from the grid.

Table 16: Cost and performance data for CHP and heat only scenarios

	CHP	Heat only
Capital Cost (£)	2,000,000	1,900,000
Grant (£)	1,533,000	1,533,000
Nett Capital Cost (£)	467,000	367,000
Project Lifetime (y)	15	15
Construction/Commisioning (y)	1	1
Plant availability factor (%)	95	95
Running Hours (h/y)	8,322	8,322
Electricity Income (p/kWh)	7.20	-7.20*
Heat Value (£/GJ)	8.97	14.03**
Export - Electricity (MW_eh/yr)	1922	-366
Export - Heat (MW_th/yr)	1282	3687

* no electricity produced so it would have to be bought.
** price required to achieve the same IRR (15%) as the CHP option.

Table x shows the amounts of electricity and/or heat able to be exported from the AD plant, in the CHP and heat only scenarios. Comparing the outputs of the AD plant with the dairy's consumption of heat and electricity:

1. CHP – CHP engines produce a set proportion of electricity and heat. The 1922MW_eh/year of electricity available for export is greater than the dairy's demand for 1600MW_eh/year, while heat production of 1282MW_th/year is not enough to meet the dairy's demand for 2361MW_th/year. This means that surplus electricity would be sold to other user/s and the diary would need to buy another form of fuel for heat (in any case another boiler capable of running on oil or gas is recommended for back-up/peak load);
2. heat only – the AD plant's production of 3687MW_th/year for export is greater than the dairy's demand for 2361MW_th/year, meaning that other user/s of the excess heat would need to be found.

However, as a note of caution, the plant's feedstock supply and therefore output would not be even throughout the year. Output would peak in May and June when most of the potatoes (and hence waste potatoes) are produced. Most of the excess heat in the heat-only option would be produced in summer. Unfortunately the incoming biomass feedstocks cannot be stored to even out supply, as the AD processes start straight away. This would simply create unused biogas in the storage area (and a lower yield of biogas in the digester, per input of already partially-digested feedstock).

Assuming that all electricity and/or heat able to be exported from the plant can be sold, Table 17 presents the financial results for the CHP and heat only scenarios.

Table 17: Cash flow forecast for CHP and heat only scenarios

Cash flow forecast (£/y)		**CHP**	**Heat only**
Credits			
Feedstock Credit		0	0
Electricity Income		138,436	186,271
Heat Income		41,389	0
	Total Credits	179,825	186,271
Debits			
Electricity		0	26,555
Maintenance @	1.50%	30,000	28,500
Rates/Insurance @	1.50%	30,000	28,500
Staff	2	40,000	40,000
	Total Debits	100,000	123,555
Nett Income		**79,825**	**62,716**

In general banks need to see an internal rate of return (IRR) for such schemes of 15% before they consider them to be viable[8]. **Our analysis indicated a negative IRR for the centralised AD plant without a capital grant, meaning that it would be losing money from the start of operations. Clearly, the plant would not be economically viable for energy production alone.** We then undertook a sensitivity analysis. To achieve a 15% IRR required:

- for the CHP scenario, a capital grant of at least 77% of the capital cost (£1,533,000), with electricity and heat at going rates (7.2p/kWh and £8.97/GJ), or no grant and an electricity price of 20.85p/kWh;
- for the heat-only scenario, the same capital grant (£1,533,000) and a heat price of £14.03/GJ.

Of the two centralised AD options considered, **CHP is more economically attractive because the value of the electricity (£20/GJ) is more that twice that for heat (£8.97/GJ).**

It would seem difficult to justify financing such a project purely for energy reasons. However AD can perform a number of other important functions that may be relevant to the Jersey context:

- nutrient management and prevention of water pollution;
- capture and usage of potent greenhouse gases (methane and nitrous oxide);
- odour control;
- waste management;
- plant disease management, through avoiding waste potatoes being returned to land;
- animal disease management, through hygienic treatment of manure (AD destroys some pathogens).

As an example, in Scotland concerns about current slurry management techniques, ground water pollution and hygiene have lead to the Scottish Executive funding six on-farm digesters in Argyll.

If co-location with the dairy is not feasible for whatever reason, then this would have very little impact on methane production: the dairy waste, while a large volume, is mostly water and produces less than 1% of the total methane. A far greater problem would be losing the dairy as a guaranteed purchaser of electricity and heat produced by the AD plant.

Sharing a site with the sewage treatment may enable sharing of the heat and power equipment which would lower costs, although not substantially, as most of the plant and equipment would need to be

[8] Discounted Cash Flow (Internal Rate of Return) - With discounted cash flow methods, the cumulative annual cash flow (C_i at year i) over the lifetime (n) of a project is discounted to determine the net present value (NPV) of the money at a particular interest rate (r) expressed as a decimal; this is calculated from:

$$NPV = \sum_{i=0}^{i=n} \frac{C_i}{(1 + r)^i}$$

The project is viable provided that the NPV $\geq$ 0 at the interest rate chosen. An alternative approach involves calculating the value of r = R such that the NPV = 0. This value R is the so called internal, or real, rate of return (IRR) on the money invested; when comparing different projects the most attractive one is that giving the largest value for R.

separated. We do not recommend that farm slurry and sewage sludge are co-digested as this may cause problems with disposal of the residue if it is applied to land. A centralised AD plant operating under the assumptions set out in this section could produce just under 650,000m^3 of methane per year, around half the amount of biogas (1,200,000 m^3) produced by the existing AD plant at Bellozanne. The difference is that taxpayer funds are provided to Bellozanne in order to perform the essential service of treating sewage, whereas (in the absence of other drivers) an AD plant would be expected to be economically viable for energy production.

Another important consideration for the viability of an AD plant is the long-term prospects for the various agricultural industries on the island. For example, over the period 2001 to 2005 there was a significant reduction in the number of cattle and a significant increase in the number of poultry.

6.4 The European context

The following information about AD is Europe is provided for comparison with Jersey.

Denmark
Figure 16 shows a typical Danish centralised AD plant. The Danish Government supported the building of a number of these plants in the 1980s and early 1990s. These plants were, on the whole, successful technically. They generated biogas efficiently and gave a good energy yield per unit volume of reactor. The plants were used (on the whole) to provide district heating in rural areas where it would not have been otherwise possible. There are a number of differences between Jersey and Denmark:

- The cost of energy in Denmark is high.
- There is a history of district heating in Denmark and in some areas the local residents are given little choice – if there is a district-heating scheme, property must be connected and natural gas is not an alternative.
- Denmark has many intensive farms within short distances of each other. This makes it an ideal area for centralised AD.
- Grants were available to build the plants and targets were set for the number of plants to be built. Since privatisation of energy in Denmark such plants have not faired so well and there is less investment in them today.

Germany
In the early 1990s the German Federal Government made the decision to support anaerobic digestion of farm waste in Germany, using capital grants. The costs of most of the farm digestion plant were in the region of £150,000. The German Government's support for AD allowed the industry to develop simple, robust designs to meet farmer's needs. In the early 1990s additional support through a favourable feed in tariff for any power generated provided the stimulus for AD to become well-established in Germany and there are now more than 2500 plants generating over 500MW power. The feed-in tariffs are guaranteed for 20 years.

The system used for building plants in Germany involved local construction, including the use of the farmer's own labour. Off the shelf pumps and other consumables are used and farmers often work together collectively to build and maintain plants, which decreases costs further. However, the major development that enables on-farm digestion to be economic in Germany is the co-digestion of food and industrial waste for a gate fee. Each digester can take up to 20% of organic waste from these sources and receive a gate fee in return.

The major differences between Germany and Jersey are:

- Capital grants for on-farm AD.
- A favourable, long-term feed in tariff for power generated. The power supply companies are obliged to purchase this power.
- The availability of large amounts of suitable organic wastes from food processing and industry for digestion on farm for a gate fee.
- The development of simple, robust designs that can be constructed by local farmers.
- Consortia of farmers working together on a regional basis, to allow the farmers to buy collectively and decrease the costs of materials and equipment.
- A strong biogas association supporting the work

- Good technical support from the AD industry.

Other experience in Europe
Other countries, such as Switzerland, Austria and Italy also have successful farm digestion programmes. The success of most of these schemes is due in part to them benefiting from one or more of the following:

- State subsidies, particularly for capital cost and favourable tariffs and obligations for the purchase of the power generated.
- District heating schemes.
- Optimised designs based on module construction, so that construction and maintenance costs are minimised.
- Utilisation of serial parts.
- Reduced cost of materials due to collective purchase and construction of farm-scale plants.
- Do-it-yourself construction with the help of engineers.
- Co-fermentation of organic waste from household and industry providing additional income through gate fees and higher gas production
- Availability of proven low-cost, turn-key installations as a result of higher competition among producers.
- Centralised biogas plants.

6.5 Potential markets for biogas in Jersey

Estimate potential annual yields of biogas given existing feedstock and suggest viable end uses of product with respect to successful schemes elsewhere – for example a national bus fleet run on biogas.

A centralised AD plant operating under the assumptions set out in section 6.3 could produce just under 650,000m^3 of methane per year.

Biogas can be used for all applications designed for natural gas. However, the methane content of natural gas is up to about 98% methane, while it is commonly 40-70% for biogas depending on the feedstock. The biogas may need to be desulphurised if it has a high H_2S content. Additionally, it must be chemically 'upgraded' to produce a much higher methane content (around 97%) if it is to be used in the gas distribution network or as a transport fuel. In contrast, boilers and CHP units do not require the high methane content of upgraded biogas.

Table 18: Potential end uses of biogas from an AD plant

End product	Internal use	External use	Options for Jersey
Electricity	AD plant uses 15% of the generated electricity.	Excess electricity fed direct to other users or into the grid.	Likely to be the most feasible scenario. Most could be used by Jersey Dairy with the excess to other users.
Heat	AD plant uses around half of the generated heat.	Excess heat, usually in the form of **hot water**, fed into a district heating network (eg Denmark) or to nearby agricultural or industrial heat users.	Most or all could be used by Jersey Dairy. No district heating network in Jersey; agricultural (eg greenhouses) or other users must be very close to AD the plant.
Heat		Export of **biogas** from the plant to a heat user very close by, to be combusted in a boiler for heat.	Agricultural (eg greenhouses) or other users must be very close to AD plant as gas pipeline installation cost = £100 per metre.

Heat		Biogas 'upgraded' and fed into the gas distribution network.	Possible, but biogas upgrading expensive. Requires gas network.
Transport fuel		Biogas 'upgraded' for use in natural gas vehicles.	Possible, but biogas upgrading expensive. Requires natural gas fleet.

In most European countries biogas is used for heat and/or electricity, feeding into existing grids. In Denmark, hot water generated by AD plants is fed into district heating networks. In the Netherlands, upgraded biogas is fed into the gas network where it is used to heat buildings.

In Jersey, where there is no district heating network and where the price of electricity is double that of heat, the best return on an AD plant is achieved through a CHP unit selling electricity and heat to the dairy.

As set out in section 6.4, the economic analysis assumes that **all** of the electricity and heat, including the surplus, can be sold at the retail rates currently paid by Jersey Dairy. The most logical purchaser would be the diary. This arrangement could be guaranteed through a long-term contract between the dairy and the AD plant (or alternatively the AD plant could be owned and run by the dairy). In return the dairy would continue to benefit from free waste disposal, through the AD plant. Alternatively, receiving a gate fee for dairy waste would improve the economics of the AD plant.

Other users for the surplus electricity (CHP option) or heat (heat only option) would need to be found. The electricity could be exported to the grid if agreed by JEC and any nearby greenhouses, factories or dwellings may be interested in purchasing the heat. However, the cost of transporting heat is high. We know of two UK examples where landfill gas has been piped a short distance to be combusted in boilers in a greenhouse and another at a factory, where the gas pipeline installation cost was £100 per metre.

The sale of electricity and heat at the going retail price may be possible through the introduction of a feed-in tariff or other financial support mechanisms as described in section 4.3.

Besides the dairy scenario (with or without other heat users such as greenhouses), another option considered by the States of Jersey would be to use the biogas for transport fuel, for example in the bus fleet. However this would be less economically attractive because of the cost of both upgrading the biogas and purchasing a natural gas fleet. Upgrading of biogas is the most important cost factor in the production of fuel from biogas (IEA, 2005). Currently, Sweden and Switzerland are the only countries where pure biogas (upgraded) is available as a transport fuel. Sweden in particular has invested heavily in biogas infrastructure for transport. At a regional level, there are bus fleets that run on biogas with 100% biogas available at many refuelling stations. The fuel can be used in any natural gas vehicle. However it should be noted that in Sweden much of the biogas is sourced at low cost from landfills, whereas in Jersey municipal solid waste is combusted in the Energy from Waste plant. The economics of producing biogas from co-digestion AD plants (animal slurry and other organic wastes) are also much more favourable in Sweden as a sizeable gate fee can be charged for waste received at the plant (or waste disposal fee avoided, for AD plants operated by the producers of waste). Sweden's fees for disposing of waste to landfill are around £60/ t, at the upper end of the European range of £40-70 / t.

6.6 Government support for biogas production

Estimate the capital expenditure on infrastructure necessary to produce biogas locally and indicate possible funding mechanisms with reference to successful schemes elsewhere – e.g. public-private funding initiatives, government subsidy

As set out in section 6.3, the capital expenditure required for a suitably sized centralised AD plant has been estimated at £2 million with CHP generation or £1.9 million for heat only, subject to a number of assumptions. This cost includes the reception hall and pit, mixing tank, digester, heat exchanger, separation tank, digestate and storage tank, generation set and electricity grid connection (for CHP) or gas boiler (for heat only). There may be additional electricity grid connection costs, depending on the state of the local grid with which we are not familiar.

The analysis in section 6.3 found that a centralised AD plant would be very marginal in Jersey and would require injection of substantial public funds (a capital grant of £1,533,000), in order to achieve an IRR of 15%.

In Jersey there are currently two support mechanisms that could be applied to biogas production:

- Rural Initiative Scheme: grant-based for rural enterprise; up to 50% of up-front costs
- Countryside Renewal Scheme: capital grants where an environmental benefit can be demonstrated; e.g. up to 66% of the capital cost of larger slurry storages.

As described in previous sections, many of the European countries with a large number of biogas plants have provided financial support in the form of capital grants and feed-in tariffs. A range of support mechanisms for renewable energy is described in section 4.3. A feed-in tariff or other financial support mechanism could be used to guarantee the sale of electricity and heat from an AD plant at the going retail price.

6.7 Key conclusions

1. On farm AD is not considered a viable option in Jersey because of the relatively small herd numbers and the high capital costs as well as operational costs of running many small AD systems.

2. We carried out yield and economic analyses for a centralised AD plant that co-digests cattle and poultry slurry, waste potatoes, other vegetable packing waste and dairy wastes. Such a plant could produce just under 650,000m^3 of methane per year, which could be used to generate electricity and heat (CHP), or heat only.

3. Of these two options, CHP is more economically attractive because the value of the electricity (£20/GJ) is more than twice that for heat (£8.97/GJ).

4. There is a range of possible end uses for biogas. In Jersey the most logistically and economically attractive option considered was for Jersey Dairy to purchase the electricity and heat, with other users to be found for the surplus electricity and/or heat.

5. Centralised AD would give a poor financial return but it may be viable if:

- the States of Jersey is prepared to fund 77% of the capital cost (£1,533,000), and sales of heat and electricity at retail prices can be guaranteed through long-term contracts with the dairy and other consumers;
- all feedstock suppliers are on board, willing to supply feedstocks to the AD plant free of charge (or pay a gate fee);
- environmental benefits are considered major drivers for investing in AD, in addition to the energy benefits.

6. We strongly recommend a more detailed feasibility study is undertaken, with up to date quotes from suppliers, discussions with JEC about electricity connection (for the CHP option) and/or investigation of other potential heat users (heat only option). Consultation with a wide range of stakeholders in Jersey would be required, which has not been possible within the scope of the current study. In particular farmers should be brought into the discussion as their support is vital for any AD scheme to work.

7 Conclusions and recommendations

This report sets out and summarises work undertaken by AEA Energy & Environment as a contribution to the development of an Energy Policy for the States of Jersey.

Our work has addressed two out of five specific Tasks originally defined by the States of Jersey within a comprehensive brief drawn up by the Environment Department. For this reason the report is not intended to provide an overall summary and picture of energy questions across the island, but rather provides data and conclusions relevant to the two Tasks that we were assigned, these being;

- ***Task 1: Exploiting and marketing the natural resources of the Channel Islands (wind and marine energy)***
- ***Task 2: Biofuels and biogas production***

For both of these Tasks we have undertaken a scoping study to identify possible resources, and the opportunities and barriers to using that resource. Our report essentially summarises our findings by technology and/or resource type, for:

- Wind Energy
- Marine Power
- Biofuels
- Biogas

Our key conclusions are as follows:

- On Jersey there is an excellent *onshore wind* resource which could be harnessed to generate significant quantities of renewable electricity. However, as with all wind developments there are also many issues that need to be resolved. If these can be overcome then there is the potential for a small number of utility scale turbines. The next step would be to engage the most relevant stakeholders starting with:
  - Jersey Airport, where a radar study needs to be commissioned
  - Radio communication operators (mobile phones, fixed links etc)
  - States of Jersey Environment and Planning Department (conservation, heritage, other planning constraints).

- *Offshore wind farms* are more difficult to develop than onshore with many more interested stakeholders. Owing to the increased development, construction and operational costs, offshore wind farms tend to be very large in terms of installed capacity to help reduce the overall cost through economies of scale. In light of this, and given the relatively low power demand of the island, offshore wind farms may be unsuitable for Jersey. However co-developing with the other Channel Islands and/or France may make offshore wind farms a more realistic proposition.

- *Wave and tidal technologies* are still in their infancy, which is a relevant factor when considering the scope for projects. There is a good *tidal energy resource* in Jersey, but some other areas of the Channel Islands and the UK have a better resource. Currently the Jersey tidal resource would be marginal for development. In the longer term, when the technology is established and farms in the faster tidal current areas have been installed, developers may turn to areas of Jersey for tidal stream exploitation. The *wave energy resource* is more limited in Jersey mainly due to sheltering effects of France. For all of these marine technologies, proximity to robust grid infrastructure as well as environmental issues relevant to marine energy deployment would need to be considered.

- There are a number of potential sites for the development of *wind and marine* power that appear unlikely to be approved for this purpose due to their sensitive nature and designation as Ramsar sites, Sites of Special Interest or other sites in planning zones with development restrictions. Investigations into the feasibility and possible location of wind and marine energy generating capacity would benefit from *high-level strategic environmental assessment (SEA).* SEA can make valuable contributions to:

- Early identification of areas with presumptions for/against development;
- Identification of environmentally preferred option(s);
- Production of development guidelines for project design, siting construction and operational management practices in relation to a preferred option and/or specific areas, thus assisting the development process for both industry and government;
- Providing information that can be used in subsequent project-level EIAs, which are also helped by the earlier identification of environmentally preferred options;
- Assessment of cumulative impacts of possible individual projects or actions.

- Deployment of renewable energy generation on Jersey at a low level of penetration (energy share) will have a smaller effect on electricity supply and generate less of an intermittency impact, and in this regard will therefore be more manageable than large scale deployment of renewable energy. There are factors suggesting that a low level of renewable energy is more likely, including:
  - *Jersey and Guernsey pay relatively little for their electricity.* It is not foreseeable that unsubsidised indigenous generation of any sort (renewable or non renewable) will be cheaper than French grid electricity.
  - It is envisaged by JEC that *within two years the terms of the interconnector contract will include penalties for not using agreed levels of electricity.* In addition, an indirect form of this penalty already exists: Jersey pays a fixed element in the interconnector usage charges, meaning that these costs are spread more efficiently if more electricity is imported.
  - *A substantial amount of renewable generation probably requires a large offshore wind project, of around 20 large wind turbines* (or more).

- There are a variety of renewable energy support mechanisms available. In the Jersey context, where there is potential for relatively few renewable energy projects and few players, any such mechanisms would need to be adapted and simplified. The *feed-in tariff* or the *tendering process* – or a combination of both – would probably the easiest to implement.

- Much of the agricultural land on Jersey, apart from that growing grass and forage crops, is planted with high value crops of potatoes, fruit or vegetables all returning gross margins (GM) approximately 10 times larger than the potential returns of crops grown for *biofuels*. Given this large disparity, we do not consider replacing these valuable crops with biofuel crops to be a viable option.

- There are a number of possible scenarios for producing biodiesel and bioethanol in Jersey, by growing oilseed rape, wheat and barley. Waste cooking oil and waste potatoes are also potential biofuel feedstocks.

- The scenarios we investigated could produce a maximum 5% share of biodiesel and an 8% share of bioethanol, by weight.

- There is a potential market for *biofuels* on the island. In particular, biofuel blends of up to 5% can be used in conventional vehicles, provided that they meet appropriate quality standards.

- *On-farm anaerobic digestion (AD)* is the simplest approach to this technology. It involves small-scale digestion, on-farm use of heat and power and export of any unwanted power to the grid. Our analysis indicates that avoided costs of heat and power for the farm, and income from surplus sales of electricity, are not sufficient to cover capital and operating costs and therefore such schemes would not be economic.

- We also considered the feasibility of a *centralised AD* plant co-digesting cattle and poultry slurry, waste potatoes, other vegetable packing waste and dairy wastes. Our analysis indicated that the plant would not economically viable for energy production alone under prevailing commercial conditions. A Government grant of just over £1.5 million would be needed to generate an Internal Rate of Return of 15%, assuming that all the electricity and/or heat could be sold at retail prices.

- *Anaerobic digestion schemes* can perform a number of *other important environmental functions* that may be relevant to the Jersey context.

8 References

Baker C, Leach P (2006) Tidal Lagoon Power Generation Scheme in Swansea Bay, A report on behalf of the Department of Trade and Industry and the Welsh Development Agency, April 2006 http://www.dti.gov.uk/files/file30617.pdf

D'Oliveira, Goulder, Lee-Elliott (2003). MacMillan Reeds Nautical Almanac. Nautical Data, UK.

Easson DL, Woods VB, Forbes, EGA (2004). Potential of Cropping for Biofuels in Northern Ireland. Department of Agriculture and Rural Development for Northern Ireland.

European Commission (2005) How to support renewable electricity in Europe?

European Commission (2006) An EU Strategy for Biofuels.

International Energy Agency (2005). Biogas Production and Utilisation.

Mistry, Misselbrook et al. (2005) Assessment of methane management and recovery options for livestock wastes. Report for the UK Department for Environment, Food and Rural Affairs (Defra).

Mortimer ND, Cormack P, Elsayed MA, Horne RE. (2002). Evaluation of the comparative energy, environmental and socio-economic costs and benefits of biodiesel. Defra project NF0422.

Mortimer ND (2006) Assessing greenhouse gas emissions savings from biofuels – recent developments by developers and for policy makers. pp68-84 5th European Motor BioFuels Forum, 11-13 September 2006, Gateshead, UK.

National Non-Food Crops Centre (2006). Biofuels: From Crop to Consumer.

Nix J. (2005) Farm Management Pocketbook. Melton Mowbray, UK.

Ortenblad H, ed. (2000). Anaerobic Digestion: Making energy and solving modern waste problems. AD-Nett, Denmark.

States of Jersey (2002) Island Plan.

States of Jersey (2006): Agricultural Statistics 2005.

States of Jersey (2006): Enabling Biofuels in Jersey to Import and/or Produce.

States of Jersey Meteorological Department (2004) Jersey Weather and Climatological Report.

Tidal Electric Limited (2004) Feasibility Study for a Tidal Lagoon in Swansea Bay, by Atkins Consultants Ltd.

UK Department of Trade and Industry (2004) Atlas of UK Marine Renewable Energy Resources. http://www.dti.gov.uk/energy/renewables/technologies/atlastechnicalreport.shtml

UK House of Commons Select Committee on Environment, Food and Rural Affairs (2006) Eighth Report, Bioenergy.

Woods J, Bauden A. (2003). Technology status review and carbon abatement potential of renewable transport fuels (RTF) in the UK. Research report for UK DTI by Imperial College, Centre for Energy Policy and Technology, London.

Appendices

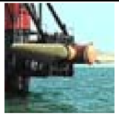
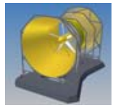
Appendix 1: Jersey Airport letter of objection to the proposed Eolores wind farm

Appendix 2: Current marine technology concepts

Appendix 1

Jersey Airport letter of objection to the proposed Eolores wind farm

Appendix 2 – Current marine technology concepts

	Marine Current Turbine	**Tidal Fence**	**Gentec Venturi**	**Underwater kite**	**Exim**	**Gorlov turbine**	**Lunar**	**TidEL**
	MCTs	Blue Energy (Canada)	Greenheat Systems Ltd	Abacus Controls	Seapower/ Delta/ Stromturbiner	GCK Technology	Lunar/Rotek	Hydrovision
Criteria								
Peak spring (m/s)	2.25 to 2.5 m/s	>1.75 m/s	0.5 m/s	2.5 < m/s < 5	>2.6 m/s	>0.76 m/s	Not available.	>2.5 m/s
Peak spring (knots)	4.5 to 5 knots	>3.5 knots	1 knot	5 < knots < 10	5 knots	1.5< knots <12	Not available.	>5 knots
Power out per device	500 to 1000kW	5 kW to 8000 MW	12.5Mwcontinuous (@7.5 knots)	90kW (@5 knots)	4 x 30 to 60kW	1kW (@1.5 knots).	1.5, 2.5 and 5 MW	1MW unit (twin)
Depth / Location flexibility	20 to 30 metres.	Not available.	>30m, but no major limits on how deep.	Depends on moorings.	Not available.	Depends on moorings. 15m+	Min 20 to 30m.	Can be installed in deep water. Must be > 30m .
Ease of installation	Requires jack up barges and monopiles	Barge likely for concrete caisson.	Moorings - anchor handling vessel.	Anchored to seabed or attached to existing structures.	Moorings.	Moorings/fix to existing structure.	Gravity foundation (self fixing).	No jack-up barge – moorings.
Ease of maintenance	Turbine raises to surface (no underwater effort)	Major parts on surface (easy - no underwater effort).					Removable section lifts to surface	Lifts to surface - no underwater effort
Project advancement	Currently 300 kW prototype in Devon. Model of 2 x 500kW. There are plans to build 10MW commercial scale project in Anglesey and a 1MW device in Northern Ireland's Strangford Lough.	100kW prototype tested in 80s, 500kW pre-commercial unit near British Columbia. Plans for full-scale 50MW fence in Philippines.	0.6m aperture system tested in Grimsby. Large-scale demonstration expected soon. Commercial power station to be built in Iceland?	40 ft wide twin-turbine will be deployed in the Gulf Stream off Florida. The 120-kilowatt system also works in tidal basins and rivers.	Prototype turbine used to find best site for tidal generator for Shetland grid. Final evaluation of locations with good streams. 1st production unit 2004.	Installing permanent turbine array off South Korea – to generate 100MW. Plan to install 6 twin turbines in vertical, side-by-side arrangement.	A 1/20th model was tested in April 2004, and a 1MW prototype is expected in 2005, with commercial launch as soon as 2006. Recent DTI grant of £5.66m received.	Testing on a 1/10th model testing has been carried out with DTI funding. Full size unit planned for 2006.
Pitch/yaw/self positioning?	Pitch mechanism to reverse flow.	Pitch mechanism.	Fixed rotor. Self aligning	Fixed rotor. Self aligning	Not available.	Fixed rotor. Self aligning	Fixed rotor. Accepts tidal flow offset by 40 degrees.	Fixed rotor. Self aligning
Shipping Channel Impact	Boats will not be able to sail in farm areas.	Can be built as bridge (but will disturb shipping traffic).	Potential to install in deep water without affecting shipping.	Boats will not be able to sail in farm areas.	Boats will not be able to sail in farm areas.	Boats will not be able to sail in farm areas.	Potential to install in deep water without affecting shipping.	Boats will not be able to sail in farm areas.