Strategic Tidal Stream Assessment for Alderney

Report to Alderney Commission for Renewable Energy

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Executive Summary

The Alderney Commission for Renewable Energy (ACRE) is a body set up by the States of Alderney to license, control and regulate all forms of renewable energy within the island of Alderney and its Territorial Waters. ACRE commissioned AEA to prepare a strategic assessment of the impact on the island and its community of tidal and/or wave energy development within the Territorial Waters. This report examines the technical implications of using these technologies and the environmental and socio-economic impacts of such a development.

This strategic assessment is based on an open centred, bottom mounted tidal stream generator developed by OpenHydro. Although the focus of this assessment is based on OpenHydro's technology other possible tidal stream and wave power technologies have been reviewed. It was not possible to cover all of these technologies in the same level of detail as OpenHydro's technology, but the main differences and similarities have been highlighted.

The report is intended to inform ACRE of the key issues and implications of tidal energy development, particularly at a large scale. It considers the impact of the technology based on two very large hypothetical developments within the Territorial Waters, one of 1GW and a larger one of 3GW, both located in the Alderney Race. The report will enable ACRE to evaluate the overall cost/benefit of the full scale development and to ensure that necessary controls and conditions are in place before any long term licence is granted.

Strategic Techno-economic impacts

Most tidal stream device concepts are based on horizontal axis turbines although some vertical axis devices and even oscillating hydrofoil concepts have been proposed. Devices would be secured to the sea floor by piles, bolted or rely on gravity. Some devices are bottom mounted and operate close to the sea floor. Deployment and retrieval would require cable connection from a surface vessel to either lower or raise the device to the surface before transfer to or from a shore base. OpenHydro's device and at least one other rival concept use this principal. Other devices rely on a surface piercing pile foundation to raise or lower them from or into the sea before detachment. A further permutation is a floating device anchored to the sea floor via cables.

The projected capital and operating costs and energy capture are highly uncertain as these technologies are still in an early stage of development. Estimates should therefore be treated with some caution. Few devices have advanced to a prototype stage and only limited trials have been achieved in the open sea. OpenHydro has been testing a small test device for 12 months, but performance data have not been released.

The most logical export market for large scale tidal energy development is France. Exporting power to the UK would require a 100 km DC link, four times the distance to France.

Wave Energy

The economics of wave energy devices depend strongly on the annual average power density at the chosen deployment site. The capital and operating costs of a facility are fixed but the revenue depends on the energy input from the waves, i.e. on the power density.

Wave power density is around 10-15 kW/m which is too low for the technology to operate profitably. A 10 km array might be able to generate between 438 and 657 GWh/year.

In conclusion, Alderney's wave energy resource is much smaller than its tidal resource, although it would be large enough to supply around half of the Channel Islands needs, provided that the devices could be operated profitably. However, the annual average power levels are too low to enable the current generation of wave energy converters, and possibly the next too, to operate profitably.

Strategic Environmental impacts

A 1GW array could potentially reduce CO_2 emissions by between 360,000 te(CO_2) and 700,000 te(CO_2) per year), through displaced fossil fuel generation.

Reviews of environmental issues have identified a number of potential impacts that could arise during the installation and operation of tidal stream devices and cable laying. These impacts include disturbance to sediment, noise and vibration linked to drilling, adverse effects to fish caused by Electro Magnetic Forces (EMF) and collision risk with marine mammals. Potential changes in tidal currents in the vicinity of devices may change sediment dynamics and the local benthic ecology. There may also be indirect effects on sea birds, if for example, their prey was disturbed. However, there is a lack of evidence on the scale of these possible impacts. Preliminary research has been commissioned to evaluate some of these issues. Environmental monitoring of prototype devices is also planned to establish a better picture of potential impacts.

It is possible that some environmental impacts may be limited in the case of Alderney. The impact of sediment disturbance during cable laying could be minimised by the natural rapid dispersal of the sediment. The use of gravity based foundations, such as structures that would be used by OpenHydro's open centred turbine, would not require drilling to secure them to the sea floor. This would avoid one source of noise and vibration. In contrast, other tidal energy technologies rely on drilling to secure foundations to the sea floor. The resultant noise could cause temporary disturbance to fish and marine mammals.

There is evidence from the offshore wind industry that structures implanted into a marine environment act as artificial reefs, attracting some species of fish, crustaceans and other invertebrates. However, the extent of the colonisation associated with tidal stream devices is not known.

It is recommended that tidal energy development around Alderney would benefit from generic environmental research in the following four areas:

- Assessment of the potential impacts related to energy depletion from a large tidal stream device scale array.
- Assessment of the potential impact of tidal stream energy on sea birds and their prey.
- Review and assessment of the impact of EMF from submerged cables and tidal stream generators.
- Review and assessment of the potential for tidal stream devices to induce colonisation and increase biological productivity.

Strategic Socio-Economic impacts

Financial Benefits

Revenue to the States of Alderney from seabed rental could be between £0.93M and £1.87M per annum from a 1GW array depending on the amount of electricity generated. A 3GW array could yield between an annual income of between £2.8M and £5.6M.

An estimated 6,149 tonnes of CO_2 emissions from the use of fuel oil generated electricity could be saved if tidal energy replaced the island's existing power plant.

Complete electrification of the island would displace the equivalent of an estimated 3,176 tonnes of fuel oil at a cost of £1.9M. The cost-benefit to the island would depend on the cost of tidal energy as well as the cost of fuel oil. Assuming a cost of €150/MWh or £0.144/kWh for tidal energy the cost of supplying the bulk of the island's energy demand (excluding transport) would be £6.4m/year or more than three times the cost of saved fuel (at 2006 prices). Therefore, with a tariff of £1.07/MWh and tidal cost of £0.114/KWh complete electrification would only be economic if the oil price were to reach three times the 2006 level, and would become increasingly so with further rises in the price of oil beyond that.

Fishing

Fishing is an important tourist industry for Alderney contributing up to 5% of the island's tourist income. There is also a small but important commercial fishing industry that includes lobsters and crabs as well as fin fish.

Fishing grounds near Alderney and the Casquets are often located on large sand banks. Although these areas are unsuitable for tidal energy developments, the management of fishing vessels and those involved in tidal energy development would need to be carefully controlled to avoid collision. There is also the possible potential for temporary disturbance to fishing grounds.

Navigation

Large bottom mounted devices possibly up to 2MW in size could be deployed in the Race in less than 40m depth. Devices of this size occupy up to 20m of water leaving less than 20m clearance above the device. This is potentially too shallow for large commercial vessels therefore a permanent exclusion zone would need to be applied. The use of pile mounted, surface piercing structures, or floating devices, would present obvious navigation hazards and would require a permanent exclusion area. They would also create some visual impact. Smaller bottom mounted devices (<2MW) would occupy less depth, allowing the safe passage of large commercial vessels. They would, however, generate less energy.

During construction, and to a lesser extent during operation, there would be an increased presence of vessels operating from both Cherbourg and Braye Harbour.

Tourism and Recreation

Alderney is heavily reliant on tourism and any large scale infrastructure development would need careful consideration to avoid changing the island's character.

Tidal energy development could have some impact if a large substation was built on the island. However, if this facility was located in Mannez Quarry it would be largely concealed from the rest of the island. Electricity generated from a tidal energy array in the Race could be transmitted directly to France avoiding the development of large substations on Alderney. Surface piercing technologies would create some visual impact depending on their proximity to the island creating some modification to the seascape. There is also the potential for conflicts of interest between developers and those involved in recreational pursuits.

The active promotion of the technology would create added interest for tourists, particularly if there was a dedicated visitor centre.

Employment

During construction of a large scale array an estimated 130 personnel could be directly involved in tidal energy development. This does not include pre-construction activities such as resource assessment, environmental monitoring or survey work. Most of the work force would need to be based in Cherbourg but up to ~24 could be based on Alderney. These estimates do not include additional service related jobs generated by the presence of migrant workers.

Buildings and Infrastructure.

Alderney is a small island of only 11 km^2. Much of the land area has either protected conservation status or has specific land use designations which permit only limited development. Any new infrastructure on the island would, therefore, be subject to stringent planning requirements which may limit the extent of any land based facilities.

Installing subsea cables will also need careful consideration. Longis Bay on the east coast might be a possible route for cables linked to an array in the Race. However, this location has a sensitive sublittoral habitat. One possible solution would be to run the cables along the side of the existing causeway to Raz Island.

New supplementary accommodation might also be necessary for construction personnel.

Table of contents

1 Introduction

The Alderney Commission for Renewable Energy (ACRE) is the body set up by the States of Alderney to license, control and regulate all forms of renewable energy within the island of Alderney and its Territorial Waters. ACRE has commissioned AEA to prepare a strategic assessment of the impact on the island and its community of tidal and/or wave energy development within the Territorial Waters. This report examines the technical implications of using these technologies and their environmental and socio-economic impacts.

The States of Alderney owns the seabed beneath its Territorial Waters, which extend three nautical miles from Alderney and its offlying islands of Burhou and the Casquets. The accessible Territorial Waters have been subdivided into 92 Blocks of one square nautical mile, each of which would be separately licensed for development by ACRE (see Figure 3.1).

In December 2005 the States signed an Agreement with a local company Alderney Renewable Energy (ARE) granting it exclusive access to the Territorial Waters for a period of five years to research, survey and test marine devices for the purpose of electricity generation from Alderney’s tidal and wave resources. Subject to ARE and its technology partner(s) meeting certain targets and to other conditions precedent, the Agreement provides that ARE will be granted a Master Power Generation Licence giving it exclusive access to fifty percent of the Blocks for a minimum of fifty years. ARE is currently working on a commercial tidal power project with technology developer OpenHydro, using that company’s open-centre turbine technology. To demonstrate the engineering and commercial viability of the technology ARE and OpenHydro plan to deploy three or four tidal turbines off the south coast of Alderney during 2009. This test deployment was originally planned for the Swinge, but that site was found to be less suitable due to the turbulence of the currents.

This strategic assessment is based on an open centred, bottom mounted tidal stream generator developed by OpenHydro. Although the focus of our work is based on OpenHydro’s technology we were asked to consider the full range of possible tidal stream and wave power technologies. It was not possible to cover all of these technologies in the same level of detail as we did for OpenHydro, but we have highlighted the main differences and similarities.

The report is intended to inform ACRE of the key issues and implications of tidal energy development, particularly at a large scale. It considers the impact of the technology based on two hypothetical developments within the Territorial Waters, one of 1GW and a larger one of 3GW, both located in the Alderney Race. The report will enable ACRE to evaluate the overall cost/benefit of the full scale development and to ensure that necessary controls and conditions are in place before any long term licence is granted.

The report is divided into four main sections.

Section 2 outlines the current status of both tidal current and wave energy technologies. The report describes different concepts that are currently under development and compares the advantages and disadvantages of these technologies.

Section 3 covers the techno-economic evaluation of tidal energy development assuming two different scenarios. Firstly, a 1GW development and secondly, a 3GW development, in the Race. The implications of a smaller scale option assuming supply to the other Channel Islands as well as Alderney have also been considered. These evaluations have been based on an OpenHydro open centred bottom mounted turbine deployed in arrays consisting of 2MW units. The economic evaluation has been based on information supplied by OpenHydro specifically the performance of these devices and the capital costs. The section also examines the implications of exporting power directly to the French mainland and the UK.

There is a short section on wave energy as a potential power supply for Alderney.

Section 4 covers the strategic environmental impacts. It briefly describes the marine, nearshore and shoreline habitats of Alderney and Burhou and the main fauna and flora recorded. The key environmental sensitivities are then highlighted and the potential impacts that tidal energy development may cause.

The potential implications for carbon emissions generated as a result of development are discussed assuming 1GW and a 3GW schemes. The overall global benefit from carbon savings as a result of displaced fossil fuel generation have been quantified.

There is a short section on the implications for the cultural heritage of Alderney, particularly ship wrecks.

The concluding section is a review of existing research on the environmental implications of tidal current energy and recommendations for additional work which may need to be commissioned.

Section 5 reviews the socio-economic implications of tidal energy development for Alderney. The section is subdivided into six key areas:

- Financial benefits
- Fisheries
- Shipping and navigation
- Tourism and recreation
- Job creation
- New buildings and infrastructure

In each of these subsections there is a brief description of the existing conditions. The implications of tidal current development are then discussed assuming development at a scale of 1GW and 3GW. The impact of development has been based on estimates of manpower and equipment provision from OpenHydro. The magnitude of the impact has also assumed that these developments would be phased.

2 Introduction to tidal and wave technologies

2.1 Tidal current technology

2.1.1 Technology status

Tidal-current energy is the direct extraction of kinetic energy from naturally occurring tidal currents in the open sea.

Strong tidal currents are most frequently found near headlands and islands. Energy can be extracted using devices that move in response to the forces the current exerts, and use this movement to drive an electrical generator.

The majority of tidal current energy collectors are horizontal axis turbines, which look and operate like underwater wind turbines. There are, however, several other types, most importantly vertical axis turbines, which have long straight vertical blades that sweep out the shape of a cylinder as the turbine rotates. Oscillating hydrofoils and venturi devices have also been tried, but are more complex and have only been taken up by a small number of developers. It should be stressed that this technology is at an early developmental stage. Most concepts are still in the initial research and development phase and most have only been evaluated under laboratory test conditions. However, some concepts have now advanced to prototype trials in the open sea, although very limited performance data have been published.

Apart from the nature of the collector itself, the biggest difference between device concepts is in the way they are held stationary in the moving water. Methods under development include:

- a vertical steel tube cemented into a socket drilled into the seabed;
- a heavy concrete base resting on the seabed and held in place by its own weight;
- a tripod or other support structure bolted to the seabed;
- a “tension-leg” system similar to that used on some oil platforms;
- a turbine suspended from underneath a floating pontoon held in place by chains and anchors.

Some tidal turbine concepts also have flow modifying structures, such as ducts or cowls, surrounding them.

Some devices have a fixed orientation but others have “yawing” mechanisms so they can orientate themselves to the direction of flow. This is useful if the ebb and flood current directions are not 180° apart.

The long-term economic prospects for tidal-current energy are still highly uncertain. Although a large number of device-concepts have been researched, only a small number have reached full-scale prototype testing at sea, none have operated for more than a few days with the exception of OpenHydro’s open centred turbine. The company has reported that a small scale test device has been operating for 12 months in a marine environment at the European Marine Energy Centre (EMEC) on Orkney. This device is much smaller than the devices envisaged for commercial operation. The full scale generation capacity of the turbines and their size has not yet been determined for Alderney. For the purposes of estimating the power output in this study a turbine size of 2MW has been assumed. Operating performance data are strictly confidential and have not been released to AEA. The technology must therefore be viewed as one that is still in its R&D stage.

There are several potential challenges on the path to commercialisation. These are:

- Demonstrating a reliable and safe method of installing devices in moving water;
- Operating the devices for extended periods with high levels of availability;
- Reducing the generating cost;
- Decommissioning.

2.2 Wave energy technology

2.2.1 Technology status

Wave energy is the extraction of useful energy from the motion of water in surface waves on the sea. Wave energy devices are usually designed to generate electricity, although their use to directly drive water desalination plant has also been suggested.

Waves contain energy by virtue of their motion and elevation. In a wave energy device, the waves exert forces on a moving *collector element*. This is a large structure whose shape varies from one device concept to another. Spheres, cylinders, doughnuts, paddles and other more complex shapes have all been used. One of the first wave devices to be developed, the *oscillating water column*, uses a column of air as its collector element.

The collector element is connected, via a *power take off system* to a *reaction source*, which could be the seabed, a large inertial mass or another collector element that moves out of phase with the first. The power take off system converts the relative motion of the collector element and the reaction source into a usable form of energy, usually electricity.

The most common type of power take off system is a *hydraulic circuit* where the motion of the device pumps fluid to a hydraulic motor that drives a rotary electrical generator. Onshore power generation using conventional hydropower turbines powered by high pressure, wave pumped sea water is also under consideration. However, an increasing number of device developers are investigating the use of direct drive *linear generators*. Wave energy device concepts differ from each other mainly in the following ways:

- type of collector element
- type of reaction source
- type of power take-off system
- type of mooring system
- the intended location of the device (such as shoreline, near shore or offshore, floating or bottom mounted and so on)

There is a large number of potential permutations of these characteristics and this has led to the development of many different device concepts.

In the last few years a large number of other wave energy device development companies have been set up, each with its own unique patented device concept, and over 40 companies can be found on the internet.

One of the best known is the Edinburgh-based company Pelamis Wave Power formerly known as OPD. This company has been developing the Pelamis wave energy converter which, after 10 years of R&D, appears to be on the verge of installing its first multi-device farm. Pelamis consists of three power conversion modules linked by hinged joints to cylindrical sections. The wave induced motion of these joints is resisted by hydraulic rams which pump high pressure oil through hydraulic motors linked to electrical generators. The device is designed to maximise power capture from waves whilst maintaining system reliability and survivability.

Despite this long history and multitude of devices and companies, the present development status of wave energy is roughly the same as that of tidal-current. To date, several full-scale prototypes have been built but have only operated for short periods of time. Very limited operating data have been published apart form the LIMPET test device on Islay. As yet there are no operational wave energy facilities generating continuously.

The principal technical challenges facing wave energy are:

- operating for extended periods and achieving high levels of availability;
- confirming energy output predictions and validating theoretical models;
- safe installation and retrieval;
- reducing generating costs by reducing capital and operating costs and enhancing power output;

- decommissioning.

2.2.2 Environmental issues

Wave energy facilities are likely to have some environmental impacts that are similar to tidal current energy, although no systematic study of them analogous to the one for tidal-current energy has been undertaken. Possible impacts include:

- Direct disturbance of the seabed, benthic ecology and marine mammals during installation;
- The potential collision risk associated with diving birds and marine mammals;
- Potential changes in the wave dynamics in the vicinity of the device due to the removal of energy from the waves, resulting in changes in coast erosion and sedimentation dynamics;
- Acoustic emissions from the operating devices could disturb migrating or resident cetaceans, pinnipeds and other marine animals;
- Visual Impact;
- Navigation hazards.

3 Strategic Techno-economic impacts

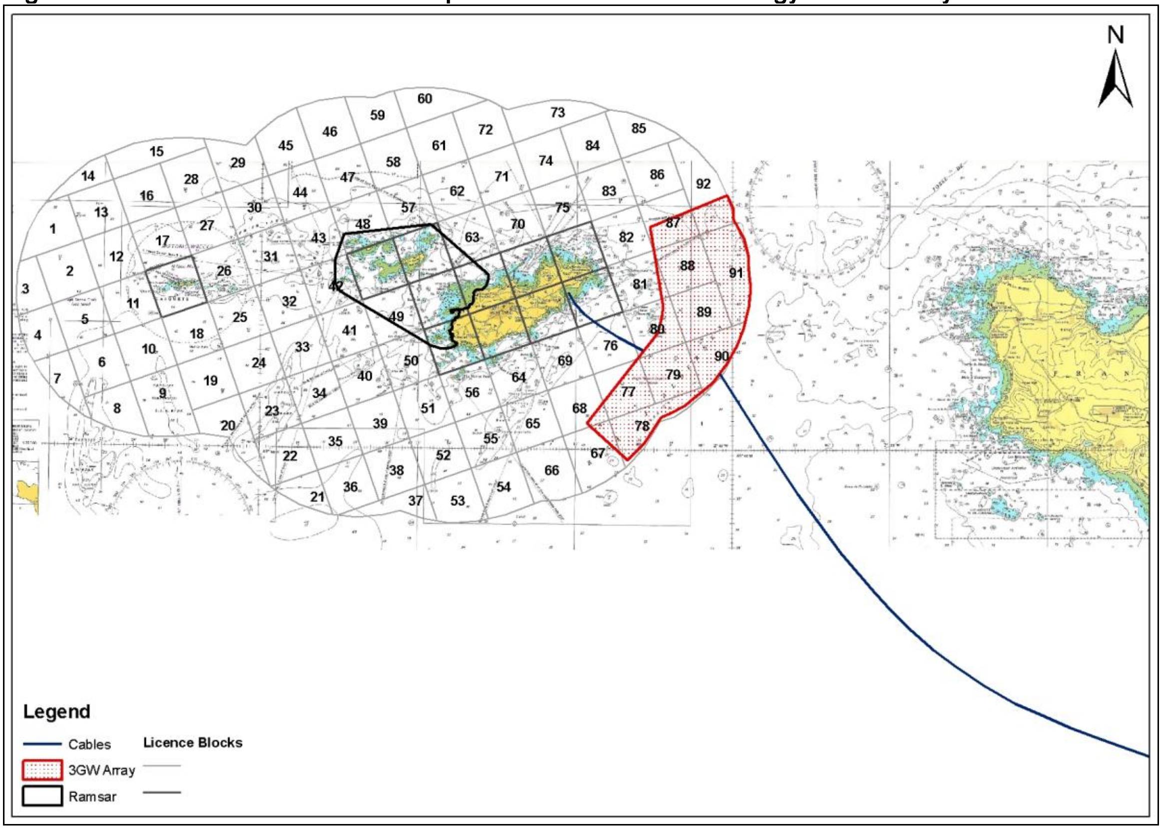
3.1 Technical and economic assessment of tidal current technology

3.1.1 Tidal current resource

The Race of Alderney and the Swinge are well known locations for strong tidal currents induced by the morphology of the island and its proximity to the French mainland. The development of this form of tidal resource is attracting growing interest in the UK where this phenomenon is observed. The developer, Alderney Renewable Energy (ARE), has expressed particular interest in the Race of Alderney although it has also review the potential of the Swinge. The company has a small trial area to the west of Alderney where it originally planned to test its devices. Sea bed conditions were found to be less suitable and ARE and its technology partner are now planning to deploy three or four devices in a new trial area in the Race in 2009.

Development of a tidal energy resource on the scale of 1GW – 3GW would entail a significant seafloor area. The company has indicated that a resource of 3GW within Alderney's 3 nautical mile territorial limit would require 24km^2 as depicted in Figure 3.1.

Figure 3.1 Potential area for the development of a 3GW turbine energy turbine array



The possible cable routes to the French mainland and Alderney are shown as blue lines. OpenHydro has commented that discussions between ARE and Électricité de France (EdF) have established Flamanville as the closest viable point for a grid connection of a tidal energy development at this scale.

3.1.2 Tidal current technology

OpenHydro's technology

OpenHydro has developed a tidal energy technology based on a fixed bladed turbine that is encircled by the generator stator, as depicted in Figure 3.2. The device is comprised of a tubular frame mounted on a tripod. It is secured to the seafloor by gravity. This concept has the advantage of avoiding drilling, piling or other anchorage technique which rival device developers favour. Alternative installation methods are currently under development. Any comparison between OpenHydro's device and other concepts must, therefore, be treated with some caution.

The open centre turbine was first developed in 1995. OpenHydro claims that several large scale prototypes have been tested in a marine environment since that date. In 2006 OpenHydro completed installation of the first tidal turbine (250 kW) at the European Marine Energy Centre (EMEC) in Orkney. This test device is mounted on piles to enable frequent and rapid access. This configuration would not be used, however, for large-scale commercial deployment. Following 12 months of testing OpenHydro upgraded this turbine. Performance data remain confidential and have not been released.

A 1GW array would comprise of 500 turbines connected to the shore by 25 separate subsea export cables.

A 3GW array would require three times the number of cables. This configuration would allow continued operation if one or more sub-arrays either fails or has to be shut down. Clearly this number of cables and associated onshore substations would have a significant footprint. This aspect of development is discussed in more detail in Section 5.

Other tidal technologies

There are over 20 tidal device concepts being developed around the world.

The majority of these are at very early stages of development.

One developer, Marine Current Turbines Ltd (MCT), www.marineturbines.com, based in Bristol, has previously deployed an experimental device, Seaflow off the coast of North Wales. They recently installed a much larger prototype in the Strangford Narrows. A small number of others, principally Lunar Energy, and Tidal Generation Ltd (TGL), are less well advanced than MCT but more so than the majority.

Marine Current Turbines

MCT's device is horizontal axis turbine mounted on a foundation that resembles an underwater wind turbine. MCT has been developing this device since the late 1990s.

The company's 300kW prototype device in the Bristol Channel was deployed 3.5 km north of Lynmouth on the north Devon coast in June 2003. At the time of writing, the machine has not yet been decommissioned and is still in position. Seaflow is an experimental device and has only generated electricity during a small number of test runs. It was operated in a series of short tests to evaluate the performance of the device [3.1].

MCT has constructed a 1.2MW twin rotor machine called SeaGen which it has recently installed in Strangford Narrows, Northern Ireland. This machine will be grid connected and will operate on a commercial basis.

SeaGen was designed to be mounted on a vertical "pile" - i.e. a steel tube, approximately 3m in diameter, cemented into a hole in the seabed. Because of problems with the availability of suitable jack-up barges that would be needed to drill the hole in the seabed and install the pile, MCT has changed the design to one in which a shorter pile is attached to a four legged "quadrapod" structure that rests on the seabed and is held in place by bolts. It is not clear whether this is a one-off solution to a specific problem or whether MCT will adopt this approach on all future installations.

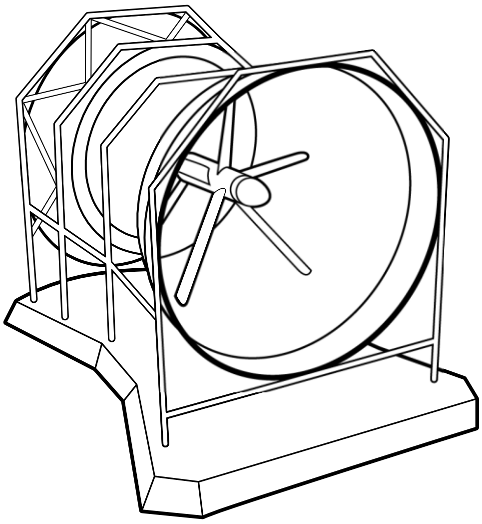
MCT has stated that its technology can only be installed in water depths up to around 25m. Although the Race of Alderney does contain some areas that are shallower than this, the majority is deeper and so would not be accessible to an MCT-style device.

MCT's device is also surface piercing, which may have implications for navigation and visual impact - especially for a large-scale farm with many hundred's of devices.

Lunar Energy

Lunar Energy Ltd has developed a ducted turbine on a concrete gravity base. The device is intended to occupy the bottom of the water column.

To date, Lunar is in the process of building its first prototype device for testing at sea. It recently announced a partnership with E.On to develop a multi device facility in Pembrokeshire [3.2]. The size of the farm has not been officially announced but press reports say that it will consist of eight devices [3.3].



Tidal Generation Ltd (TGL)

TGL was set up in 2005 by former MCT employees. It is working on the development of a tripod mounted turbine for deep water sites. The nacelle which houses the power train and the turbine can be detached from the tripod foundation so that it can be raised to the surface for rapid recovery. The process is reversed when the nacelle and turbine are redeployed. The device is designed for deployment in deep water +30m in depth. The company is currently planning to deploy a 500kW prototype at EMEC during the Autumn of 2008.

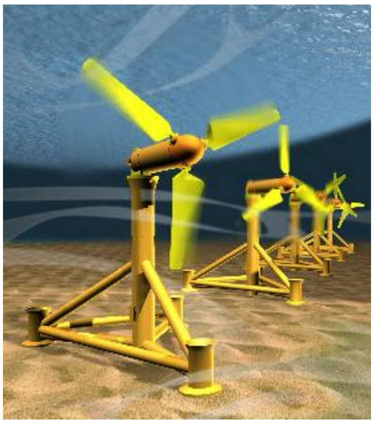


Table 3.1 below lists some key differences between the MCT and Open Hydro device concepts.

Table 3.1 - key differences between OpenHydro and some other device concepts.

	MCT	**Lunar Energy**	**TGL**	**TidEl**	**Open Hydro**
No of blades	2	7	3	2	16
Solidity[1]	Low	Low	Low	Low	Very high
Duct	No	Yes	No	No	Yes
Power take off	Conventional gearbox driving conventional electrical generator contained in a nacelle.	Rotor drives hydraulic pump that drives a generator contained in an attached pod.	Conventional gearbox driving conventional electrical generator contained in a nacelle.	Conventional gearbox driving conventional electrical generator within two buoyant nacelles.	Circumferential generator with rotor attached to the blades and stator in the surrounding duct.
Support structure	Vertical steel tube (pile) ≈ 3m in diameter either cemented into a hole in the seabed or attached to a tripod or quadrapod structure resting on the seabed.		Vertical pile on top of a tripod structure bolted to the sea floor.	TidEl consists of a pair of buoyant turbine/generators that are fixed together by a cross beam and secured to the seabed using a mooring system.	Tubular steel gravity base resting on the seabed.
Position in water column	Rotor occupies as much of the water column as possible, with a few metres clearance between the bottom of the rotor and the seabed, and the top of the rotor and the Lowest Astronomical Tide (LAT).	Rotor occupies a small proportion of the water column near the bottom.	Bottom of water column	Suspended within the water column. Rotors occupy central section between the surface and seabed.	Rotor occupies a small proportion of the water column near the bottom.
Surface piercing	Yes	No	No	No	No
Deployment location	Relatively shallow water up to 25 - 30m depth.	not stated, probably deep water	Deep water > 30m	not stated, probably deep water	Not stated.

[1] Solidity is defined as the proportion of the area that a device turbine blades occupy as a proportion of the total area they operate through.

Deployment and operation

The choice of turbine technology could have implications for deployment and operation. This will mainly depend on the type of support structure that is used to hold the turbine in place. These can be divided into four categories:

- **Pile mounted** - as in MCT's device, described above.
- **Gravity base** - which relies on its own weight to keep it in place on the seabed. OpenHydro and Lunar energy are of this kind.
- **Bolted base** - similar to a gravity base, but lighter and held in position by bolts drilled into the seabed.
- **Moored floating structure** - the turbine is suspended underneath a floating pontoon, which in turn is held in place by chains or ropes anchored to the seabed.

Two other possible fixing methods are the suction caisson and the tension leg system, but to date no tidal turbine device concept has been proposed that would use either of these methods. Table 3.2 below lists the advantages and disadvantages of these four fixing systems.

Table 3.2 - advantages and disadvantages of different fixing methods for deployment and operation

	Advantages	Disadvantages
Pile mounted	Enables the turbine to be sized so as to occupy almost the entire water column, from a few metres above the seabed to a few metres below LAT, thereby maximising energy capture. Rotor can be raised above the surface for access. Top of pile above the water surface could make the turbine clearly visible to other vessels.	Requires a jack-up barge, which limits the depth in which it can be installed. Jack-up vessels cannot operate easily in fast currents. Surface piercing structure could pose a navigation hazard. Some visual impact from surface piercing concepts. Decommissioning could be a significant challenge.
Gravity base	Can be installed by simply lowering to the seabed. Tends to occupy a small proportion of the water column near the bottom, depending on the depth, this could allow sufficient clearance for vessels to sail over.	Requires heavy lifting vessels to cope with the weight of the base. Decommissioning could also be difficult. Near the bottom of the water column the turbines will see lower velocity currents than near the surface. Even if there is technically sufficient clearance for overhead navigation, it may still be designated as a hazard.
Bolted base	Lighter than a gravity base, enabling smaller cranes and vessels to be used for deployment.	Requires seabed material capable of holding the bolts. Decommissioning could require divers or ROVs to break the bolts. Near the bottom of the water column the turbines will see lower velocity currents than near the surface. Even if there is technically sufficient clearance for overhead navigation, it may still be designated as a hazard.
Moored floating	Enables the turbine to harvest energy from the top of the water column where the current is faster. Turbine can be towed into place without the use of specialist lifting vessels. Easier to access for maintenance. Easy to decommission. Floating structure on surface would be clearly visible to other vessels.	Floating structure on surface could pose a navigation hazard. Decommissioning would require ROVs or divers to detach cables from anchorage points on the sea floor.

To date, there is virtually very limited practical experience in using any of these systems and, as yet none at full scale within the UK. This is needed before a definitive view can be formed on their relative merits.

These technologies are still in an early stage of development. A report [3.4] published by the Renewables Advisory Board on the status R&D marine renewable energy technologies that had received grant support from the Department of Business and Regulatory Reform concluded:

- that the technical challenges are much greater and more difficult that originally envisaged;
- BERR R&D projects have not delivered extended continuous testing of full-scale prototypes, because of extensive delays to projects;
- some developers have also been distracted by external factors including requirements for permits and environmental assessments;
- current generation cost estimates are still relatively uncertain because of the lack of progress and disclosure of information.

Consequently R&D is taking much longer than expected, although good progress has been made.

3.1.3 Tidal stream resource assessment

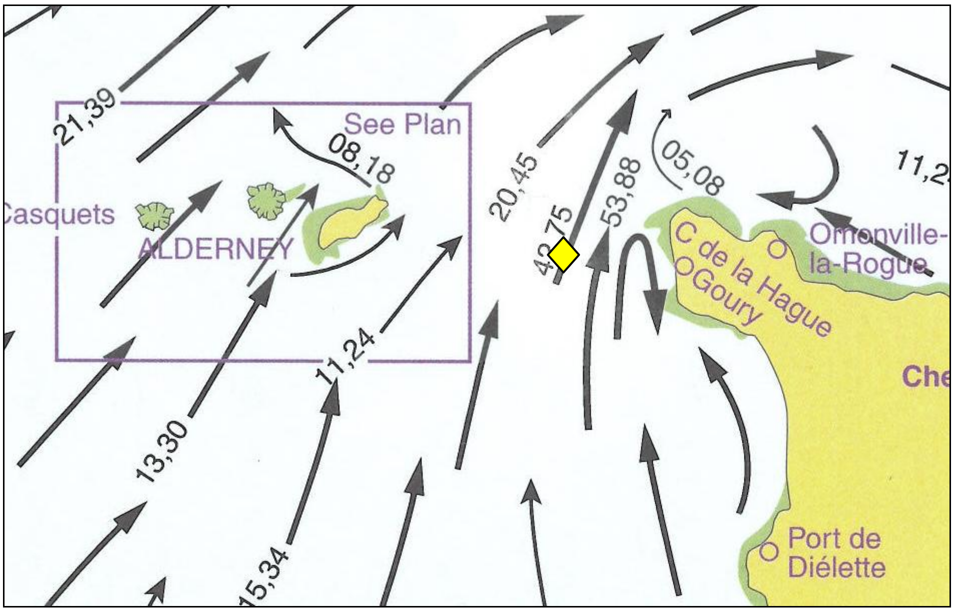
To determine the tidal stream resource at any location a number of factors have to be taken into account:

- the tidal current velocity and its variation through each tidal cycle and through each spring-neap cycle. Ideally the current profile should be at the depth of the turbine;
- the relationship between the power the turbine produces and the velocity of the water passing through its blades i.e. the Power Curve;
- the number and distribution of turbines in an array and the variation of the velocity and direction of tidal currents across the array.

The power output from a turbine can be calculated from its power curve for any given current velocity. It is therefore possible to calculate the power output over each tidal cycle and over longer periods. Conventionally estimates are calculated for one year’s output.

The tidal velocity at any given time appears to be higher towards the east of the race than it is towards the west. This is clearly shown in, Figure 3.4 below, taken from Admiralty Tidal Stream Atlas NP 264 for 3 hours before High Water at Dover (1h 50m after HW at St Helier). The yellow diamond shows the position of tidal diamond “L”. The area of the proposed 3GW array lies to the west of the tidal diamond.

Figure 3.4 Part of Admiralty tidal stream atlas NP 264, "The Channel Islands and adjacent coast of France", 3 Hours before High Water at Dover, showing approximate position of tidal diamond "L" on Admiralty Chart 3653



Furthermore, tidal current data in Admiralty charts and atlases are designed to help mariners predict when and where dangerous currents might arise, and are not designed for the prediction of the energy yield from tidal current energy collectors, for which purpose they are not accurate enough.

It is possible, therefore, that an assumption of a uniform flow regime over the whole of the race equal to that given in tidal diamond "L" may lead to an inaccurate estimate of the size of the available resource.

Myers and Bahaj (2005) [3.5] have modelled the power output of a hypothetical array of tidal turbines in the Race of Alderney. Their array had a nameplate capacity of 1.496 GW and an annual energy output of 1.343 TWh/y.

3.1.4 Value of electricity generation

At a scale of 1GW or more some of the electricity could be consumed on Alderney and the other Channel Islands, but the vast majority would have to be exported either to France or the UK, most likely France due to it being nearer.

Jersey and Guernsey import electricity from France via an 85 MW submarine cable from Surville on the French coast to Archirondel on Jersey and a 50MW submarine cable from Greve de Lecq on Jersey to Guernsey [3.8]. Annually, the Channel Island Electricity Grid (CIEG) imports nearly 1,000 GWhs from France, two thirds of which is used by customers in Jersey [3.9].

Alderney currently has a very high electricity price due to its reliance on diesel generators. Jersey and Guernsey have prices slightly higher than continental Europe and the UK, and considerably lower than Alderney. We understand that electricity consumption in Alderney has a peak value of 1.5 MW.

France

France has a series of feed-in tariffs for different categories of renewable energy. These are set out in *Arrêté du 1er mars 2007 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie hydraulique des lacs, cours d'eau et mers, telles que visées au 1° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000* [3.10]. The Appendix to this *Arrêté* states that wave, tidal-barrage and tidal-current energies are entitled to €150/MWh.

Unlike France and most countries in continental Europe, the UK uses a system of tradable certificates to provide support to renewable energy. This system is called the Renewables Obligation (RO). Under the RO, renewable generators are awarded 1 Renewables Obligation Certificate (ROC) for every MWh they generate, and licensed electricity suppliers are required to surrender to the Regulator each year a number of ROCs equal to a specified proportion of their total sales. They have to pay a Buyout Price for every MWh by which the ROCs they surrender fall short of their Obligation.

In addition to the ROCs, the generator also receives the market price of electricity.

In 2007 the Government published an Energy White Paper [3.11] in which it proposed to introduce "banding". Under a banded RO different technologies will receive different numbers of ROCs per MWh generated. The White Paper proposed that wave and tidal energy would fall into a band called "Emerging Technologies" that would receive 2 ROCs per MWh.

Both ROCs and electricity are tradable and the market determines their price. This means that it varies from day to day and is difficult to predict in the long term.

3.2 Tidal generation in the context of the electricity distribution system in the Channel Islands.

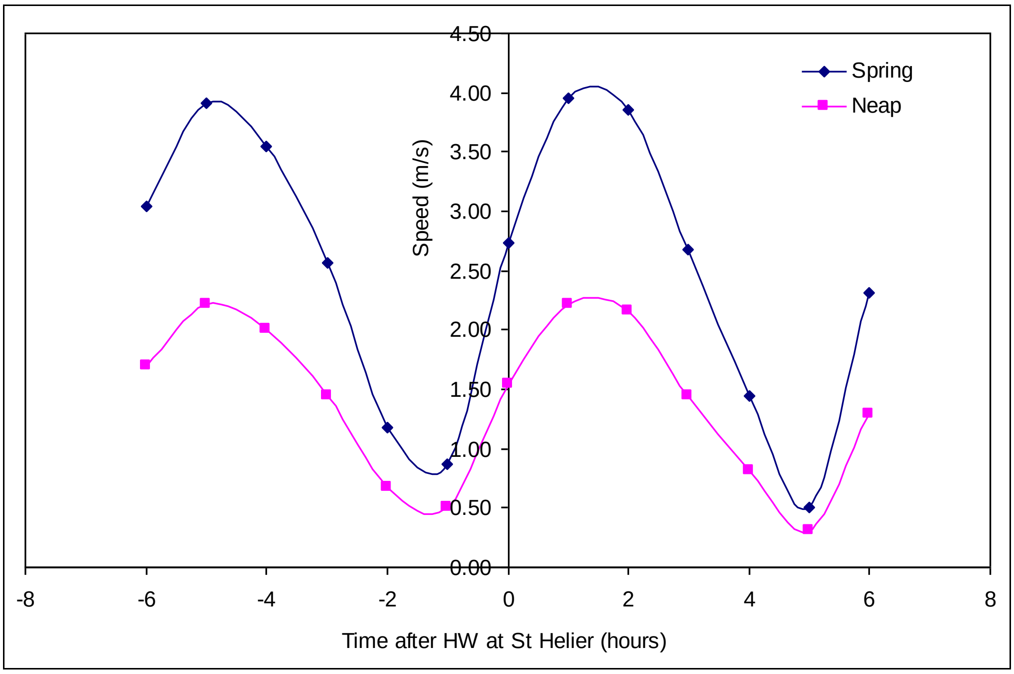
As was mentioned in Section 3.1.4 above, there is an 85 MW submarine cable from France to Jersey and a 50MW submarine cable from Jersey to Guernsey. This is known as the Channel Island's Electricity Grid (CIEG). It imports nearly 1,000 GWh/y from France, two thirds of which is used by customers in Jersey [3.12] and the remainder in Guernsey.

Alderney is not currently connected to the CIEG, and instead relies on diesel generators, leading to very high electricity prices on the island.

The tidal energy resource around Alderney is much larger than the demand for electricity in the whole of the Channel Islands.

At a typical tidal current site, power output rises to a peak and then falls to zero roughly four times in a 24 hour period. The times at which the peaks and troughs in output occur are generally unrelated to the peaks and troughs in demand. Figure 3.1 below shows a graphical plot of current speed at the site of Tidal Diamond "L" (49°42.3'N, 2°01.8'W) on Admiralty Chart 3653, which formed the input data fro OpenHydro's power estimates. This shows that the current speed never reaches zero. This is not typical of tidal sites generally.

Figure 3.1 - Current speed at Tidal Diamond "L" (49°42.3'N, 2°01.8'W) on Admiralty Chart 3653



This means that it may be possible to generate power all the time and, given the large size of the resource, that the reduced generation during the cyclical "troughs" may still be sufficient to meet the island's power needs.

Alderney 's power needs [3.13] are met by three 2.5 MVA diesel generator sets each of which is capable of meeting the island's demand which peaks at 1.6 MVA. Current demand for oil for electricity generation is 2.2 million litres.

Most tidal turbines have a "cut-in" velocity, below which the current is not strong enough to start the rotors turning. If the cut-in velocity were greater than the velocity at "slack water", then no power would be generated even though the water velocity never reaches zero. Because of the cube-law relationship between power output and velocity, the energy produced from low velocities is small compared with the total power produced. This means that even a quite high cut-in velocity does not appreciably affect the annual energy output of a tidal turbine, and so we would not expect a turbine developer to put a lot of effort into reducing it.

3.2.1 Interconnection with France or the UK

As stated earlier the electricity would need to be exported either to France or the UK. A number of options exist for exporting the power. These are explored below.

Type of cable

Two categories of subsea cable could be used to transmit the power from an Alderney tidal energy facility. These are Alternating Current (AC) or Direct Current (DC).

Each of these alternatives has advantages and disadvantages and either could be used.

Both approaches have been used in the offshore wind industry, although the use of DC appears to be a relatively recent development.

The majority of large scale subsea interconnector cables that have been installed around the world in recent years have been high voltage direct current (HVDC) systems. Unlike overhead power lines on land, a subsea cable must be insulated and the insulation surrounded by protective "armour" of steel wire. This makes the cable function as a capacitor and, above a certain length, alternating current (AC) simply charges and discharges this capacitor without getting all the way to the end of the cable. Direct current, on the other hand, does not suffer from this problem.

This effect only becomes important for cables more than about 60km long. For shorter distances, three phase AC cables are considered to be just as good.

HVDC systems also require, in addition to a conventional substation, DC – AC conversion equipment consisting of banks of power semiconductor devices which, as well as adding to the cost, require a large building to house them, further adding to the amount of land area needed ashore to receive the power.

A possible advantage of an HVDC system is that the final DC to AC conversion step can produce high quality power exactly matched to the requirements of the grid into which the power is fed. This is especially valuable for renewable generators driven by a variable speed resource, where the AC power that would be generated would not meet the quality requirements of the grid, necessitating complex power conditioning equipment.

The choice of cable type will ultimately depend on the cost, which in turn will depend on a range of project specific factors. It is not clear at this stage which option would be most cost effective.

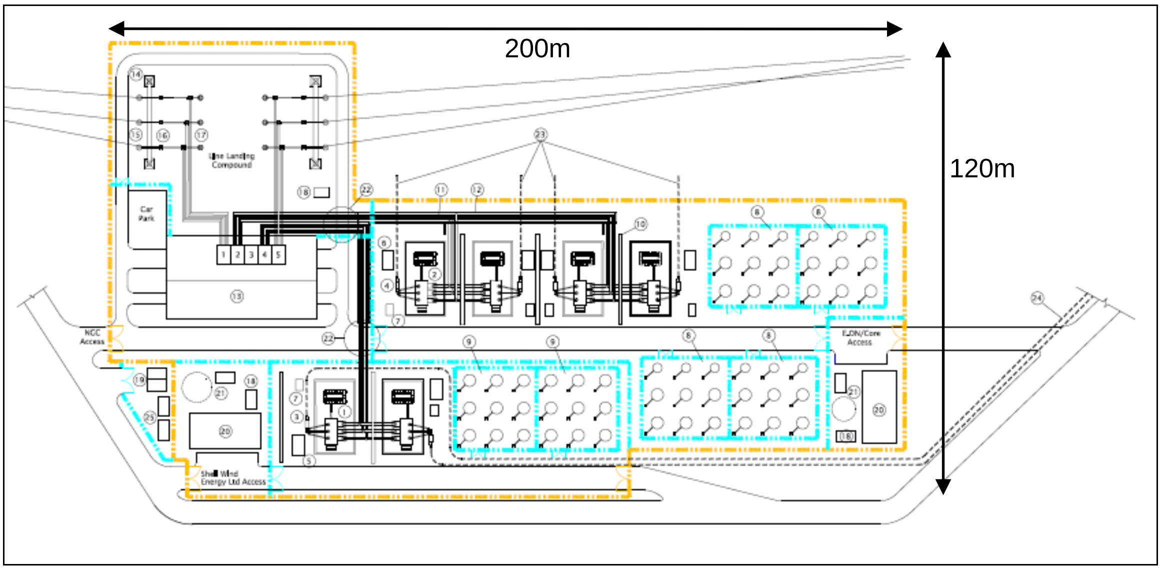
Substations

Onshore

One of the key factors to take into account when considering the options for transmitting the power to consumers is the size of the necessary substations and converter stations. It is possible that, for such a large amount of power, the necessary substation would be too large for Alderney to accommodate.

Figure 3.2 below shows the layout of the substation for the proposed 1GW London Array Offshore Wind Farm [3.14]. This has a footprint of approximately 200m × 120m.

Figure 3.2 - layout of substation for the 1GW London Array Offshore Wind Farm.



A 3GW array would require either three such substations, or one three times a large.

OpenHydro has stated in its submission that it expects any substations to be of the same size as that of the London Array.

However, if DC cables were used, then the substation would need to include DC-AC converters, which would need an additional building to house them, increasing the footprint of the installation.

Offshore

OpenHydro has not given any details of the layout of its cable network or of any offshore substations it may need to install.

The proposed 1GW London Array Offshore Wind Farm [3.15] is planned to have up to five offshore substations that will collect power from groups of wind turbines before transmission to shore via the main export cables. Each substation will contain transformers, electrical switchgear and back-up electrical generator and batteries. The offshore substations would be approximately 25m x 25m x 20m high, standing up to 40m above the level of the sea on foundations similar to those used for the wind turbines.

Export from the Array to Alderney

If the power were landed on Alderney, it would then be necessary to re-export the majority of it to its ultimate market. This would not make sense.

A substation with a footprint of approximately 200m × 120m could be accommodated within Mannez Quarry in the north of the island. This site is largely concealed from most the island, although the train terminus may have to be moved. A larger facility would be correspondingly more difficult to accommodate.

Export from the Array to France

France is geographically the nearest major market that could consume the amount of power that would be generated.

The most logical option would be to export the majority of the power directly to France, with a small proportion transmitted to Alderney to meet its needs.

This could also give the option of importing power from France during times of "slack water".

OpenHydro has indicated in its submission to AEA that this would be the planned option for large-scale development. The submission includes an indicative cable route but given the early stage of planning this could change.

Export from the Array to the UK

The UK is further away than France, and a correspondingly longer cable would be needed, which would have correspondingly higher costs.

The nearest point on the UK coast at which the power could be landed is likely to be at least 100km from the site of the array, four times the distance of the most likely landing site in France. This would necessitate a DC cable.

Connection with the other Channel Islands

Jersey and Guernsey already import electricity from France via the Channel Islands' Electricity Grid (CIEG). As discussed in Section 3.1.4 on Page 19 above, this has a maximum capacity of 85 MW and imports nearly 1,000 GWhs from France, two thirds of which is used on Jersey and the remainder on Guernsey. Given that Jersey and Guernsey already have this supply, there would seem to be no market there for tidal generated electricity from the Race.

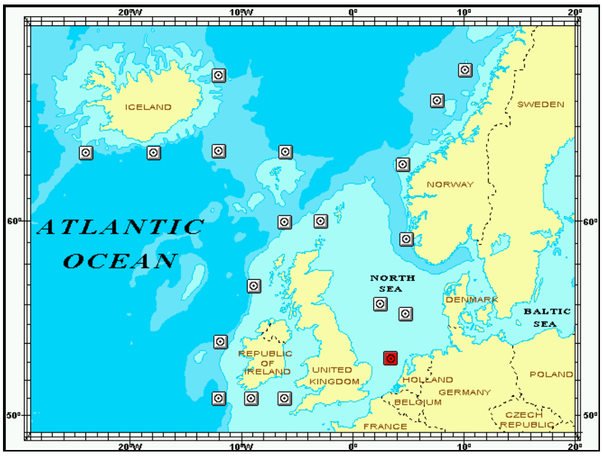
We do not know whether the CIEG as it exists now would have sufficient capacity to enable it to be extended to Alderney. If it did, a 1.5MW capacity subsea cable, sufficient to meet the island's peak demand, would be needed approximately 30km long to connect Guernsey.

3.3 Wave energy

3.3.1 European Wave Energy Atlas (WERATLAS).

The European Wave Energy Atlas (WERATLAS) was developed in the late 1990s by a collaborative EC project under the JOULE programme lead by INETI in Portugal and contains a detailed description of the wave climate at a set of 41 points off the coast of Europe. The nearest point in the atlas to Alderney is designated ATL.33 - K13 and is located at 53.13°N, 3.13°E. This is shown by the red button in Figure 3.3 below. This point in the atlas contains data collected by wave rider buoy measurements carried out between 1983 - 1994 which show an annual average wave power density over that period of 10.670 kW/m.

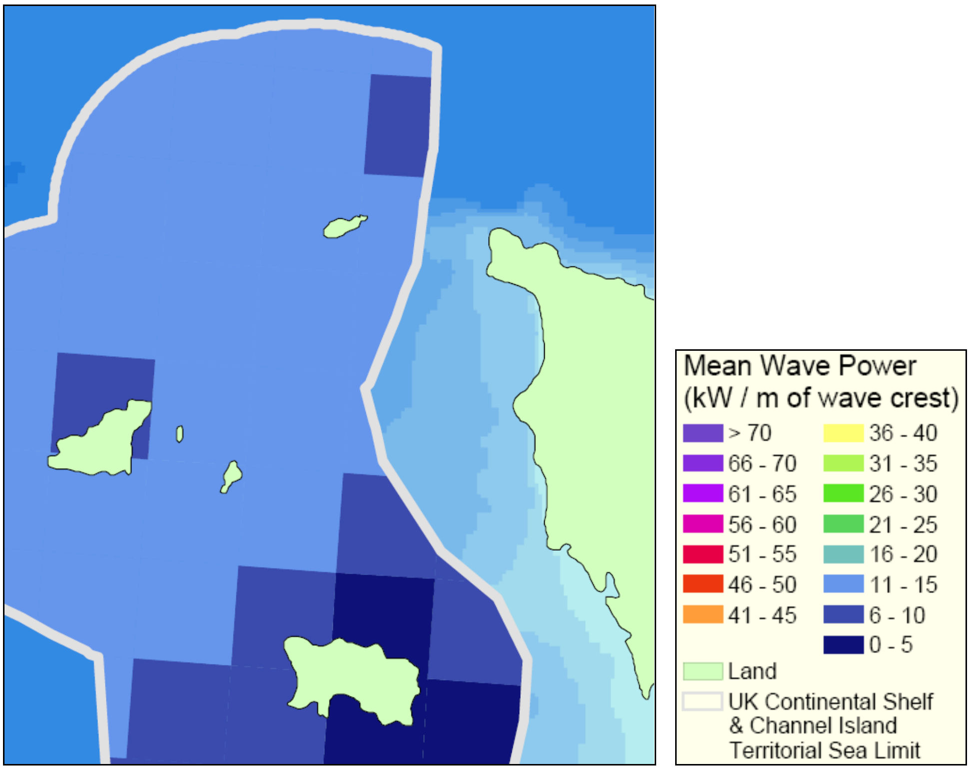
Figure 3.3 - locations of data points in the European Wave Energy Atlas (WERATLAS)



3.3.2 DTI Atlas of marine renewable energy resources

In September 2003, the then Department of Trade and Industry commissioned a study to produce an Atlas of the UK Marine Renewable Energy Resources [3.16]. Figure 3.4 below shows a small section from this atlas showing the annual average wave power density around the Channel Islands. This is shown as being in the range 11 to 15 kW/m.

Figure 3.4 - Annual average wave power density (kW/m) around the Channel Islands, from the BERR Atlas of Offshore Renewables.



It would seem reasonable, therefore, to assume that the annual average wave power density in the seas around Alderney are in the range 10 to 15 kW/m.

None of the published sources give details about the direction of the waves, but it is likely that they will come predominantly from the west.

Alderney could only deploy wave energy converters inside its own territorial sea. The maximum length of an array of wave energy converters, aligned approximately north-south to face into waves coming from the west, that could be deployed in the western part of Alderney's territorial sea would be approximately 10km.

If a 10 km array were deployed to the west of the island, and if this were able to achieve an absorption efficiency of 50%, then an annual average power output of 50 to 75 MW would be generated, or 438 to 657 GWh/y. This is much smaller than the tidal resource available to Alderney.

The economics of wave energy devices depend strongly on the annual average power density at the chosen deployment site. The capital and operating costs of a facility are fixed but the revenue depends on the energy input from the waves, i.e. on the power density. 10 to 15 kW/m is generally considered too low to enable wave energy converters to operate profitably even with the best subsidy levels available anywhere in the world.

In conclusion, Alderney's wave energy resource is much smaller than its tidal resource, although it would be large enough to supply around half of the Channel Islands needs, provided that the devices could be operated profitably and achieve an absorption efficiency of 50%. However, the annual average power levels are too low to enable the current generation of wave energy converters, and possibly the next too, to operate profitably.

Another option for wave energy in Alderney may be to incorporate them into the breakwater. Alderney has a long breakwater approximately 0.5 mile or 0.8 km long facing north. This is currently in need of repair and the Island Plan discusses options and costs of repair.

One of the earliest forms of wave energy converter is the shoreline Oscillating Water Column. These are sometimes built into the structure of breakwaters. This allows the cost to be shared between two different but complementary uses.

Shoreline OWCs are seldom economic but if a breakwater is planned to be built, or refurbished, for sea-defence purposes anyway, then the additional costs of incorporating OWCs into its structure would be much less than the cost of building a dedicated concrete OWC.

The extraction of energy from the incident waves could also reduce their damaging effect on the concrete breakwater structure thereby prolonging its life, although this effect has not been proved.

Insufficient data are available on the wave energy flux incident on the breakwater, and on the additional costs of incorporating OWCs into a refurbishment of its structure, to enable an assessment of its economics.

3.4 References

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3.2 Lunar Energy Press release dated 25th October 2007

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3.4 Marine renewables: current status and implications for R&D funding and the Marine Renewables Deployment Fund. A report to the Renewables Advisory Board, RAB (2007) 0182 URN 08/566, January 2008.

3.5 Renewable Energy 30 (2005) 1713-1731

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3.7 World Energy Council survey of energy resources 2007.

3.8 Channel Island Electricity Grid. ABB Promotional Brochure downloadable from http://library.abb.com/GLOBAL/SCOT/SCOT245.NSF/VerityDisplay/E787FE9FE44174A3C1256E360040F3CB/$File/Project%20Channel%20Islands%2090%20kV%20XLPE%20subm-land-.pdf (checked 27/02/2008)

3.9 Jersey Electricity Company web site http://www.jec.co.uk/section/77/index.html (checked 27/02/2008)

3.10 Journal Officiel de la République Française, n°95 du 22 avril 2007 page 7146, texte n° 7. Viewable on http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000794351&dateTexte=# (Checked 14 March 2008).

3.11 Meeting the Energy Challenge, A White Paper on Energy, May 2007, CM 7124, downloadable from: http://www.berr.gov.uk/energy/whitepaper/page39534.html (Checked 14 March 2008).

3.12 Jersey Electricity Company web site http://www.jec.co.uk/section/77/index.html (checked 27/02/2008)

3.13 An Island Plan: Phase 1. Sustaining Alderney's Future. November 2006

3.14 http://www.londonarray.com/downloads/ (Checked 20 March 2008)

3.15 http://www.londonarray.com/about/offshore-components/substations/ (Checked 20 March 2008)

3.16 Atlas of UK marine renewable energy resources: atlas pages, URN No: 04/1531. Downloadable from http://www.berr.gov.uk/energy/sources/renewables/explained/wind/page27403.html

4 Strategic Environmental Impacts

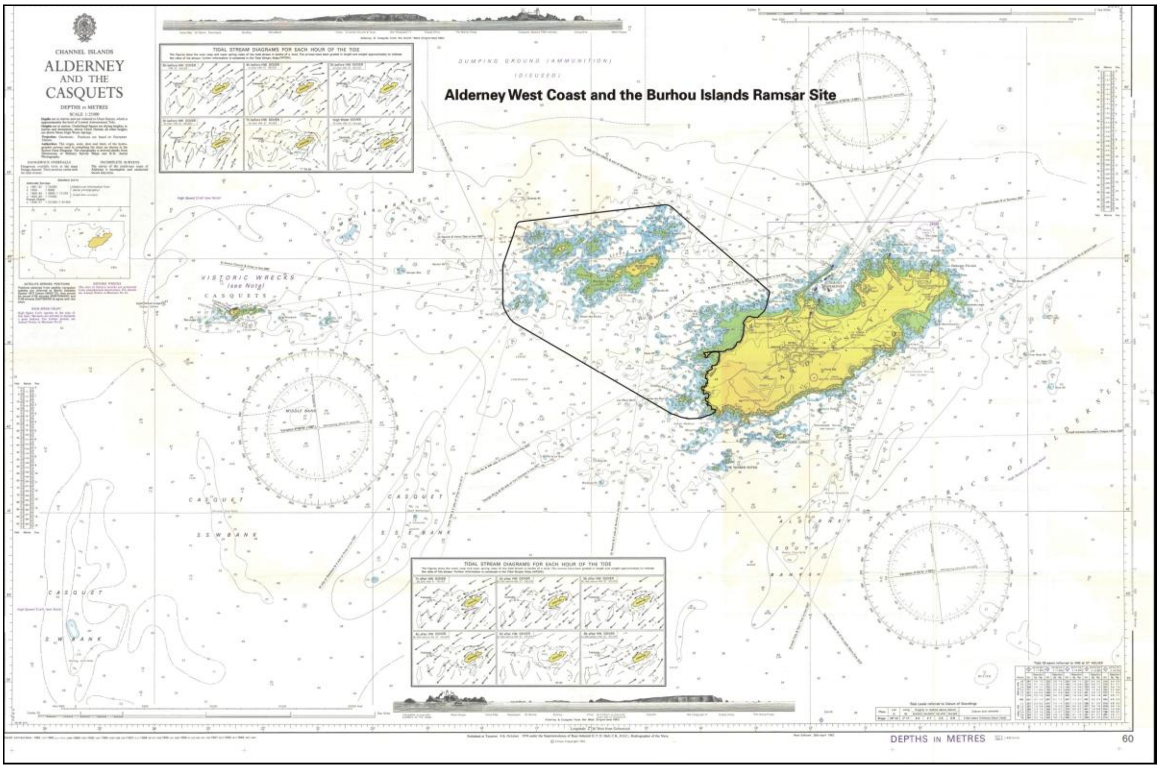
4.1 Scope of environmental impacts

4.1.1 Environmental impacts on flora and fauna

Alderney, its adjacent islands, islets and surrounding coastal waters exhibits a diverse range of marine sublittoral, intertidal and terrestrial habitats. The rocky shores, including rock pools, kelp beds, and sandbars are locally important for fish and shell fish, such as ormers, crabs, lobsters, bass and plaice. Of notable importance are large bird colonies on the island of Burhou and rocky islets which support large breeding colonies of northern gannet (*Morus bassanus)*, Atlantic puffin (*Fratercula arctica)*, and European storm-petrel (*Hydrobates pelagicus*). There is also a seal colony to the north of Burhou Island.

The conservation significance of Alderney's west coast and the Burhou Islands, has been recognised as an area of international importance. This has led to the designation of a Ramsar site in 2005 (see Figure 4.1). The designation places an obligation on the States of Alderney to develop a framework for the conservation of the Ramsar Site [4.1]

Figure 4.1 Map of the Alderney West Coast and the Burhou Islands Ramsar site



Sea birds are one of the key criteria for the Ramsar designation because of their abundance in nationally and internationally important populations. The designation also acknowledges the importance of shoreline, intertidal and sublittoral habitats and marine flora. These include a number of different habitats.

Among global priority habitats, seagrass beds occur at and below low-water mark; there is also a small area of dune slack wet-grasslands at Platte Saline. These form part of a rich complex of habitats, including vegetated shingle banks, sand dunes, dune and coastal grassland, soft cliffs, sandy, gravelly and rocky shores (including the offshore islands of Burhou, Les Etacs and Ortac) [4.2]

Burhou island has a flora and fauna relatively little modified by man. Large nesting seabird populations, which include the only European storm-petrel *Hydrobates pelagicus* colony in the Channel Islands, Atlantic puffin *Fratercula arctica*, lesser black-backed gull *Larus fuscus* and great black-backed gull *Larus marinus*. Les Etacs and Ortac support the only northern gannet *Morus bassanus* colonies in the Channel Islands. The intertidal rocky shore supports many rare species of fauna including ormers *Haliotis tuberculata*, which, within the UK, are found only in the Channel Islands [4.2].

A large nesting population of northern gannets *Morus bassanus* are established on the Garden Rocks (Les Etacs) and Ortac. Here there are 11,000 breeding birds, about 1,000 non-breeding birds, and perhaps 5,000 immature birds. This constitutes 2% of the world population [4.2].

Many rare species, which include a representative sample of north-west European fish fauna, are found in the marine area of the site. Although ormers *Haliotis tuberculata* are the most significant, there is also a high diversity of fish and shellfish. [4.2]

Marine Birds

The main communities recorded around Alderney and Burhou are listed in Table 4.1. The gannet colony has about 5,950 pairs, which are based on just two islets; the colony is important, as it is the only one in the Channel Islands. The storm petrel, which breeds on Burhou, is also very important, as it is the only colony in the Channel Islands. The puffin colony, which breeds on Burhou, is one of the more southern sites. Shore birds including oyster catchers and egrets have also been observed.

Table 4.1 Sea birds observed around Alderney and Burhou

Species	**Locations**	**Population (pairs)**	**Status***
European storm petrel	Burhou	100	SPEC, BL
Northern gannet	Les Etas, Ortac	5,950	SPEC, BL, BI
Great cormorant	Little Burhou	1	BL, WL
European shag	Burhou, Little Burhou, Les Etas	44	BL, BI
Black-legged kittiwake	Les Etacs, Ortac	16	BR
Lesser black-backed gull	Burhou, Little Burhou	273	BL, BI
Herring gull	Les Etacs, Burhou, Little Burhou	105	BDMp, BL
Great black-backed gull	Burhou, Little Burhou	32	BL, BI
Common guillemot	Burhou, Little Burhou	105	BI
Razorbill	Les Etacs, Ortac	17	BL, BI
Atlantic puffin	Burhou, Little Burhou	180	SPEC, BL

*** Status:**
SPEC, Species with unfavourable conservation status in Europe
BL, ≥ 50% of UK breeding population in 10 or fewer sites, but not rare breeders.
BI, ≥ 20% of European breeding population in UK.
BR, Five-year mean of 1-300 breeding pairs in UK.
BDMp, Moderate (25-49%) decline in UK breeding population over last 25 years.

The prevalence of gannets has been steadily increasing since initial colonization on Ortac in 1940 [4.1]. These birds feed on medium sized pelagic species such as mackerel and herring and can dive to depths of 20m. They can also feed on surface species such as sand eels. The dependence of these large populations on local fish stocks is not known. It is not clear what impact there would be if local fish stocks declined as a result of tidal energy development. It is possible that the gannet populations might forage and possibly compete with other gannets in other areas either around the Channel Islands or further away.

The only breeding population of European storm petrels in the Channel Islands nests on Burhou. These birds depend on small fish and trawler detritus. They are known to travel vast distances to forage for these food sources and are therefore less likely to be vulnerable to any local disruption.

Burhou is one of the southern most localities of the Atlantic Puffin. In the late 1940s it supported a very large colony of 100,000 birds. However, the species has been in sharp decline to its current levels. Puffins are heavily dependent on sand eels and the decline and absence of this fish around the British Islands has been blamed on the contraction of Puffin colonies further north. Although the Burhou population is small it has remained stable over the last 20 years.

Marine mammals

The presence of marine mammals appears to be fairly limited based on the reported evidence from the Ramsar designation and the Environmental Scoping Report produced by OpenHydro [4.3]. The Ramsar designation mentions a seal colony with about seven individuals off the reefs around Burhou. Their presence has also been noted near Crabby Bay and near Haument des Pics. Harbour porpoise has been observed in the Race of Alderney and Bottlenose Dolphins have been encountered in the Swinge [4.3]. The frequency and movements of dolphins around Alderney is not known. The work commissioned by OpenHydro suggests that the resident seal population prefers the more sheltered waters to the north west of Burhou.

Fish and shellfish.

Alderney is noted for its diversity of fish which include some species not evident further north along the north shore of the English Channel. Data collated on fish landings by Guernsey Commerce and Employment Department (Table 4.2) show a generally consistent trend, with some species such as Bass and Bream increasing significantly [4.4].

Table 4.2 Catch Allowances for Chartered Angling Vessels not in possession of a Guernsey Fishing Licence (i.e. landed on Alderney).

	Landings 2005 (tonnes)	Landings 2004 (tonnes)	Landings 2003 (tonnes)	Landings 2002 (tonnes)
Bass	173.0	127.8	49.2	43.8
Black Bream	158.8	49.9	131.3	28.9
Brill	13.8	9.8	9.4	10.6
Cod	0.5	1.0	3.0	3.1
Pollack	44.4	35.9	21.4	26.7
Ray	144.6	117.4	163	182.7
Turbot	8.1	7.0	4.3	3.5

Some of the species caught by recreational fishing are located near large sand banks to the south of Alderney and south of the Casquets. These areas would not be suitable for deploying tidal energy devices because of the loose unconsolidated nature of the sediment. Other areas identified by a representative of Alderney Angling include the Swinge, two locations just north of Burhou and the Race (see Figure 5.2). Although these areas are unlikely to be developed for tidal energy, the sand banks may be indirectly affected by large tidal energy development.

Other fish species observed as part of a marine survey in 2007 include Ballan Wrasse *Labrus bergylta* commonly observed around rocky habitats. In shallow waters the corkwing wrasse, *Crenilabrus melops* is also present. This species build nests in shallow areas close to the shore.

The intertidal rocky shore of Clonque Bay supports many rare species including the green ormer *Haliotis tuberculata* a bivalve not found in other parts of the British Isles. Other species include the blue rayed limpet *Helicon pellucida* and the crustacean squat lobster *Galathea squamifera*.

Pollack, *Pollachius pollachius* are also reportedly common and widespread. Juveniles have been observed at most inshore sites where surveys were carried (around the north of Alderney and one site on off the coast of Burhou) [4.5]. Adults are more common offshore, with particularly large individuals encountered at Les Étacs. Small groups of bass, *Dicentrachus labrax* were observed in shallow water, whilst probably the most common fish to be recorded was the tiny two-spot goby, *Gobiousculus flavescens,* which occurred in large numbers at some of the shallow and more sheltered sites.

Red mullet, *Mullus surmuletus* was seen at Braye Rock. This is a southerly species which seems to be becoming more common in the British Isles. At all of the survey sites where sand and gravel marine deposits occur outside sheltered bays, large shoals of lesser sand eel could be seen. These are an important food source for young seabirds, particularly puffins. Small numbers of Black face Benny have also been observed. This species has a distinctive presence in the Channel Islands although it also occurs along the south coast of England. It frequents rocky shore lines where it inhabits protective crevices.

Tidal energy arrays may provide a new habitat for shell fish, fish and crustacean colonisation. This potential benefit is discussed in Section 4.2.

Benthic and intertidal ecology.

The strong tidal currents induced by the position of Alderney relative to French mainland, and the bathymetry have a profound influence on the sea bed sediments and marine habitats around the island, Burhou and the Casquets.

The British Geological Survey Sheet 49 of the sea floor around Alderney, Burhou, Ortac and the Casquets shows predominantly pebble-sized sediments generally less than 1m thick [4.6]. This sediment type is corroborated by observations carried out at St Esquere Bay, an area west of the Grois rocks and the Lugg south west of Burhou as part of the Seascape marine survey carried out in 2007 [4.5].

The basal gravel layer is often overlain by a thin layer of finer sediment which can be formed into sand ribbons or sand waves. There are also rock outcrops particularly around the islands. Local variations in sediment thickness do occur. Accumulations of up to 20m thick are present as sand banks between Alderney and Sark. Sand Banks are also evident south of the Casquets [4.6]. These accumulations are the result of strong tidal currents and indicate a high degree of sediment mobility. Where the bottom stress induced by currents is strongest gravel or bare rock is observed at the sea bed, whereas finer sediments are found where they are weakest [4.7].

The background information on the benthic ecology has come from a Seasearch survey carried out jointly by the Marine Conservation Society and the Alderney Wildlife Trust [4.5]. The survey included 15 sample points mostly around the northern shoreline of Alderney and one sample point off Burhou. In each case different sublittoral habitats were surveyed and categorised.

The habitat surveyed at Longis Bay is of particular interest because this section of coast line is a potential landing site for subsea cables. It is also a good example of an area with the three sublittoral habitats observed around the coast of Alderney.

The outer part of the bay comprises of fine sand. Most of the entrance to the bay between a depth of 3.5m and 7.0m is comprised of an extensive eel grass bed. This habitat supports a community of anemones, molluscs and fish notably juveniles, pipefish and seahorses. The eelgrass habitat is relatively sheltered and is used as an anchorage, however this makes it vulnerable to damage.

In contrast, the eastern side of Raz Island consists of rocky slopes which are covered in kelp forest. The kelp forest habitat supports a diverse algal community of 46 species of seaweed at this location. Kelp and other seaweed species were commonly observed at other localities where the algae could attach to rocks or boulders. They are not evident in exposed locations with loose sediment because of the strong tidal currents.

A total of 276 species was recorded from all 15 sample sites during the 2007 survey comprising 165 animals and 111 plants in the following groups:

Table 4.3 Fauna and flora recorded from the 2007 survey

Sponges	Porifera	27
Jellyfish hydroids anemones and corals	Cnidaria	27
Flatworms	Playthelminthes	1
Segmented worms	Anellida	6
Barnacles crabs prawns and lobsters	Crustacea	14
Shells bivalves and sea slugs	Mollusca	26
Sea mats and sea mosses	Bryozoa	15
Horseshoe worms	Phoronida	1
Starfish sea urchins and sea cucumbers	Echinodermata	7
Sea squirts	Tunicata	16
Fishes	Pisces	25
Red seaweeds	Rhodophycota	72
Brown seaweeds	Phaeophyceae	31
Green seaweeds	Chlorophyceae	7
Flowering plants	Angiospermae	1

Species diversity varied depending on the habitat, with rocky and boulder habitats supporting the greatest floral diversity. In more exposed offshore locations, dominated by tidal currents, animal diversity was comparatively high.

4.1.2 Environmental impacts on seabed and shoreline

Large sale deployment of tidal stream arrays might consist of 500 individual devices arranged in groups of 20 linked to a single cable. For a 1GW array 25 cables would be required and development on this scale might not be permitted on Alderney because of space constraints. However, cable connection from an offshore array to supply a local electricity supply would have less impact. Alderney is dominated by rocky shoreline and cliffs which would be less suitable for installing power cables. There are relatively few beaches and the only one present on the east coast is Longis Bay. Whilst this is geographically closest to the Race, the anti tank wall could complicate cable installation on a large scale. The physical impact of cable installation is discussed in more detail in Section 5.1.5.

Tidal stream development on a large scale may also have indirect affects on the island's marine and terrestrial ecology.

The extent of sea floor disturbance will depend on the type of tidal current technology. OpenHydro has a design which relies on gravity to holds the device in place. Other technologies would rely on foundation pins drilled into solid rock which are then secured to three or four supporting legs. In this instance the displaced cuttings would be distributed to the surrounding sea by the powerful tidal currents. In both cases deployment will require relatively flat seafloor which is composed of solid rock or has a thin veneer of unconsolidated sediment.

Once in position and operational there will be some loss of energy from the natural system. The extent to which this could affect sediment movement is difficult to predict without detailed assessment of sediment transport processes. The seafloor in the Race is known to have highly mobile coarse grained sediment which can give rise to large sand banks further south and west of this location. It would be important, therefore to assess how sediment movement and accumulation patterns might change.

Other environmental impacts

In 2002 a report by Robert Gordon University for BERR [4.8] identified the following potential environmental issues:

1. A direct disturbance of the seabed and benthic ecology with regard to installation of tidal energy devices and overall operation.

2. Potential disturbance of seabirds, pinnipeds[2] and cetaceans in the installation phase related to equipment activity, both visually and auditory.
3. The potential changes in water quality and turbidity due to associated seabed disturbance and chemical leakage from the device and installation equipment.
4. The potential collision risk associated with diving birds and marine mammals.
5. Potential changes in the tidal and wave dynamics in the vicinity of the device and on a local level due to the structure itself, the rotor vortices and the extraction or blockage of tidal energy.
6. The potential seabed disturbance and change in sediment dynamics due to the potential changes of tide and wave dynamics mentioned in item 5 above.
7. The possibility that acoustic emissions from the operating devices will be sufficient to disturb migrating or resident cetaceans, pinnipeds and other marine animals.
8. Visual impact.
9. Navigational hazard.

The first three of these are likely to be localised and persist only during and for a short time after installation. Item 4 is likely to be small and item 7 can be minimised using suitable measures such as air curtains to limit acoustic emissions.

Items 5 and 6, on the other hand, are not yet understood, and further research is needed to assess the impact of extracting energy through tidal current devices and the effects on tidal flow patterns, sedimentation processes and seabed morphology.

4.1.3 Environmental impacts on Air and Climatic factors

A tidal energy facility generates renewable electricity, which leads to CO_2 emission reductions through the displacement of electricity generated by fossil fuel.

The construction, installation and operation of the facility will lead to positive CO_2 emissions. The two main sources of these emissions are:

- Fossil fuels used (directly and indirectly) in the manufacture of materials such as steel, copper and plastics.
- Fossil fuel used by vessels during installation, operation and decommissioning.

The magnitude of these emissions and displacements is subject to considerable uncertainty. The principal sources of uncertainty are:

- **The amount of electricity that the facility would generate**. As was mentioned in Section 3.1.4 above, the proposed facility is hypothetical. The current power output estimates that have been produced are based on Admiralty chart data and simple cube law analysis. More detailed measurement work at the site and numerical modelling of the devices, the resource and their interaction is needed before a high degree of confidence can be placed in the size of the annual energy production.

- **Embedded emissions of materials.** These are the emissions that occur during the manufacture and transport of the materials; principally steel, copper, plastics and rubber, from which the devices, cables and other equipment are made. These are subject to uncertainty because:
    - Different manufacturing plants have different levels of energy efficiency.
    - The materials will have to be transported different distances from manufacture to end use, possibly using different modes of transport.
    - Different specifications of the same material may have different levels of embedded emission. This effect is particularly pronounced for plastics, where a very large number of variations exist that could have large differences in embedded emissions.

[2] any of various families of aquatic, fin-footed mammals, principally seals and walruses

Published emission factors, on the other hand, cannot take all these factors into account and are intended to be "averages". In some circumstances the precise material is not known with any accuracy. This is the case, for example, with the insulation materials in subsea cables.

- **The amounts of materials involved.** Because the proposed facility is hypothetical, it is quite likely that the materials inventory of the devices and associated equipment could change during the design process.

- **Fuel consumption of installation, operation and decommissioning vessels**. Fuel consumption depends on engine type and the way in which the vessel is operated. The requirements for vessels and the mount of time they could be needed has been estimated. On the basis of information provided by OpenHydro it has been assumed all vessels would remain operational for 16 hours a day.

This section attempts to give an approximate carbon balance of the project as a whole. A carbon balance takes account of the amount of carbon saved by the scheme by displacing fossil fuel emissions from conventional power generation and the amount of carbon used throughout the lifecycle of the project. The carbon balance is the time the scheme takes to generate the amount of energy and displaced carbon equivalent to the carbon used during the lifecycle of the scheme.

4.1.4 Energy Output

4.1.5 Embedded emissions

Turbine

We have assumed that a single 16m diameter turbine contains 300 tonnes of steel and 0.8 tonnes of copper.

Emission factors

Steel 1.63 te(CO_2)/te(steel)
Copper 1.65 te(CO_2)/te(copper)

This gives a total embedded emission of 245,161 te(CO_2) for the 1GW array (500 turbines)

4.1.6 Impacts on Cultural Heritage

The presence of wrecks around Alderney and the Casquets is well known and of historic significance.

One of the best know sites is an Elizabethan wreck which is situated in 26-30 metres of water, 900 metres to the north of the Alderney lighthouse and approximately 300 metres west by north of a reef known as the Ledge. The site is marked on Figure 5.2. A half-mile exclusion zone is in force around the wreck. Any unauthorised activity (fishing, diving, anchoring, etc.) within the zone is strictly prohibited. The restricted area is monitored by radar from the Harbour Master's office. The Alderney Maritime Trust was established in 1996 by the States of Alderney to oversee the security, excavation, conservation, display and publication of the wreck and its contents [4.15].

There is another much larger exclusion zone centred on the Casquets (see Figure 5.2). There may be as many as 300 wrecks in this area. Two are of particular historic interest. HMS Victory, which sank in 1744, has never been located and the passenger ferry the SS Stella which sank in 1899. More recent maritime casualties include the chemical tanker the Levoli Sun (2000) and the French trawler the Kleine Familia (2006). Because of the historic interest, and obvious navigational hazard presented by the Casquets, it is assumed that the present exclusion zone would also apply to any tidal energy development [4.16].

It is possible that wrecks or debris of historic interest may be present in other areas. It is recommended that sites of all potential tidal stream developments are thoroughly surveyed first to avoid damage to wrecks.

Substation construction and cable installation should also avoid sites of historic interest. Surveys to detect archaeological artefacts should also be implemented.

4.2 Review of existing research on the environmental impacts of tidal current technology.

4.2.1 Summary of existing research topics (co-ordinated by the Research Advisory Group programme) on the environmental impacts of tidal current technology.

The growth in the development and interest in marine renewable energy in the UK has raised important environmental issues, particularly with the prospect of developing offshore technologies on a large scale. In 2003 the UK government established the Research Advisory Group on Marine Energy (RAG) to facilitate a co-ordinated approach to address key environmental issues. RAG includes representatives from the following UK government departments BERR, Defra, DfT, Crown Estate, SEA programme, and periodic participation from devolved administrations and conservation agencies.

RAG funds strategic and generic research on offshore wind, wave and tidal stream device deployments and their effects [4.17]. Funded research includes seasonal distribution of seabirds, seal ecology offshore, shipping collision risk methodology, cable laying methods and effects, and windfarm effects on sediment processes, marine radar, and seabed fauna. Research on wave and tidal energy includes use of sonar to study animal collision with tidal turbines, and the ecology of areas with strong tidal flows.

In addition to RAG the UK's EPSRC SUPERGEN Programme was launched in 2003 to support research into marine renewable energy conversion and delivery. The programme's collaborative research covers five themes; modelling, device testing, guidance, economics, and outreach [4.18].

The Crown Estate has also established a trust to fund environmental research on the effects of offshore windfarms. The Collaborative Offshore Wind Research into the Environment (COWRIE) was set up in 2001, and has already supported research into important environmental issues some of which are of direct interest to tidal stream technologies. Studies funded by COWRIE of relevance to tidal stream include, a review of electromagnetic fields and their effects, piling noise and mitigation, and seabird survey methodology.

Tidal stream technologies are at an early stage of device development and the multiplicity of technology concepts means that understanding of effects is in its infancy. This will be addressed by both site specific environmental monitoring of individual devices and generic research funded by RAG. However, studies of commercial scale deployments will be needed.

In some cases the basic understanding of some components of the marine ecosystem has hindered strategic decisions and individual project consents for all marine renewable developments. Specific examples include the distribution, ecology and temporal variability of cetaceans, seabirds when offshore and some seabed species and related habitats.

RAG has identified 37 topics of direct relevance to tidal stream technology. The 11 topics of most interest are listed in Table 4.11.

Table 4.11 – Research Topics on environmental issues related to tidal stream energy identified by RAG

Research Topic or Issue Identified	RAG Recommendations
Energy removal - Review existing research and hydrodynamic model availability	Review existing data and model availability
Tidal flow effects of energy removal	Review existing data and model availability
Sediment and sea flow effects of energy removal	Review existing data and model availability
Faunal collision with rotor or vane	Priority for data collection during demonstrator projects
Operational acoustic emissions	Priority for data collection during demonstrator projects
Characteristics of operational vibration	Priority for data collection during demonstrator projects
Functional importance to potential development areas to mobile species	Review existing literature and other data.
Navigational impacts	Prime strategic consideration
Impacts on other users (fishing recreational use)	Prime strategic consideration
Ecology of seabed in tidal streams	Review existing literature and other data.
Ecology of tidal streams in relation to mobile species	Studies of usage and behaviour needed at representative sites

Research of direct relevance to tidal stream energy that is published, underway or proposed in summarised in Table 4.12.

Table 4.12 – Published, current or proposed research related to tidal stream energy

Subject Area	Project Title	Objective	Status
Fish, Shellfish and Benthos	6.3 Review of cabling techniques and effects applicable to the offshore windfarm industry.	The project aims to provide an information resource and guidance to government and developers on the range of cable installation techniques available, their likely effects and potential mitigation, drawing on windfarm and other marine industry practice and experience.	Complete Jan 2008RAG
Fish, Shellfish and Benthos	6.8 Reef effects, guidance and mitigation	The aim of the project is to provide a scientifically credible review of two aspects of the physical presence of windfarm structures: 1. the likely reefs effects on fish, shellfish and other marine biota 2. the potential to enhance the reef effect for commercial species. The review is expected to result in testable predictions on these two aspects and proposals for field studies necessary to test the predictions.	Wind Complete Jan 2008RAG
Fish, Shellfish and Benthos	6.12 Biological implications of the removal of energy from the marine environment.	Monitoring to confirm the validity of predictions for different technologies. Review of the reliance of habitats and species on energy (wave and tidal stream) in the marine environment. Predictions of the biological impact of energy extraction (wave and tidal). Assessment of the scaling up of projects from demonstrator to commercial farms will require consideration in the future – for example what will be the impact of arrays on wave regimes? First step in a broader consideration could be a high level position paper developed by physical oceanographer, sedimentologist and ecologist.	Wave and Tidal Active CCW/CE
Fish, Shellfish and Benthos	6.5 Measurement and effects of EMF	**Phase 1** of the COWRIE EMF study was a desk based study to calculate the strength, frequencies and wavelengths of the electromagnetic fields produced by 33 kV (EPR) and 132 kV (XLPE)	Complete COWRIE EMF-01-2002

		cables. The study also calculated the effects of burial and / or shielding (at various depths, strata, sediment type and thickness) on electromagnetic fields.	
Fish, Shellfish and Benthos	Electromagnetic Fields Review	The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms – a review	Complete COWRIE-EM FIELD 2-06-2004
Soundscape	Noise and vibration mitigation study and guidance (for construction, operation and decommissioning)	A review of the efficacy of proposed mitigation and possible alternatives (e.g. bubble curtains etc) is required studying the technical solutions available and the efficacy, reliability and practicality of those solutions. The development of guidance on industry best practice for effective mitigation for egg piling. A review of the efficacy of deterrents such as pingers and scarers is required particularly in the context of long periods of construction or similar during which receptors may become conditioned to such measures	Proposed
Marine mammal behaviour	development of sonar for use in animal detection and collision	This project will test the development of sonar to detect marine mammals in close proximity to tidal stream turbines and the associated collision risk. The technique is to be tested at near MCT's prototype in Strangford Narrows and at EMEC.	Contracted (funded under MRDF)
General Monitoring techniques	interpretation of seabed video and photos around the EMEC facilities to document communities	This project will evaluate the effectiveness of seabed video to observe benthic communities near tidal test sites at EMEC	Contracted (funded under MRDF)
Marine mammal behaviour	Seal Tagging	Use of seal satellite tagging to investigate behaviour and ecology during and post-construction.	Ongoing

4.2.2 Relevance of existing environmental research to potential tidal energy development near Alderney.

This section outlines the relevance of existing environmental research to potential tidal energy development near Alderney taking account of the preliminary conclusions that can be drawn from initial research.

Understanding the environmental impact of any tidal energy development will need to take account of the type of technology, site specific conditions and the scale of development.

Tidal energy developers will need to be able to monitor sea bed conditions before and after installations. A project to evaluate the effectiveness of using seabed video to observe benthic communities near tidal test sites at EMEC has recently been commissioned (Table 4.12). The development of this technique will therefore be of direct benefit to either site specific or generic research.

One of the main areas of uncertainty is the effect of depleting energy from a marine current. There is evidence of highly mobile sediment around Alderney [4.6, 4.7] and an associated pristine marine habitat that supports a diverse range of fish, shellfish and benthos. These features are directly attributed to the tidal regime around the island. The extent to which tidal stream devices could affect this environment has already been identified as an area for research by RAG. Research has now been commissioned by the Countryside Council for Wales (CCW) to review the biological implications of the removal of energy from the marine environment (see Table 4.12). This research has not been completed.

The deployment of tidal stream devices has also raised concerns over potential collision risk with marine mammals and larger species of fish. Two projects, one recently contracted, will address this issue. One project will test the development of sonar to detect marine mammals in close proximity to tidal stream turbines and the associated collision risk. The technique is to be tested near Marine Current Turbine's prototype, SeaGen, which has recently been installed in Strangford Narrows. It will also be tested at EMEC. SeaGen is due to be commissioned during the summer of 2008, consequently it will be at least a year before results of this technique will become available. There is a complementary seal tagging study also underway. Relevant results should become available within the same time scale (Table 4.12). The results of these studies will be of some relevance to tidal energy development near Alderney, although observational evidence suggests that the marine mammal population is relatively small.

Some research has already been completed on the potential collision risk between marine mammals and cable laying vessels. The risk is perceived to be minimal because of the slow speed of these vessels which operate below 10 knots [4.19].

The implications of cable laying have been investigated for offshore wind [4.19] and could have some relevance to tidal stream devices. The impact of cable laying depends on the type of methodology used and the substrate. However, there will be some disturbance of benthic (sea floor) habitats particularly increased turbulence. Although the effects are temporary there could be some impact on benthic species such as lobsters and crabs and fish species such as sand eels that spawn on the sea floor. The current recommendation to mitigate the impact of marine cable laying is to survey the proposed routes of cables and ensure that proposed routes are carefully planned. The high level of sediment mobility around Alderney suggests that there would be rapid dispersion of sediment and the impact would be minimal. Studies to determine the rate of recolonisation following disturbance suggest that the process can be relatively rapid [4.19]. Intertidal and near shore habitats are considered to be more vulnerable to cable laying and take longer to recover following installation. The presence of eel grass beds near Longis Bay would need to be evaluated in this context, although it may be possible to avoid this habitat.

Experience from the offshore wind industry has also highlighted the potential impact of Electromagnetic Forces (EMF) induced by current transmitted through cables. Some species of fish particularly elasmobranchii (sharks and rays) are known to be sensitive to EMF in the marine environment. Preliminary evidence from two of the earliest established Danish offshore wind sites did not detect any significant impacts. A review of fish sensitivity to EMF has been completed (Table 4.12). Research funded by COWIE, under laboratory conditions, has been unable to determine the precise extent of EMF detection for many marine species or their behavioural response to it. The next stage is to evaluate the phenomenon under controlled conditions within a marine environment. This could have some relevance to tidal stream energy because of the EMF associated with underwater generation as well as transmission may need to be taken into account.

The impact of noise and vibration is another key impact that has been previously investigated by the offshore wind industry. However, comparison with tidal stream energy depends on the type of technology. Bottom mounted technologies like OpenHydro's open centred turbine, relies on gravity which would only cause noise for a short period during installation. Other technologies rely on pins (2-3 m short piles) drilled into the sea floor to secure devices which have three or four tubular legs. Floating devices would require anchorage points which would not require large piles. Some tidal stream devices that are under development would rely on a single pile and are therefore comparable to offshore wind. However, if such a technology were contemplated for Alderney a large hole would need to be drilled into the sea floor before the pile could be inserted because of the underlying hard rock. Noise emissions from offshore wind farms are based on driving piles into soft sediment are therefore not directly comparable to tidal stream. Nevertheless marine mammals are known to be sensitive to noise and avoid sounds of $90bB_{ht}$ or above. Noise may not be a significant issue especially if OpenHydro's technology is deployed. The issue would need to be investigated if technologies that relied on drilling were considered for Alderney.

The impact of tidal stream technologies on sea and shore line birds has not yet to been identified. However, sea birds colonies around Alderney are dependent on prey, although not necessarily in the Race or other areas within the island's territorial limits. It is possible that device and cable installation could cause temporary displacement of prey. The extent of this impact would clearly require further investigation. Shore line birds may also be affected by temporary disturbance during cable installation.

The installation of structures into a marine environment is known to induce colonisation of algae, invertebrates and some species of fish [4.20]. There is evidence to indicate that juveniles of some species preferentially colonise rocky reefs, for example, whiting, crabs and lobsters. Colonisation associated with the creation of new habitats might be further enhanced if fishing exclusion zones were also established [4.20]. It does not appear that there has been any research in UK waters to test this hypothesis.

4.2.3 Identification of future research topics that would be relevance to tidal energy development near Alderney

The development of tidal energy within Alderney's territorial waters will clearly benefit from research that has already been commissioned including environmental impacts of prototype devices that will be assessed elsewhere. There are also areas of generic research which could be carried out around Alderney which would be of general interest not only to developers on Alderney but also to tidal stream development in other locations.

Based on research completed for this study, and a review of research identified by RAG and COWIE, the following topics are recommended as potential candidates for generic research which would be relevant to tidal energy development near Alderney.

1. Environmental impact of energy depletion from tidal currents. The objective of this research would be to assess the impact on the local environment caused by a large scale tidal stream development in the Race of Alderney. The research could be subdivided into two broad areas. Firstly, baseline monitoring to gain a thorough understanding of existing conditions, particularly the interaction between currents, sediment movement and the marine ecology. The second area would include the development of a hydraulic model to simulate current and sediment movement. Field measurements would be desirable to calibrate these models. The impact of energy depletion could be modelled assuming device arrays of different sizes. The research could be refined to take account of any changes to sedimentation. The work would build on the study already commissioned by CCW (see Table 4.12).

2. Review impact on sea birds caused by large scale tidal steam development. The objective of this study would be to determine what impact, if any, there would be on sea birds caused by large-scale tidal stream development. The research could examine existing data on large sea bird colonies around Alderney, particularly foraging habits and prey location. It could then explore potential links between prey disruption and tidal stream development. This project would be a useful adjunct to the first study.

3. Assess the effects on EMF from tidal stream turbines. The objective of this research would be to determine the field strength of EMFs emitted by tidal stream turbines and whether it causes any adverse deterrence or abnormal attraction to devices. It is recommended that this research should only proceed once proposed experimental field observations had been completed.

4. Potential reef building effects and associated increases in biological productivity. The objective of this research would be to ascertain whether tidal stream devices create reef habitats that increase biological productivity. The study could also examine the benefit of creating fishing exclusion zones. Initial base line monitoring would be essential prior to installation followed by longer term monitoring.

Research on the potential collision risk of marine mammals is already underway and therefore a lower priority for generic research. Similarly most research on underwater noise is less relevant to Alderney although this would need to be reviewed if technologies that relied on piling or drilling were considered.

4.3 References

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4.9 Renewable Energy 30 (2005) 1713-1731

4.10 Downloadable from http://www.defra.gov.uk/environment/business/envrp/conversion-factors.htm (Checked 31/03/2008)

4.11 Digest of UK Energy Statistics (DUKES) 2007, downloadable from http://www.berr.gov.uk/energy/statistics/publications/dukes/page39771.html (checked 31/03/2008)

4.12 ABB promotional brochure: "Subsea Power Cables. Offshore cables to/between platforms. Ref ABB HVC 2GM5010-gb 200 rev 2007-02-16" Downloadable from: http://library.abb.com/GLOBAL/SCOT/SCOT245.NSF/VerityDisplay/B659D8705A55706EC1257287002A6EF8/$File/Subsea%20Power%20Cables.pdf (Checked 31/03/2008).

4.13 IPPC BRef Note for the Polymer Industry. Downloadable from http://eippcb.jrc.es/pages/FActivities.htm (Checked 31/03/2008). Table 3.9 on Page 62 says the European Average primary energy consumption to produce a tonne of high density polyethylene is 1420 kWh(primary)/te. Assuming that the primary energy is natural gas (0.206 kg(CO2)/kWh), this is equivalent to 0.29 kg(CO_2)/kg(material).

4.14 EMEP/CORINAIR Emission Inventory Guidebook - 2007, Chapter ##, Table ##. Downloadable from http://reports.eea.europa.eu/EMEPCORINAIR5/en/page002.html (Checked 31/03/2008)

4.15 Alderney Elizabethan wreck http://www.alderneywreck.com/

4.16 http://en.wikipedia.org/wiki/Casquets

4.17 BERR, Marine Renewable Energy Research Advisory Group, Wave & Tidal Stream Monitoring & Research Strategy V6-070906 in association with Defra and Crown Estate

4.18 http://www.supergen-marine.org.uk/news.php

4.19 Review of cabling techniques and environmental effects applicable to the offshore wind farm industry, Technical Report for BERR in association with defra, January 2008.

4.20 Review of reef effects of offshore wind farm structures and potential for enhancement and mitigation. Technical Report for BERR in association with defra, January 2008.

5 Strategic Socio-economic Impacts

5.1 Scope of socio-economic impacts

This section of the report outlines the socio-economic benefits and impacts of potential large-scale tidal energy development within Alderney's territorial waters on the following areas:

- Financial Benefits
- Fisheries
- Shipping and navigation
- Tourism and recreation
- Job creation
- New buildings and infrastructure

5.1.1 Financial Benefits to Alderney

The island of Alderney has a strong opportunity to benefit financially from future tidal energy development, since the development will be regulated by the Alderney Commission for Renewable Energy (ACRE) who will charge the developer a tariff on each MWh they generate. This practice has already been established by the Crown Estate for offshore wind farms developed with the UK's territorial limits.

Savings through reduced oil consumption

According to the Island Plan [5.1], in 2006 Alderney's power station consumed 2.2 million litres of fuel oil per year, at a cost of £3,549 per day, equating to roughly £600/tonne. The station generates "around 9 million" kWh/year for which consumers currently pay £0.30/kWh. The cost of the fuel oil used in the generators accounts for about half of this final price.

If tidal-generated electricity displaced oil-generated electricity, the net saving to the island economy would be the reduced cost of imported fuel oil. This is based on the assumption that Alderney Electricity's operating inputs are all sourced on the island and that its profits remain within the island's economy.

For the purposes of this calculation we have assumed that the value of electricity used to displace fuel oil will be a feed in price equal to that which the operators are able to get in France, which is currently €150/MWh, equivalent to £0.114/kWh_e or 11.4p/kWh_e, assuming an exchange rate of £0.762/€.

Assuming a gross Calorific Value of 12,028 kWh/tonne, a generation efficiency of 35% and a fuel price of £600/tonne we calculate that the cost of fuel oil per kWh of electricity generated is £0.143/kWh_e or 14.3p/kWh_e. This is 2.9p/kWh higher than our assumed price of tidal electricity, and so switching would make a small financial benefit at the 2006 oil price.

Oil has recently undergone a dramatic price rise and this cost is likely to be higher than this today.

Consequently, the saving to the island economy from displacing fuel oil, at 2006 prices at least, is not enormous, but could be considerable at 2008 prices.

The total saving will depend on the amount of oil-generated electricity that is displaced. It has been assumed that some back up diesel generated electricity will be necessary during periods of slack water.

As discussed in Section 3.2 above, it is likely that the tidal facility will have regular periods of zero output during times of "slack water". As Section 3.2 also points out, the water in the Alderney Race is never slack, but tidal turbines have a "cut-in" speed below which they will not operate. The length of time during which the facility produces no power will depend on the level of this cut-in velocity, starting from zero if it is less than the "slack water" velocity.

If this were the case, it would mean that 8.1GWh of oil-fired electricity would be displaced, which would have required £1.15M worth of oil to generate. The tidal electricity that would displace it would cost £0.925M leading to a saving of £ 0.228M per year in the cost of oil imports at 2006 oil prices.

However, as mentioned above, the price of oil has recently undergone a large price increase, and the saving would be correspondingly greater compared with the 2006 price used in our calculation.

A provision to import electricity from France by cable during slack water rather than operate the diesel plant would be beneficial. Apart from the difference in the cost of generation there would be a saving in the maintenance of the plant and an additional saving of CO_2 emissions.

CO_2 savings

In addition to a cost saving, a reduction in fossil fuel consumption would lead to a saving of CO_2 emission. We make the following assumptions:

- Density = 1,019 litres per tonne [5.2]
- Emission factor = 3.16433 kg(CO_2)/kg(fuel) [5.3]

From this we conclude that 2.2 million litres of fuel oil would, if burned, emit $\frac{2.2 \times 10^6}{1019} \times 3.16433$ = 6,832 tonnes of CO_2 per year. If 90% of this were displaced by tidal electricity, then 6,149 tonnes of CO_2 per year would be saved.

5.1.2 Complete Electrification

ACRE wishes to consider the option of complete island electrification to replace fossil fuel fired heating and cooking appliances on the island. This would have the effect of increasing overall electricity consumption and would therefore require capital expenditure to upgrade the electricity network to accommodate the extra current. It is assumed that the cost of the new electric heating and cooking appliances would be met by each household.

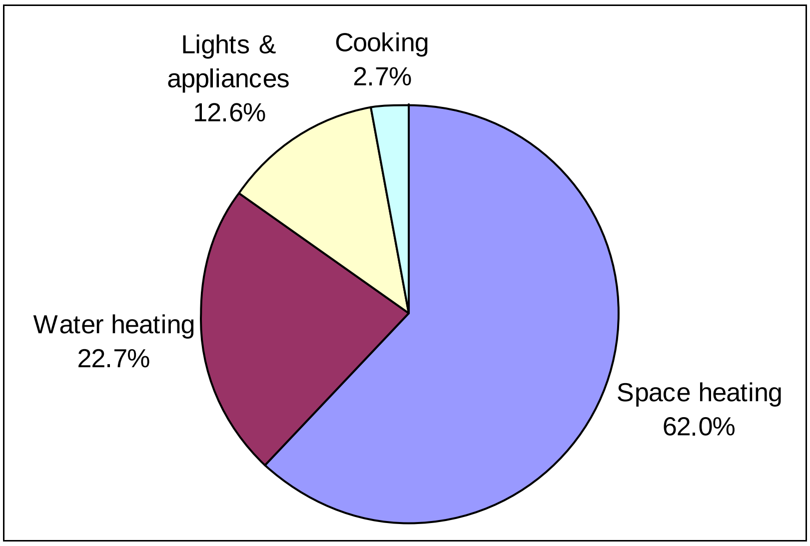
We have considered what the cost benefit of complete electrification would be based on the value of displaced fossil fuels using tidal energy generated electricity. Unfortunately, we have not been able to base this analysis on the cost of upgrading the island's electricity network. We have therefore estimated the annual energy demand from heating and cooking to calculate the value of this energy.

The Island Plan states that Alderney's power station consumes 2.2 million litres of fuel oil per year which is used to generate around 9 million kWh of electricity. Electrical demand peaks at 1.5MW and 9 million kWh per year is equivalent to and annual average of 1.027 MW, so the peak is approximately 1.5 times the average.

AEL has estimated that if the island were all-electric the electricity consumption would peak at 12 MW which, if the peak to average ratio were the same, it would mean that the end users that currently use electricity account for around 12.5% of delivered energy. This is a much smaller proportion than in the GB housing sector, where electricity accounts for around 20% of delivered energy. However, it is very similar to the proportion of delivered energy used in "lighting and appliances" in the GB domestic sector, whose breakdown is shown in Figure 5.1 below:

Figure 5.1 - breakdown of GB domestic sector delivered energy consumption by end use[3]

[3] Building Research Establishment. Domestic Energy Fact File 2003. Figures refer to the year 2001.



However, it is not necessarily valid to assume that a given end use would need the same amount of energy to accomplish a given task when different fuels are used. For example, it is not obvious that it would take the same amount of energy to cook the same meal on an electric cooker as on a gas cooker. However, there are no easily accessible data to enable this factor to be included in the calculation and so we have had to assume that the amount of energy is the same. This will add a small amount of uncertainty to the answer.

We will therefore assume the breakdown of delivered energy consumption shown in Table 5.1 below.

Table 5.1 - Assumed annual energy consumption by end-use and fuel

	Delivered Energy (million kWh)	Delivered Energy (%)	Assumed fuel
Space heating	44.2	62.0%	Oil
Water heating	16.2	22.7%	Oil
Lights & appliances	9	12.6%	Electricity
Cooking	1.9	2.7%	LPG
Total	71.3	100.0%	

The price of LPG is not readily available in the public domain. As this would only account for 2.7% of the overall amount of energy used anyway, we will assume that all of the 62.3 million kWh/y of non-electrical energy is oil. This is unlikely to result in a significant error given the overall precision of this approximation.

As mentioned under Savings through reduced oil consumption, the tidal array will not generate for a short period around "slack water". The length of this period depends on the cut-in velocity of the turbines. In the absence of hard information, we assume that this will account for 10% of the demand, and that it will need to be supplied from the existing power station to meet demand during these slack periods.

This means that 0.9 $\times$ 62.3 = 56 million kWh/y will be supplied by tidal electricity, and the remaining 10%, i.e. 6.23 million kWh, will be supplied by electricity from the existing power station. We assume that the power station has an overall efficiency of 35% and so the oil consumed to generate this will be equal to 6.23 $\div$ 0.35 = 17.8 million kWh.

Assuming a calorific value of 12,028 kWh/tonne the amount of oil displaced by tidal electricity will be 4,656 te/y and the extra oil used in the power station to meet demand during "slack water" will be 1,480 te/y resulting in a net saving of 3,176 te/y of oil. At a cost of £600/tonne this would be equivalent to £1.9M/y.

If 56 million kWh/y were supplied by tidal electricity at a cost of €150/MWh, equivalent to £0.114/kWh, then the total cost would be £6.4M/y. This is more than three times the cost saving that would be achieved through complete electrification.

Therefore with a tariff of £1.07/MWh and a cost of tidal electricity of £0.114/kWh complete electrification would only be economic if the oil price were to increase to three times the 2006 price. It would become increasingly so with further rises in the oil price.

As well as being first approximations, the results of these calculations are strongly dependent on the level of the tariff levied by ACRE and the feed in price that the Island pays for the tidal electricity. It is understood that these are not yet finalised but they will be set out in the licence terms.. If ACRE were to fix a higher tariff than the £1.07/MWh assumed in the above calculations, and pay a lower price than £0.114/kWh, then the benefit to the island could be much more positive.

A provision to import electricity from France via a cable rather than operate the diesel plant during slack water would also be beneficial since it would reduce the cost of generation and eliminate the maintenance costs of the diesel plant.

5.1.3 Impacts on Fisheries

Commercial and recreational fisheries are an important market for Alderney's economy. A combination of warm water currents, strong tides, numerous rocky outcrops and protected sandy bays creates favourable conditions for rich and diverse marine habitats. This combination of favourable conditions generates locally important fisheries.

The abundance of fish species includes bass, bream, pollack, turbot, brill, tope, ray, dogfish, cod, conger, coalfish, ling, garfish, wrasse, conger eels, black bream, thick-lipped mullet, and even sharks. There are 18-20 registered British Fishing vessels in Alderney but only four are full time fishing vessels. One is a trawler; two are dedicated potters and the fourth carries out potting, net and line fishing.

Sea and shore angling on the island is tailored to both novices and experienced anglers and is one of the island's primary tourist attractions. Sea fishing is carried out using local offshore charter vessels which can carry up to 12 anglers at a time [5.4]. Five to six chartered vessels regularly cross the English Channel from Weymouth for recreational fishing between April and October.

The main fishing season lasts from March to October, although some fishing continues during the winter. The majority of charter boat angling trips operate between Monday to Friday, thereby providing trade and commerce opportunities during the weekdays.

As an important tourist attraction, sport/leisure fishing brings considerable benefits to a number of related local businesses. The industry provides a valuable income to the local hospitality sector through creating a demand for accommodation and catering throughout the 6-month fishing season. Retail trade in shops specialised in the angling equipment, transportation and guide service sectors also benefit from expenditure by visiting anglers.

The total number of bed-nights anglers spent in Alderney in 2005 was 3,649. Table 5.3 provides a breakdown of the income received as a direct result of the spending associated with Alderney's Charter Boat Angling Industry [5.5, 5.6].

Table 5.3 Economic benefits from Alderney's Charter Boat Angling Industry, 2005

AREAS OF ECONOMIC BENEFIT	TOTAL INCOME FOR 2005
Accommodation	£122,689
Food and Drink	£143,955
Tackle and bait	£22,000
Oil	£21,245

Duty Free	£20,440
Taxi service	£18,245
Harbour dues	£3,600
Shopping	£95,790
Total value to Alderney	£447,964

Source: *Alderney Tourism response re. consultation on the introduction of catch allowances for charter angling vessels not in possession of a Guernsey fishing licence [5.7].*

The total annual income generated by the local angling industry was nearly £450,000, which is a substantial figure and accounts for 5% of the overall tourism market on Alderney.

There are no robust statistical data indicating the quantities of catch harvested by Alderney's charter boat angling industry. To fill in this gap in the data, Alderney Tourism Board recommended the implementation of a logbook system in order to record amounts and species of fish that are caught and retained by charter fishing boats. Such a system is designed to enable monitoring and sustainable management of the fish stocks and related fishing activities.

The data on commercial landings by the Guernsey Commercial Fishing Fleet are available for 2005 and are shown in Table 5.4.

Table 5.4: Landing of major target species taken by Guernsey registered vessels

	Landings 2005 (tonnes)	Landings 2004 (tonnes)	Landings 2003 (tonnes)	Landings 2002 (tonnes)
Bass	173.0	127.8	49.2	43.8
Black Bream	158.8	49.9	131.3	28.9
Brill	13.8	9.8	9.4	10.6
Cod	0.5	1.0	3.0	3.1
Pollack	44.4	35.9	21.4	26.7
Ray	144.6	117.4	163	182.7
Turbot	8.1	7.0	4.3	3.5

Table 5.4 reveals that the landings of Black Bream have increased significantly since 2002. Bass landings in 2005 were the highest ever taken in a calendar year by GU registered vessels. Alderney also sustains a small lobster and crab potting business.

The development of tidal energy from subsea devices deployed anywhere within Alderney's territorial limits could have some potential impact on fishing activities. This would depend on the extent of tidal energy development and proximity to favourable fishing grounds.

Figure 5.2 shows where recreational fishing tends to be concentrated. It is evident from this map that fishing areas generally coincide with large sand banks south of Alderney and the Casquets. These areas are not suitable for tidal energy because of the thickness of accumulated sand. However, tidal energy development would increase the number of vessels operating in the open sea and present a minor collision risk. There may also be some indirect effects depending on the scale of tidal energy development. The pattern of sediment accumulation is heavily dependent on current distribution and strength. Localised reductions in currents due to tidal energy may cause subtle changes to sediment and possibly fish distribution. The extent of this change and its related effects to fish distribution would need to be investigated in some detail. The extent of change will also depend on the location and size of tidal energy development.

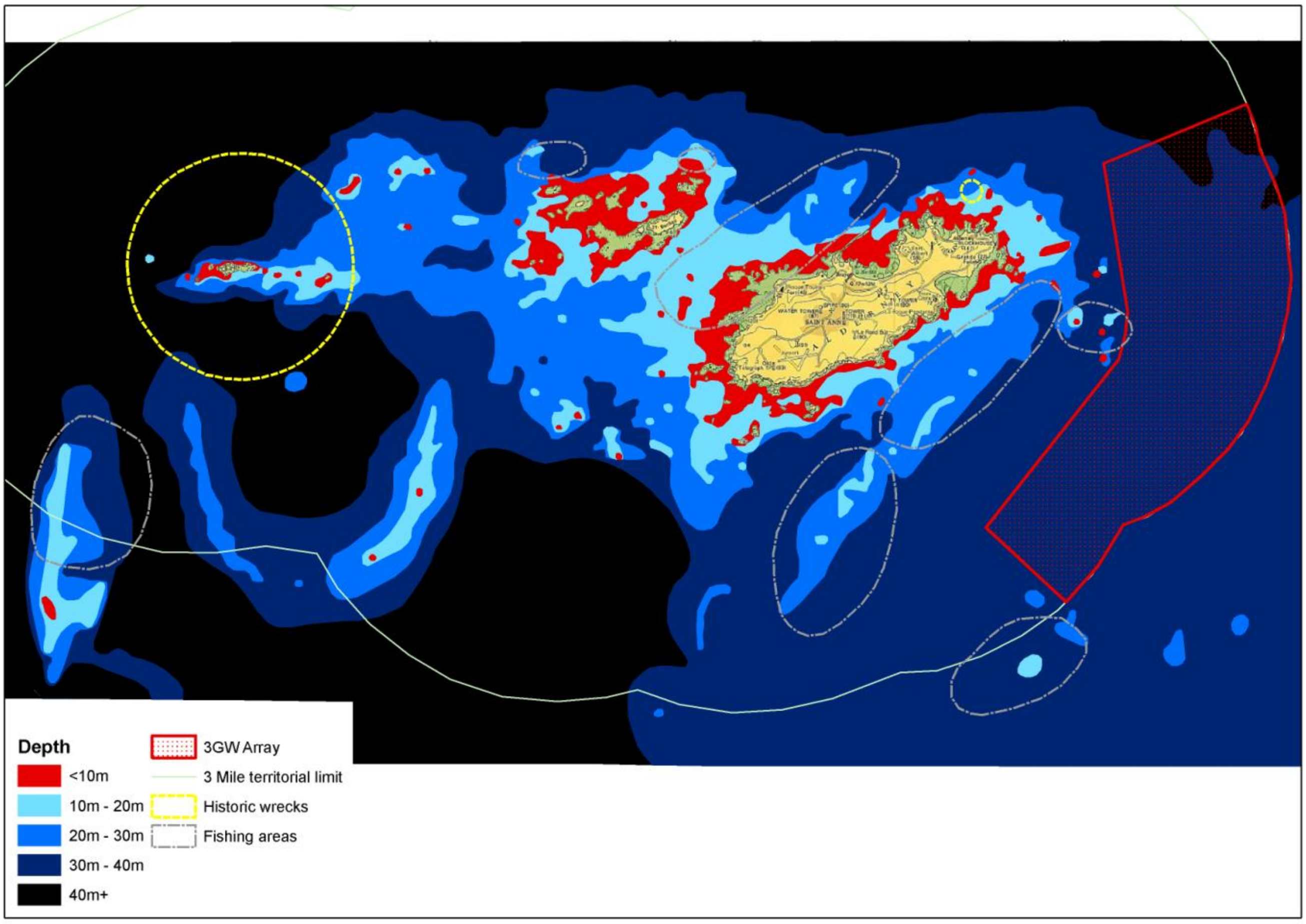


Figure 5.2 Bathymetry and exclusion areas within the Alderney 3 mile territorial limit. (Location of main fishing areas has been provided by courtesy of Alderney Angling).

If the 1GW development was implemented, 500 submarine turbines would be deployed across 8 km^2 of the seafloor in the Race. Deployment of turbines and laying underwater turbines on the seafloor may cause temporary disturbance to the existing fishing grounds in this area although the effects are not known. The construction period is likely to be at least 34 months for a development on this scale. During this period there may be at least two and possibly four vessels operating in the area at any one time. It should be noted that the main area of interest for fishing in the Race is not in the potential area where tidal energy would be developed. Consequently the operation of fishing vessels and construction traffic would not necessarily be compromised provided adequate precautions were in place. In addition to normal safety procedures and navigation practices the developer could provide Alderney's authorities with details on proposed construction and operation works, including exact positioning data, time and duration of the works, as well as the types and numbers of vessels in use. The island's authorities, particularly the Harbour Master, will then be able to disseminate this information to anglers and angling boat operators, thereby enabling them to plan their activities in advance and to implement all necessary safety precautions. An official web-site maintained by the Alderney Tourism Board may also be used to spread such information to potentially affected parties. Locations of the tidal energy facilities will need to be clearly designated on charts available to all involved in fishing activities in the area. The increased vessel traffic during the construction phase may result in some fishing opportunities for commercial fishing vessels being reduced or lost in the Race.

Once a tidal energy array on the scale of 500 turbines is established there is the potential to affect sedimentation patterns, although the extent of changes to sediment movement is unknown. The effect would become even more pronounced for a 3GW development with 1,500 devices.

5.1.4 Impacts on Shipping and Navigation

Summary of current shipping operations around Alderney and port facilities

The Alderney Shipping Company was established in 1969 and now operates a sea link for freight between Guernsey and Alderney and back and also provides an all-year-round cargo service (including cars), on a weekly basis between Alderney and Guernsey and fortnightly between Portland, Rotterdam, Cherbourg and Alderney [5.8].

Weekly day trips are available around the island, to Guernsey, Sark and France. All vessels are licensed to carry up to 12 passengers and are available for charter.

Ferry transportation is provided by an operator Manche Iles Express, a subsidiary of Société Morbihannaise de Navigation. Ferries operate between Dielette (near Cherbourg), St. Peter Port (Guernsey) and Alderney from April until the end of September. In 2007, the number of passengers travelling by Manche Iles Express went down considerably from 7,313 in 2006 to 2,762, due to Manche Iles Express reducing the number of its sailings in an attempt to fill the service by reducing the frequency of sailings. As a result of a meeting that was held in September 2007 with the States of Alderney Marketing Department, the Alderney Harbour Master and Manche Iles Express, it was agreed that the latter would offer more direct sailings from France and Guernsey to Alderney, as well as an increase in the number of daytrips to Guernsey for Alderney residents and visitors [5.9].

Condor Ferries operate regular passenger and car ferry services from Weymouth and Poole to Jersey and Guernsey, and from France to Jersey and Guernsey.

Fishing boats also operate in Alderney's waters. Shore fishing prevails in shallow waters of the Swinge to the north-west off the island (with the predominant depths of up to 30 m). Boat fishing occurs in the Race south-east off Alderney at the depths of 20-30 m, and in deeper waters of the open sea (up to 40 m) to the south off Alderney (Figure 5.2).

There are a number of other anchorages around Alderney, in addition to Braye. None provides any facilities, and all are only safe in calm weather and/or offshore winds. Clockwise from Braye harbour these are:

- Saye and Longis Bay with sandy bottoms;
- Telegraph Bay – a small sandy bay that is located on the south-west point of island and dries from half-tide down, holding patchy in sand and heads of rock;
- Hannaine Bay located south of Fort Clonque;
- Burhou Island where the landing is prohibited between 15th March and 27th July due to the island's conservation status.

Potential impact on shipping routes and operations

Tidal energy development could potentially occur anywhere within the three mile territorial limits depicted in Figure 5.2, provided there is a suitable tidal energy resource and no obvious constraints.

A potentially large scale deployment within the Race on the scale of 1GW could consist of up to 500 submarine turbines and as many as 1,500 for a 3GW array. At this scale the development would extend across 24km^2 of seafloor. This potential area of interest in the Race is less than 40m in depth which could potentially place constraints on commercial shipping which requires a minimum safety clearance of 20m. Bottom mounted devices could occupy a vertical height of 20m and consequently require a minimum depth of 40m, however the dimensions of devices has yet to be determined. Decreasing the scale of turbines would improve the safety margin for large vessels but decrease the energy capture potential. Alternatively navigation restrictions could be imposed either by excluding large vessels completely in marked exclusion zones or providing shipping lanes.

Other areas within the territorial limit, particularly north of Alderney and west of the Casquets are sufficiently deep enough (i.e. >40m in depth) to accommodate large bottom mounted tidal energy devices without compromising commercial shipping.

Another impact of the shipping operations may stem from an increased shipping traffic between the island, the port of Cherbourg and the tidal development site. The project work force would operate from Cherbourg and Alderney throughout the project lifecycle, including an estimated 5 vessels[4] operating out of Cherbourg and 6 vessels[5] out of Alderney. During the construction phase, the vessels would operate over an estimated 34-month period in the case of the 1GW development and over a 100- month period in the case of the 3GW option. The operational phase will require the continual presence of vessels on a permanent basis as turbines are either replaced or repaired. Full scale decommissioning would take an estimated 34 months for the 1GW scheme and 100 months for the 3GW option.

Additionally, the project personnel accommodated in Cherbourg and Alderney will be transported to the development site using small-size vessels. Although the number of such offshore transfers will be kept to a minimum, these trips may contribute to the intensification of the existing shipping traffic and as a result may affect the general navigation safety in the area.

In order to reduce the potential impact, the developer could notify the States of Alderney about vessels routes and traffic schedule. Rigorous and continuous monitoring of the vessel movements could also be carried out. To minimise the risk of an accident involving the project's craft and third party vessels, the following safety measures could be implemented:

- Location of the tidal energy development site should be marked on the existing charts,
- Navigation and warning signs and lights should be used in the location and along the marked shipping lanes,
- All construction and operational craft should be equipped with navigation illumination in accordance with the requirements of the SOLAS Convention[6].

5.1.5 Impacts on Tourism and Recreation

Alderney's sparsely populated coastline, sandy beaches, mild climate, rich flora and fauna including famous seabird colonies makes it a popular holiday destination.

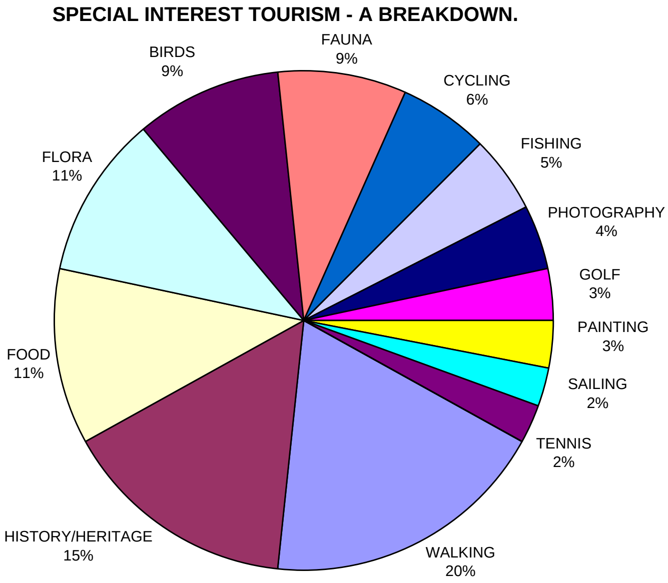
The tourism sector is a pillar of Alderney's economy. Throughout the year it offers visitors to the island a broad array of recreational, sports and cultural activities that cater for different interests, age groups and social segments. Walking, historical interest and heritage sightseeing and local natural history are the main attractions as well as cycling, golf, fishing and sailing. Figure 5.3 summarises the breakdown of the tourist markets [5.9].

Figure 5.3 Breakdown of tourist markets in Alderney

[4] 2 standard tugs, 2 OpenHydro deployment vehicles, and 1 offshore supply vessel.

[5] 1 Multicat, 2 RIB, 2 patrol boats, and 1 x ROV Crew.

[6] The International Convention for the Safety of Life at Sea.



Source: 2007 Annual Report, PR&Marketing Department, Alderney Tourism Board [5.9].

Thanks to its relaxed atmosphere, Alderney appeals predominantly to people over 50. Alderney is also famous for its vibrant nightlife, including popular dance events that attract many visitors of younger age, especially in the summer season. The island is also popular with visitors who have independent means of transport. In 2005 ~1,200 private aircraft and ~6,000 yachts contributed an estimated £3.5m to the local economy [5.9].

The famous seabird colonies draw birdwatchers and naturalists from around the world and throughout the year. In total, the island's bird list contains nearly 300 species. Of particular interest are the colonies of puffins in a bird sanctuary of Burhou and the gannets that nest on Les Etacs/Garden Rocks and Ortac. In August 2005, Alderney's west coast, including Burhou Island, Les Etacs and Ortac, was designated as a wetland of international importance protected under the Ramsar Convention. During the summer season, daily boat trips are available from Alderney to take visitors to this Ramsar site [5.10].

The rich natural heritage includes Blonde Hedgehogs, black rabbits and a wide variety of wild flowers and plants[7] are among primary attractions to visitors of the Alderney island. 50 miles of footpaths with unique flora and fauna, nocturnal bat walks, cliff walks through the south coast with its remarkable Victorian and Second World War German fortifications, sandy beaches interspersed with picturesque Victorian forts along the north and east coast make Alderney a compelling tourist attraction [5.6].

Many of Alderney's beaches are ideal for various water sports, particularly fishing, windsurfing and surfing. Local sports and leisure clubs offer a wide array of recreational activities such as golf, cycling, sailing, scuba diving, horse riding and tennis. Tourist demand for accommodation and catering services helps maintain a considerable number of guesthouses, restaurants and public houses on the island.

As can be seen from Table 5.5, the year 2007 marked a significant increase in the number of beds available in the self catering tourist sector.

Table 5.5 Bed availability at Alderney's tourist facilities

[7] Over 900 species of vascular plant are currently recorded on the island including rarities such as the spotted rockrose [Alderney Wildlife Trust].

Accommodation Type	Number of beds available in 2006	Number of beds available in 2007
Hotel Beds	101	101
Guest House Beds	122	115
Self Catering Beds	289	312
Total Beds	512	528

Source: 2007 Annual Report, PR & Marketing Alderney Tourism Board. [5.9]

The direct use of tidal energy from power generated in local schemes will necessitate the construction of a substation on the island either to integrate the power into the island's electricity network or to export surplus. The impact could be minor for a relatively small scale development of up to ~40MW. However the impact caused by the construction of substations, switchgear and high voltage links to either France or the UK on the scale of 1GW or more would be considerable.

A substation intended for the 1GW generation would require 0.03 km^2 of land, whereas a 3GW array would occupy an area of nearly 0.1km^2. At present, a considerable part of Alderney's territory either has protected status (biologically important terrestrial, freshwater and marine habitats and archaeological sites) or is designated as recreational. Stringent restrictions are currently imposed on any other modes of land use due to the limited land resources. Given the existing constraints the accommodation of a sizeable substation on the island would entail development on land with an existing land use. Moreover, there would be a substantial visual impact which could affect the island's attractiveness as a tourist destination. It should be stressed that siting a large substation on Alderney is purely a hypothetical option for the purpose of this report rather than a proposal by ARE or OpenHydro.

The tidal stream installations could potentially become a tourist attraction owing to their novelty and originality, as well as their potential significance to the island's economy.

A convincing example of a tidal facility becoming a major sightseeing attraction is the La Rance tidal power plant located in Brittany and operated by Électricité de France. The unique nature of the La Rance power station attracts over 300,000 visitors annually [5.11]. A dedicated visitor centre could well prove to be an attraction on Alderney.

The visual impact of the tidal scheme to be developed on Alderney is expected to be negligible assuming the devices are placed on the seafloor and, if developed on a large scale, power is exported directly to the mainland of France without recourse to the development of large substations on Alderney. Tidal energy technologies that rely on surface piercing structures, such as MCT's Seagen, would create some visual impact depending on weather conditions. The necessity for navigation hazard warning lights and markings would make the visual impact more noticeable.

Another source of the impact on tourism is the project-related offshore construction and maintenance works. Craft involved in construction works could be present over a period of 2.5 years in case of a 1GW development and 6-7 years in case of the 3GW development. These timescales assume phased development in a series of stages. There is the potential to interfere with some sports and recreational activities taking place in water areas adjacent to the deployment site. At least 6 vessels with the total crew of 14 are expected to operate out of Braye harbour during the indicated construction period and during the operation period. Utilisation of the harbour for the purposes of the project would coincide with activities of the Alderney Sailing Club and the large number of yachts the visit Braye harbour.

Tourists who choose Alderney for the abundant sea fishing opportunities the island affords, may perceive presence of the project's vessels as a disturbance that potentially affects their catch. Tidal schemes developed in the Race are in close proximity to four areas frequented by anglers (see Figure 5.2). Consequently they may need to choose those areas to the west of Alderney.

5.1.6 Impacts on Job Creation

Direct Employment

The deployment of a tidal power scheme in Alderney's waters will offer a variety of direct employment opportunities both for residents of the island and for skilled workers from other locations in the United Kingdom and Europe. A range of technical specialities will be required at the stages of construction, operation and decommissioning of the project's installations, thereby generating direct employment (full and part-time salary and wage jobs created in accordance with manpower requirements of the project).

The following qualifications will be required for development of the tidal scheme:

- heavy and mechanical engineering,
- marine engineering and hydraulics,
- electrics and timberwork,
- testing and control equipment technology,
- metalwork assembling,
- construction and haulage,
- welding,
- surveying and reconnoitring,
- repair and maintenance,
- vessel and ROV operation.

Development of a tidal energy scheme on the scale of 1GW or greater is likely to be implemented in a series of stages. Such an approach would allow the retention a work force over a period of few years, enabling partial completion before full-scale operation. Most of the local labour force on Alderney is either orientated towards tourist related businesses including recreational fishing, finance industry and e-commerce or building and renovation work. The majority of the work force employed for a large scale construction project and the subsequent operation and maintenance of a large scale tidal energy scheme will be non-resident. The migrant workers would need to be accommodated either on Alderney or at Cherbourg. It is anticipated that the bulk of the workforce would need to be located in or near the French port because this is the most suitable facility for the large-scale deployment of turbines.

Braye harbour has limited infrastructure and is unsuitable as base for large-scale construction, operational and decommissioning operations that would be envisaged for a scheme of 1GW or greater.

Table 5.6 presents the numbers of the Cherbourg-based workforce, based on the types of vessels and equipment that would be used. Duration of the employment (person-days) per a 200MW unit of power is also shown.

Table 5.6: Cherbourg stationed workforce per 200MW power unit

Vessel	Crew Compliment	No. Days by Phase		
		Construction	Operation	Decommissioning
2 x Standard Tug	7 per vessel	180	200	180
2 x OpenHydro deployment vehicle	5 per vehicle	180	200	180
1 x Offshore Supply Vessel	22	20	0	20
Shoreside support inc. cranes etc	16 FTE	180	200	180
Project Management & Administration Team	10 FTE	180	200	180

The estimates presented in Table 5.6 were provided by OpenHydro. They assume that each unit can be deployed in one 24 hour period. For every 100 days of full-time marine operation another 80 days has been added to account for downtime as a result of poor weather conditions. Based on these estimates a workforce of 72 would be required mostly based in Cherbourg. Assuming that every 100 units takes 180 days to install it would take approximately 2.5 years to install an array on the scale of 1GW and over 6.6 years for a 3GW array. These estimates assume that the development of large-scale tidal stream arrays would proceed in a series of successive incremental stages.

Part of the workforce could operate out of Alderney's Braye harbour. The Alderney-based personnel could be transported to the site by vessels of a smaller size. Braye harbour is within a 10km distance from the Race development site, and this implies only short-distance offshore transfers and less fuel demand.

The ROV and other survey work would also be required throughout all phases of the project. This type of operation could give rise to potential employment opportunities for a crew consisting of 2 personnel based on Alderney.

If a substation were ever considered on the island, an estimated extra construction crew of 35 persons would need to be employed for 9 months for a 1GW project and for 27 months for a 3GW project. Given that majority of the workforce is expected to be non-resident, most of these personnel would need to be accommodated on the island.

The total number of directly employed technical staff that would need to be housed both in Cherbourg and Alderney could reach over 130 (96 vessel crew and project management personnel together with 35 construction workforce, in case a substation is installed on the island).

In addition to the technical and administrative manpower to be employed a range of pre- and post-construction activities would need to be carried out, that would also require the involvement of specialised and skilled labour. Pre-construction activities include site surveys, marine and ground reconnaissance, site clearance and levelling, finance and legal counselling, procurement, project development (including permissions, licensing and liaison with the authorities), as well as environmental and technical monitoring after the construction has been completed. In total, the involvement of an estimated extra 20 personnel and external consultants might be required to carry out these studies.

The bulk of the project workforce would need to be brought from outside Alderney. However, the proposed tidal development could result in some direct employment opportunities for the local skilled labour. Such opportunities include up to 10 FTE management, finance, legal and administration jobs. Additionally, a number of local fishermen may be willing to utilise and expand their skills to fulfil the survey requirements of the project. Vessel crews may partially be comprised of local seamen. A certain proportion of Alderney's workforce have already been engaged in building works on the island. This manpower can readily be used for construction works associated with the project. The maximum number of direct part-time and full-time local jobs generated by the project is estimated to reach 20.

Indirect Employment

In addition to the direct employment benefits associated with the proposed tidal development scheme, some indirect employment would also be expected especially in local service industries. Indirect employment occurs in businesses in the local area supplying the tidal stream facility.

The necessity for accommodating a portion of the project personnel on Alderney would help to stimulate the local hospitality industry which is likely to respond by upgrading and expanding the capacity of existing housing facilities, e.g. hotels, hostels and guest houses. Some landlords may be willing to rent private accommodation for a short or medium term. In such cases the demand for extra letting properties could bring a further advantage to the local housing market. This could, however, exacerbate the strains on this sector that are already apparent from the Island Plan [5.1]. The States might need to expand the amount of rented accommodation to ensure that the indigenous population and the migrant workforce could be adequately housed.

An expected increase in demand for auxiliary services such as cleaning and laundry, catering and provision of foodstuffs, local transportation and security services is likely to result in some growth of employment opportunities in each of these sectors. The local labour market will be able to benefit from such growth by covering the demand.

The project's workers accommodated on the island will have some disposable income for personal purchases and consumption, thereby benefiting local retail trade and entertainment sectors.

The tidal stream technology is likely to arouse interest from tourists visiting the island. To promote and maintain this interest, educational and information provision would be an advantage possibly via a dedicated visitor centre.

It is assumed that the island will receive revenue from the generation of tidal energy as a condition for any developer. The proceeds from licence fees and operating tariffs would represent additional income to the island, possibly enabling investments in training initiatives and professional development. Such initiatives, in turn, will help strengthen and expand the local skills pool and retain people of working age on the island.

Taking into account these projections, it can be assumed that the tidal energy project for Alderney has a high potential for generating indirect employment due to the large scale of the proposed development scheme. As this would be one of the first projects of this kind these figures should not be regarded as firm estimates.

5.1.7 New buildings and infrastructure

Existing infrastructure and land tenure system

Alderney is the third largest of the British Channel Islands. The island is 3.5 miles (5.6 km) long and 1.5 miles (2.5 km) wide, with the total area of 4.2 square miles (nearly 11 km^2).

The limited size of the territory and existing land use constraints have resulted in the imposition of stringent planning regulations. Much of the island has either designated conservation or recreational status which restricts development.

In 2006, the Building and Development Control Committee issued the Land Use Plan for Alderney [5.12]. This plan forms the basis for all new planning applications.

The Land Use Plan distinguishes between so-called Designated Area and Building Area. The former is further subdivided into six zones: Agricultural, Commercial, Protected, Public Utility, Recreational, and Residential. There is a presumption against future development in the Designated Area, although certain development activities are permitted. These activities are listed in Table 5.8.

Table 5.8 Alderney's Designated Area Zones

Zone Type	Permitted Activity/Facility	Permitted Extent of Development
Agricultural	Cultivation or production of crops, producing and rearing of livestock, fish and crustacean, all on a commercial basis	Only for the purpose of appropriate agricultural business.
Commercial / Industrial	Hospitality, catering, retail and wholesale, workshops, offices, and storage areas	Renovations or rebuilds that do not increase existing total ground floor area and height of the existing building.
Protected	Biologically important terrestrial habitats, freshwater habitats, marine habitats, and archaeologically important areas and sites	No development, unless approved by the Committee in order to restore or protect a feature / aspect of Protected Zone. The siting of nautical navigational aids is exempted from this. Any development is subject to an EIA.
Public Utilities	Facilities for providing electricity supply,	No new building or enlargement of

	water, sewerage, waste / rubbish disposal, telecommunications or other public services	existing buildings, unless deemed essential for proper provision of public utilities. Any new building, enlargement or increase in height is subject to an EIA.
Recreational	Recreational facilities	New recreational buildings are permitted for example the proposed new sports hall.
Residential	Housing and associated facilities	New dwellings are permitted but are subject to strict planning regulations. Minor extension or reconstruction of existing buildings.

Alderney's entire coastline, Longis and Braye bays, as well as all the rocks and islets within Alderney's waters, including all inter-tidal rock formations have protected status. The intertidal area between the western end of Platte Saline and the western end of Telegraph Bay is designated as an internationally important Ramsar site.

Recreational areas are mainly located in the northern and north-eastern part of the island, where they intermingle with the protected and agricultural zones. The Recreational zone includes a football pitch, golf courses, the mini-railway and railway lines, a railway shed, tennis and squash courts, together with common recreational areas.

The central, north-western and southern parts of the island are mainly used for agricultural purposes. Facilities of the Agricultural zone include farms, glass- and greenhouses, agricultural and fishing stores, stables, barns, and animal sheds.

Facilities of the Commercial/Industrial zone are few in number and area. Only three of the facilities are categorised as light industrial: 2 sheds of Berry's Quarry in north-east, Ronez Asphalt Production Plant in the north, and Platte Saline Gravel Works in north-west. The rest are hospitality and catering facilities.

Facilities designated as public utilities are a water pumping station, waste treatment and disposal unit, an airport guidance station, a civil emergency unit, cemeteries, a slaughterhouse, a TV mast and satellite dish, reservoirs, the lighthouse and the island's power station which occupies the Glacis site adjacent to Braye harbour. The total area of this site is approximately 14,100 m^2.

The Building Area allows for carrying out of certain construction, extension and renovation works implemented within the limits stipulated in the Alderney's Land Use Plan. Such works must be consistent with the original designation of each area to be developed, e.g. residential, recreational, light industrial, harbour operations, health care facilities, health-related needs, etc.

A number of territories within the Building Area of the island are important wildlife habitats and serve as Alderney's 'green lungs' thanks to their abundant vegetation and forestry. The Land Use Plan discourages the implementation of development activities in such areas which are described in Appendix 3.

The rebuilding of the commercial quay is regarded as a priority.

Impact of installing new infrastructure facilities on Alderney

When planning any development activities on Alderney, all proponents should aim at making the most efficient use of the extremely limited land resources. The scenario of "no development" prevails on most of the island's territory due to the stringent restrictions enforced by the Alderney's Building and Development Control Committee. When the development is permitted, it must be in consistency with the originally intended usage of the area.

Implementation of the proposed tidal scheme off Alderney's shore would have considerable impact on the existing land use pattern if a large substation were built on the island. A substation intended for the 1GW generation would require an area of ~32,400 m^2 and would occupy 3.24 hectares (about 0.03 km^2). A 3GW array would require the an area of nearly 0.1km^2. Given that the larger part of Alderney's land area is designated solely for recreational, traditional agricultural, and residential use new infrastructure on this scale would compromise existing land use designation which would have to be changed to allow development.

Accommodating a substation on a smaller scale on the island could be deemed as a more viable option which will help avoid significant impact. A 40MW scheme, for example, would satisfy the island's own energy demand and also allow the surplus power to be exported to the other Channel Islands. A substation for a scheme of this size would occupy 960m^2 equivalent to an area of 31m x 31m, which is substantially smaller compared with GW scale projects. It may not even be possible to allow development at this scale within existing land use designations given the limited availability of land for commercial, industrial or utility.

If a new substation was contemplated for Alderney its presence on the island should result in the least possible intervention and disruption to the current land use scheme. If tidal power was only required for the island's use a small substation could be incorporated into the existing power station site which is located in Zone 7A (Glacis) in the vicinity of Braye Harbour. The Alderney's Land Use Plan reserves Zone 7A for general harbour usage and recycling, and most importantly for supporting any potential marine energy projects. It is, however, stipulated that these operations shall utilise existing buildings to the extent possible. The current power station and adjacent land occupies the area of ~14,100 m^2 . If electricity were to be imported from France by cable the power station would become redundant for diesel generation and could become a substation with analogous footprint.

If development of a much larger substation were contemplated the most obvious location would be the abandoned Mannez Quarry which is largely concealed from most of the island. Any development at this site would need careful scrutiny to avoid any negative impacts on the adjacent nature reserve. The island's train would also need to be relocated.

Power supplied from a tidal stream energy scheme directly to the island implies the use of power cables and a substation based on Alderney even at a modest scale. Selecting a location suitable for the subsea cables landfall also presents a challenge in the light of the rigorous land use restrictions that are currently in force. Longis Bay on Alderney's east coast is the most suitable landing site for buried cables. However, Longis Bay has a sensitive marine habitat immediately offshore. One potential solution that would avoid damage to this important habitat would be the placement of cables along the causeway which leads out to Ile de Raz. Given that Alderney's entire coastal belt has protected status and its beaches are the main tourist attraction, any infrastructure development on the island's shore would need to be subject to detailed appraisal by the States of Alderney planning department.

Implementation of the tidal energy development involves accommodating the project's workforce on the island. An estimated 24 personnel might need to be accommodated on Alderney if a large scale 1GW tidal energy scheme were contemplated. If the option of constructing an inland substation for a scheme on this scale were contemplated an extra 35 construction personnel would need to be stationed on the island for at least 9 months. The same workforce would need to remain for an estimated 27 months for a 3GW development. The housing demand for these personnel could place an additional strain on Alderney's existing housing stock. Should the project's workforce require building new supplementary accommodation, the latter may be sited in the zones where residential development is encouraged by the Alderney authorities, e.g. in Zones 2A/B, 6, 9, 10 A/B/C, 11, 12, 14A/B, as described above. Any new dwellings will have to demonstrate that they fit within the topography of the selected site and the existing landscape. If residential development for the purposes of the project is planned in the Fort Zone (Zone 8), the historic value of the forts must be taken into account. Zone 15 in Val Field to the west of and adjacent to Le Val is also designated for housing, however, primarily of some community significance, such as nursing care homes, sheltered housing, social housing and medical facilities.

5.2 References

5.1 An Island Plan: Phase 1, Sustaining Alderney's Future, October 2006

5.2 DUKES 2007, Annex A pages 207 - 210

5.3 AEAT/ENV/R/2347 Review of Carbon Emission Factors in the UK GHG Inventory)

5.4 Alderney Angling http://www.alderneyangling.co.gg/

5.5 Alderney Government http://www.alderney.gov.gg

5.6 Alderney Tourism http://www.visitalderney.com

5.7 Alderney Tourism response re. consultation on the introduction of catch allowances for charter angling vessels not in possession of a Guernsey fishing licence.

5.8 Alderney Shipping Company Ltd. www.aldshp.co.uk/

5.9 2007 Annual Report, PR&Marketing Department, Alderney Tourism Board.

5.10 An Island Plan: Phase 1 Sustaining Alderney's Future, November 2006.5.9 Alderney Wildlife Trust http://www.alderneywildlife.org/

5.11 Clark, P., Klossner, R., and Kologe, L. Tidal Energy, Cause 2003: Final Project: La Rance – A Working Case Study, p. 22.

5.12 Alderney Land Use Plan (2006)

6 Conclusions

6.1 Strategic Techno-economic impacts

Tidal stream technology is still at an early stage in development. Few devices have advanced to a prototype stage and only limited trials have been achieved in the open sea. OpenHydro has been testing a small test device for 12 months, but performance data have not been released to AEA.

Most device concepts are based on horizontal axis turbines although some vertical axis devices and even oscillating hydrofoil concepts have been proposed. Devices would be secured to the sea floor by piles, bolted or rely on gravity. Some devices are bottom mounted and operate close to the sea floor. Deployment and retrieval would require cable connection from a surface vessel to either lower or raise the device to the surface before transfer to or from a shore base. Other devices rely on a surface piercing pile foundation to raise or lower them from or into the sea before detachment. A further permutation is a floating device anchored to the sea floor via cables.

The footprint for a 1GW array substation would need to be at least 24,000 m^2 in size. A 3GW array would require 72,000 m^2. The most logical export market for large scale tidal energy development is France. Exporting power to the UK would require a 100 km DC link, four times the distance to France.

Wave Energy

Wave power density is around 10-15 kW/m which is too low for the technology to operate profitably. A 10 km array might be able to generate between 438 and 657 GWh/year. It is possible that an OWC type wave energy generator could be integrated into the island's breakwater.

6.2 Strategic Environmental impacts

Alderney, its adjacent islands, islets and surrounding coastal waters exhibits a diverse range of marine sublittoral, intertidal and terrestrial habitats. Of notable importance are large bird colonies on the island of Burhou and rocky islets which support large breeding colonies of northern gannet, Atlantic puffin and European storm-petrel.

The conservation significance of Alderney's west coast and the Burhou Islands, has been recognized as an area of international importance. This has led to the designation of a Ramsar site in 2005. The designation places an obligation on the States of Alderney to develop a framework for the conservation of the Ramsar Site.

The seas around Alderney also support a diverse range of pelagic fish species often located in close proximity to large sand banks. These areas are popular for both recreational and commercial fishing. Large shoals of sand eels are also observed. This species is an important food source for puffins and other sea birds.

Powerful tidal currents have resulted in highly mobile coarse gained sediments generally less than 1m thick. In some locations these sediments can form sand ribbons and waves. They can also accumulate in banks up to 20m thick.

A 1GW array could potentially reduce CO_2 emissions by between 360,000 te(CO_2) and 700,000 te(CO_2) per year), through displaced fossil fuel generation.

Potential environmental impacts could be caused during the installation and later operation of tidal stream devices and cable laying. These include disturbance to sediment, noise and vibration, adverse effects to fish caused by EMF and collision risk with marine mammals. Potential changes in the tidal currents in the vicinity of the device may change sediment dynamics and the local benthic ecology. There may also be indirect effects on sea birds, if for example, their prey was disturbed

Some environmental impacts may be limited. The impact of sediment disturbance during cable laying could be minimised by the rapid disperse of the sediment. The use of gravity based devices such as OpenHydro's open centred turbine would not require drilling to secure them to the sea floor. Other tidal energy technologies rely on drilling to secure foundations to the sea floor; the resultant noise could cause temporary disturbance to fish and marine mammals.

There is evidence from the offshore wind industry that structures implanted into a marine environment act as artificial reefs, attracting some species of fish, crustaceans and other invertebrates. The extent of the colonisation associated with tidal stream devices is not known.

It must be stressed that there is no definitive evidence for these changes and further research is necessary to determine potential impacts. The UK government through RAG has committed support for research to gain a better understanding of the impact of marine renewables including tidal stream. A number of research topics have been identified including:

- Tidal flow effects of energy removal
- Sediment and sea flow effects of energy removal
- Faunal collision with rotor or vane
- Operational acoustic emissions
- Characteristics of operational vibration
- Functional importance to potential development areas to mobile species
- Navigational impacts
- Impacts on other users (fishing recreational use)
- Ecology of seabed in tidal streams
- Ecology of tidal streams in relation to mobile species

It is recommended that tidal energy development around Alderney would benefit from generic environmental research in the following four areas.

- Assessment of the potential impacts of energy depletion from a large scale array using a combination of modelling and surveys.
- Assessment of the potential impact on sea birds and their prey from tidal energy.
- Review and assessment of the impact of EMF from submerged cables and tidal stream generators.
- Review and assessment of the potential for tidal stream devices to induce colonisation and increased biological productivity.

6.3 Strategic Socio-Economic impacts

Financial Benefits

Revenue to the States of Alderney from tariff levied could be between £0.93M and £1.87M from a 1GW array depending on the amount of electricity generated. A 3GW array could yield between £2.8m and £5.6m.

An estimated 6,149 tonnes of CO_2 emissions from the use of fuel oil generated electricity could be saved if tidal energy replaced the island's existing power plant.

Complete electrification of the island would displace the equivalent of an estimated 3,176 tonnes of fuel oil at a cost of £1.9m at 2006 prices. The cost-benefit to the island would depend on the cost of tidal energy as well as the cost of fuel oil. At a cost of €150/MWh or £0.144/kWh for tidal energy the cost of supplying the bulk of the island's energy demand (excluding transport) would be £6.4m/year or more than three times the cost of saved fuel (at 2006 prices). Therefore complete electrification would only be economic if the price of oil increased to three times the 2006 price, and the benefit would increase as the oil price increased beyond that point.

If electricity were to be imported from France by cable during slack water periods there would be no need for the diesel plant and the saving would be greater. This would also eliminate the cost of maintaining the diesel plant and would further reduce CO_2 emissions.

Fishing

Fishing is an important tourist industry for Alderney contributing up to 5% of the island's tourist income. There is also a small but important commercial fishing industry that includes lobsters and crabs as well as fin fish. There is also a small but important commercial fishing industry which is an integral part of the island's economy and way of life.

Fishing grounds near Alderney and the Casquets are often located on large sand banks. Although these areas are unsuitable for tidal energy developments, the management of fishing vessels and those involved in tidal energy development would need to be carefully controlled to avoid collision. There is also the possible potential for temporary disturbance to fishing grounds.

Navigation

Large bottom mounted tidal stream devices possibly up to 2MW in size would be deployed in the Race in less than 40m depth. This is potentially too shallow for large commercial vessels therefore a permanent exclusion zone would need to be applied. The use of pile mounted, surface piercing structures, or floating devices, would present obvious navigation hazards and would require a permanent exclusion area. During construction, and to a lesser extent during operation, there would be an increased presence of vessels operating from both Cherbourg and Braye Harbour.

Tourism and Recreation

Alderney is a popular tourist destination and its economy is heavily reliant on the annual influx of visitors. Tidal energy development could have some impact if large substations were built on the island. The extent of this impact depends on the scale of development. Surface piercing technologies would create some visual impact depending on their proximity to the island creating some modification to the seascape. There is also the potential for conflicts between developers and those involved in recreational pursuits.

The active promotion of the technology would create added interest for tourists, particularly if there was a dedicated visitor centre.

Employment

During construction of a large scale array an estimated 130 personnel could be directly involved in tidal energy development. This does not include pre-construction activities such as resource assessment, environmental monitoring or survey work. Most of the work force would need to be based in Cherbourg but up to ~24 could be based on Alderney. These estimates do not include additional service related jobs generated by the presence of migrant workers.

Buildings and Infrastructure.

Alderney is a small island of only 11 km^2. Much of the land area has either protected conservation status or has specific land use designations which permit only limited development. Any new infrastructure on the island would, therefore, be subject to stringent planning requirements which may limit the extent of any land based facilities. A substation for a 1GW array, for example, would occupy an area of 32,400 m^2. Even a smaller 40 MW array substation would require 960 m^2. One possible solution could be the use of space within Mannez Quarry. It is recognised that the island's train terminus might need to be relocated. Total dependence on tidal energy would require an alternative power supply via subsea cable from either France or Guernsey.

Installing subsea cables will also need careful consideration. Longis Bay on the east coast might be a possible route for cables linked to an array in the Race. However, this location has a sensitive sublittoral habitat. One possible solution would be to run the cables along the side of the existing causeway to Raz Island.

New supplementary accommodation might also be necessary for construction personnel.

7 Appendix 1 – Glossary of Technical terms

Glossary of technical terms

k	kilo 10^3
M	Mega 10^6
G	Giga 10^9
T	Tera 10^{12}
kWh	kilowatt-hour(s).
m	metre(s).
M	mega or million(s).
m/s	metre(s) per second.
MWh	Megawatt-hour(s).
te	tonne(s); 1te = 1000kg.
kt	kilotonnes, 1,000 tonnes

Capex	Capital cost for a project or scheme. The value should include all capital costs required to develop and build a scheme including design, management and environmental monitoring and impact assessment as well as capital outlay for materials, plant and labour.
Chart datum (CD)	The datum for Admiralty chart depths of water, equal approximately to the level of a lowest astronomical tide (LAT).
Coefficient of performance, C_p	Power out/(1/2AρV^3) where A = swept are of blade, ρ = density of water and V = current velocity.
Discount rate	This is a rate expressed as a percentage, used in discounting all benefits and costs to present day values.
Discounting	This is a method of assessing the present worth of a stream of costs or benefits arising at various times in the future. The calculation is made in real terms and is not an allowance for inflation. It attempts to allow for the preference for money now rather than later.
Habitat	The area inhabited by a plant or by a plant community that has been colonised as a result of influential external factors.
Jack-up barge	A barge with retractable support legs that can be raised to allow the vessel to be floated and towed to different sites. Once in position the legs are lowered to provide a stable self supporting platform for drilling.
Net present value	This is the net amount of the discounted future costs and revenues expressed in real terms associated with a capital investment.
Numerical model	A computer-based simulation of a real situation. In the case of numerical hydrodynamic models, the equations of motion and continuity are usually solved in one or two dimensions.
Opex	Operation and maintenance costs required to run and maintain a project or scheme. This should include all costs associated with the project for example maintaining ground water levels and operation of ship locks as well as operation of the power plant. Opex should also include the cost of replacing major items of plant.
Ordnance Datum (OD)	Arbitrary zero height, assumed to be the mean sea level at Newlyn, Cornwall, and from which the heights above sea level of all official benchmarks in Britain are measured.

Power train	Combined turbine, gear box and generator combination which converts energy in a fluid flow into electrical energy.
Ramsar sites	Ramsar sites are wetlands of international importance designated under the Ramsar Convention
Rated Capacity	The capacity of a generator is the maximum energy output from the generator when it is operating at a specific optimum condition.
Rated velocity	The current velocity that is required to achieve the rated capacity for a turbine generator.
Stator	The stationary component of an electrical generator. In an open centred turbine the stator forms a continuous rim around the rotor.
Sublittoral	The near shore zone below mean low water level and extending to a depth of 200m.
Tidal current	A marine current caused by the moving gravitational fields of the sun and moon relative to the earth.
Tidal range	The difference in water levels between high water and low water.
Turbidity	A measure of the clarity of water from which the amount of suspended solids in the water may be inferred.
Wave height	For this assessment, taken as the significant wave height, which is the mean height of the $1/3^{rd}$ largest waves.
Wave period	The time between successive wave crests.
Yaw	The angular rotation of an object about a fixed axis within a horizontal plane.
Yawing mechanism	The mechanical or hydraulic components of a turbine generator device which enable it to rotate about a fixed axis within a horizontal plane.

8 Appendix 2 – Discounted Cash Flow Analysis and Net present Value

Methodology for calculating the unit cost of energy

The unit cost of energy for tidal, or any other power plant, is the value of energy, expressed as £/MWh or p/kWh, that would be required to repay the capital investment in the power plant. The methodology relies on a discounted cash flow over the technical life of project. In the case of a tidal current array a technical life of 20 years has been assumed. The methodology also assumes an annual operation and maintenance or running cost which must be included for each year of operation. For renewable energy schemes the energy is free.

A Discounted cash flow (DCF) analysis uses future free cash flow projections and discounts them (most often using the weighted average cost of capital) to arrive at a present value, which is used to evaluate the potential for investment. The analysis in this study takes no account of taxation, inflation or profit and should be regarded as a simplified method to indicate the value of energy for a specific scheme in present day values. The discounted cash flow can be calculated using the following equation where n equals the number of years that the scheme is in operation. The energy that is generated each year is also discounted using the same methodology and over the same number of years. The unit cost of energy is the sum of the discounted cash flow divided by the sum of the discounted energy.

Calculated as:

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \ldots + \frac{CF_n}{(1+r)^n}$$

CF = Cash Flow

r = discount rate (WACC)

Net Present Value (NPV)

NPV is an indicator of how much value an investment or project adds to potential investors. With a particular project, if C_t is a positive value, the project is in the status of discounted cash inflow in the time of *t*. If C_t is a negative value, the project is in the status of discounted cash outflow in the time of *t*. Appropriately risked projects **with a positive NPV could be accepted. This does not necessarily mean that they should** be undertaken since NPV at the cost of capital may not account for opportunity cost, i.e. comparison with other available investments. In financial theory, if there is a choice between two mutually exclusive alternatives, the one yielding the higher NPV should be selected. The following sums up the NPVs in various situations.

If...	It means...	Then...
NPV > 0	the investment would add value to the investor.	the project may be accepted
NPV < 0	the investment would subtract value from the investor	the project should be rejected
NPV = 0	the investment would neither gain nor lose value for the investor	This project adds no monetary value to the investment. Decision should be based on other criteria, e.g. strategic positioning or other factors not explicitly included in the calculation.

However, NPV = 0 does not mean that a project is only expected to break even, in the sense of undiscounted profit or loss (earnings). It will show net total positive cash flow and earnings over its life.

9 Appendix 3 – Land use categories used on Alderney

- Zone 3: Area adjacent to La Vallee, the Terrace and Valley Gardens in north-west of the island (development only allowed within restrictions of the agricultural zone);
- Zone 4: Butes Field and York Hill in the north (development only allowed within restrictions of the recreational zone. An EIA study to be conducted for all proposals);
- Zone 5: Cotil du Val and Valongis above the 40m contour. This zone also includes the harbour area, Braye Bay and Braye Street described above (development only allowed within restrictions of the protected area zone);
- Zone 13: Historically important Ladysmith, north of Petit Val (development only allowed within restrictions of the protected area zone).

Low density housing development, which requires that dwellings not exceed a density of 4 properties per acre, is allowed in the following areas of Alderney:

- Zone 2B – area adjacent to Butes Lane in the north of the island;
- Zone 6 – existing Ribbon Development to the south-east of Routes des Carrieres;
- Zone 10C – area bounded by Fontaine David, Braye Road and the northern property boundary of Audeville estate;
- Zone 11 – southern slopes of Cotil du Val, adjacent to Longis Road and Champs Beulai;
- Zone 12 – land at Les Rochers;
- Zone 14B – land adjacent to Wide Lane.

Medium density residential development implies that every new dwelling is built on a plot that has a minimum area of one-eighth (0.125) of an acre and that the whole of the minimum area is sited in the zone in which the development is to take place. Medium density housing development is permitted in the areas as listed:

- Zone 2A : Grand Hotel Site in the north of Alderney;
- Zone 10B : middle slopes of Cotil du Val;
- Zone 14A : land adjacent to Rue de la Saline in north-west.

The following zones are designated for higher density or terraced housing development:

- Zone 9: Brickfields in the western part of the island (no additional commercial or light industrial development is allowed);
- Zone 10A: Lower slopes of Cotil du Val adjacent to Newtown Road.

The Fort Zone (Zone 8) that consists of Forts Albert, Houmet Herbé, Tourgis, Arsenal and Fort Ile de Raz is an important historical military feature of the island. All the ports, except for the Arsenal, can only be used for residential, educational and tourism purposes. Light industrial development, along with commercial and residential use, is allowed in the Fort Arsenal, provided that it is consistent with the historic nature of the area. Any development proposed for the Fort Zone is subject to an EIA study and full-scale public consultation.

The development restrictions that are currently in force in Alderney due to the shortage of land resources limit any development opportunities to a minimum. Only few sectors can potentially be considered for commercial and industrial projects:

- Zone 7A: Glacis which is adjacent to Braye harbour. The usage of this area is restricted to recycling operations, States usage and general harbour usage. Alderney’s power station is also situated in this Zone.
- Zone 7B: north of Crusher site. The site is reserved for harbour-related facilities to allow adequate working space for harbour operations during the construction works at the commercial quay.
- Zone 7C: south of Crusher site. Commercial and light industrial development is permitted in this area.

- Zone 16: Breakwater, Grosnez and Quays. This area is reserved for the development of the harbour facilities, including for recreational, amenity and commercial purposes. Any development proposed for this area is subject to an EIA study that shall aim at recognising and protecting the sensitive nature of the harbour area.
- Zone 18: La Corvee. Any development within this area is for the benefit of the commercial and industrial sector of the island’s economy. An EIA study must be conducted for any proposed activities. The developments should provide for adequate and safe road access, landscaping, appropriate car parking facilities, full and proper separate drainage agreed with the States Engineers.

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