GREC

Guernsey Renewable Energy Commission
Pre-feasibility Technical Report
November 2009

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Contents

1 Introduction

1.1 *Scope*

This report provides a brief study into the Islands of Guernsey, Herm and Sark with regard to their potential for development of Marine Renewable Energy. The report covers the main technical criteria for early assessment of site suitability including preparation, equipment and logistics. A Rough Order Cost for two alternative schemes is included.

1.2 *Primary Objectives*

The following primary objectives were set at commencement of this task;

- To provide the first technical inputs to the States of Guernsey Marine Renewable Energy project

- To provide background information of a clear and unbiased nature to environmental specialists to aid them in completing relevant sections of the Regional Environmental Assessment, (REA)

- To suggest development scenarios for further detailed assessment

- To provide Rough Order Cost, (ROC), estimates of a typical development project covering capital and revenue costs, for use in more detailed financial modelling

2 Resource

2.1 Tidal Stream

The resource assessment used for this work has been progressed in support of that described the REA scoping document. This was a desk top study based mainly on the BERR Atlas of Marine Renewable Energy Resources. This source is useful in the preparation of a pre-feasibility study to identify areas worthy of further detailed survey and potential commercial exploitation.

The figure below illustrates potential sites identified from the above source and basic Admiralty Chart bathymetric data.

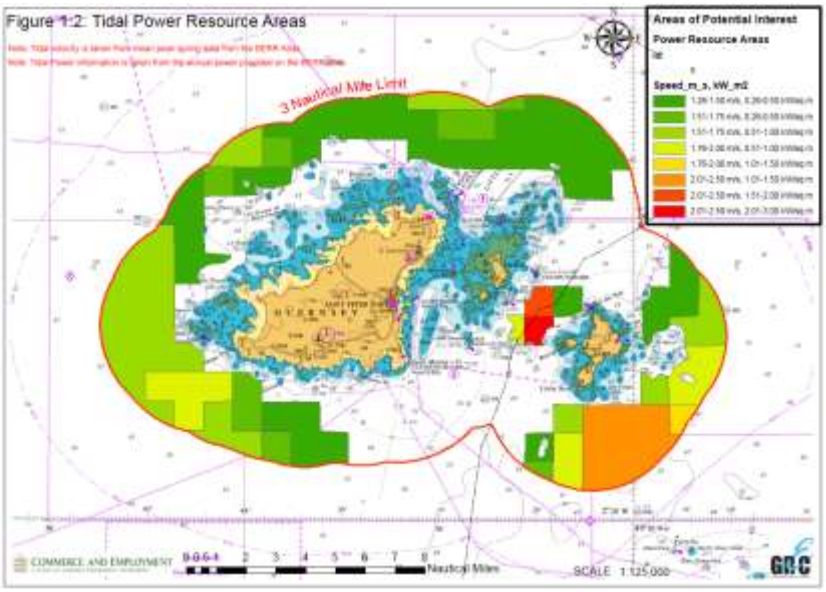

Figure 2.1 – Tidal Stream Resource

The BERR atlas is produced using a large modelling grid and is thus recognised as limited in its accuracy. It must be recognised that locally observed or known areas of energy resource, both wave and tidal, are therefore not always shown in the atlas. Work is currently being undertaken to identify and quantify the tidal resources available in the study area by the Robert Gordon University.

2.2 *Tidal Range*

Whilst many of the bays and inlets around the island appear to have good tidal range the small surface areas of water that could be enclosed by barrages limits makes them unsuitable. The actual volumes that could be contained could not generate enough electricity to justify the initial capital investment or environmental impact.

2.3 *Wave*

Again, using data taken from the BERR Atlas of UK Marine Renewable Energy Resources, there is evidence of a 10-15kW/m total power resource around Guernsey. A commercial wave device developer, Pelamis, states that for its devices any area of a yearly average resource with a 15kW/m resource there is a possibility that energy could be generated at competitive prices. (http://www.pelamiswave.com/content.php?id=155). The significant wave height indicated by the BERR Atlas is of the order of 1.51-1.75m (excluding the region east of Sark). Suitability of Wave Energy Resource also depends on the wave frequency, which is not covered by the BERR Atlas. Furthermore, it should be noted that this is just an average. Power will not be constant and is also subject to the same potential inaccuracies as the tidal power data.

Before detailed specification and design of a wave energy site is commenced detailed resource surveys are required. This will require the placement of measuring devices in the areas of interest over a period of at least twelve months. This data will then allow the most appropriate form of technology to be selected for the wave resource available. This is important as the current technologies are diverse in their mode of operation and require different sea conditions to operate at peak efficiencies. Starting this work soon would be beneficial in attracting developers.

3 Development Strategy

3.1 *Capacity Target and Purpose*

A target installed capacity should be set based upon the available resource, the state of development of the desired technology, and the Island's aspirations toward the proportion that renewable energy should take in the overall supply mix.

The commission has a minimum targeted capacity for installation of 90MW from Tidal Energy and 10MW from wave energy as stated in the REA scoping document.

These targets are ambitious and require detailed resource measurement survey work to be completed in order to identify suitable sites for installation. The area of sea that is available to be exploited can diminish significantly once all the relevant environmental and marine spatial planning constraints have been taken into consideration. For the purposes of Rough Order Cost estimation, a typical 40MW tidal array will be used to develop figures for comparison, methodologies and points for discussion.

3.2 *Ownership scenarios*

As the marine renewable energy industry develops into commercial operation, the range and nature of schemes being proposed will change. Initially much of the proposed and installed equipment will be prototype and this is currently being undertaken by technology developers themselves at test sites such as the European Marine Energy Centre (EMEC) in Orkney and Strangford Lough in Northern Ireland. However large power station operators are now beginning to invest in particular technologies and to apply for leases to the UK Crown Estates for sites to develop. This can be seen with Scottish Power investing in Pelamis PB2 machines for test at EMEC and companies such as International Power, RWE and Scottish and Southern Electric bidding for sites in the Pentland Firth.

3.3 *Community Ownership*

It is estimated that the cost of establishing a Wave Energy Development of 20MW will be in the region of £30M, whilst a 40MW Tidal Energy Development would be in the order of £70M. These prices will vary considerably dependent on distance offshore, seabed conditions and bathymetry. However, it is unlikely that the States would wish to make such a large investment themselves.

Any offshore marine energy venture is currently considered to be high risk. Until sites have been installed and a history of operation developed there is little evidence to which insurer's can refer to formulate sensible insurance schemes with realistic premiums. The financial impact of having to perform any type of unplanned repair activity is high. The cost of chartering a suitable vessel, mobilisation of the required equipment and loss of generation income are all significant. These costs can increase rapidly if there is a need to wait for a suitable weather window. If not correctly prepared for, these factors can lead to months of delay before a repair can be made with the correspondingly high financial penalties.

Some form of local community benefit is generally considered essential in the establishment of renewable energy farms. This is an important consideration for this study as most residents of the Bailiwick of Guernsey will have some sense of ownership of the seas around the Islands. Methods of returning funds to the community for re-investment in community projects are established and documented for wind farm development.

3.4 Commercial Ownership

It must therefore be taken into account that the level of funding required to develop, install and operate a commercial marine energy farm requires an organisation of considerable size. These are most likely to be the large power scheme developers such as utility companies. They are commercially aware organisations who will want to see a return on their initial and long term investment.

In some part, the utility companies are using income from more traditional power sources to offset losses incurred in the early stages of developing marine renewable energy projects. The sums of money required to undertake the initial development work are relatively small when compared to their annual turnover and they do understand the need for initial less profitable schemes to be undertaken. However, any large-scale scheme must show the potential for profit at some stage.

3.5 *Staged Development*

At present the UK has several test or demonstration sites either in existence or under development. This is as a result of a coordinated strategy involving various stages of testing in ever-more exacting environments. They generally begin with tank testing, moving to the New and Renewable Energy Centre (NAREC) in Northumberland followed by deployment at EMEC for wave and tidal flows that are of commercially exploitable potential.

However, several developers, both wave and tidal, have experienced difficulties in their early stage deployments and so it is now perceived that a first development should not be in the fastest tidal velocities as has currently been pursued.

4 Potential device technologies

4.1 *Tidal Stream*

There is a diverse range of tidal device designs currently under development and they can broadly be divided into four main categories based on their principle of energy extraction; horizontal-axis turbines, vertical axis turbines, oscillating hydrofoils and devices utilizing the Venturi effect (it should be noted that although Venturi could perhaps be considered a sub-set of horizontal axis machines, they present different considerations when undertaking Environmental Impact Assessments (EIAs). Therefore, it is appropriate to treat them as a separate category).

- **Horizontal-axis turbines** work on a similar concept to on-shore wind turbines. The moving water turns the blades in a similar manner to air flowing past a wind turbine. The SeaGen is an example of a horizontal-axis device (http://www.seageneration.co.uk/).

- **Vertical-axis turbines** work on a similar principle to horizontal-axis turbines, the major difference being that the rotor's axis has been re-orientated by 90° so that it is vertical. The Proteus Mark III is an example of a vertical-axis device (http://www.neptunerenewableenergy.com/).

  Horizontal and vertical turbines can also be further sub-classified into lift and drag type turbines, the first of which are characterised by blade speed exceeding water speed and latter having lower blade speed in comparison with speed of water. Lift type devices are known to be more efficient than drag devices [HydroVolts; The evaluation of an axial flow, lift type turbine for harnessing the kinetic energy in a tidal flow, W.J. Swenson, Northern Territory Centre for Energy Research, Northern Territory University]

- **Oscillating hydrofoils** move due to water flow on either side of an aerofoil section. The tidal current flow over the hydroplane section creates vertical forces which cause it to oscillate. This motion and force is used to drive a hydraulic motor and subsequently turn a generator to create electrical power. The Pulse hydrofoil concept is an example of a device utilizing this technology (http://www.pulsegeneration.co.uk/).

- **Venturi Effect** devices are enclosed in a duct, whose diameter reduces in order to increase flow rate through the turbine. The orientation can be horizontal or vertical. The accelerated water can either drive a turbine directly or produce a pressure difference which is used to drive an air-turbine. The Rotech Tidal Turbine is an example of a device utilising the Venturi effect (http://www.rotech.co.uk/).

A range of different systems are used to secure devices to the seabed. Thus tidal devices can also be sub-classified as floating, gravity based or pile mounted. Floating devices can be attached to the seabed using a flexible cable or chain and be allowed to move relatively freely responding to the changes of tidal direction. Alternatively, they can be secured by a fixed rigid mooring to limit movement, or arranged in a group of turbines on a supporting platform which responds to water level changes. Devices that are gravity based are mounted on the seabed or resting on it rigidly due to the device's large weight. Pile mounted devices rest on a pile drilled into the seabed and can often be lifted up for maintenance.

In general, the trend for tidal stream devices (irrespective of the energy capture principle) is for offshore deployment in water depths of up to 100m, with typical depths of approximately 20-50m. This study focuses on an area with a water depth of 20-50m which is suited to most offshore tidal devices. Large scale applications of tidal devices will involve the installation of numerous devices or device arrays known as tidal energy farms. It is anticipated that for an array footprint of 0.5km^2 (30-50 devices), the potential generating capacity could be in the order of 30 to 50 MW.

4.2 Tidal Turbine Structures

To support the actual turbine itself it is necessary to mount it on some form of suitable sub-structure secured to the sea bed. This structure will have tolerances set on its alignment in both the horizontal and vertical plane to ensure the turbine operates efficiently. These limits are unlikely to be above +/- 4 degrees.

There are currently three approaches considered to achieving anchorage to the sea bed, namely gravity based, piling or tension mooring.

- **Gravity Base** is becoming the design aim of the majority of device developers. It relies on building a structure of sufficient mass in water, or that can be ballasted with sufficient mass, to create frictional drag on the sea bed of a magnitude able to withstand the drag-forces induced by the tidal flow and the overturning forces (moments).

- **Pile or pinning.** A mono pile is driven into the sea bed or "pins" are driven which pass through and are used to clamp a steel structural frame to the sea bed.

- **Tension Mooring.** The device is positively buoyant and floats in the water column attached to the sea bed via tension legs which are in turn anchored through either gravity or by pinning. This allows the device to slew and move to its optimum orientation with respect to tidal flow.

Each of these techniques has obvious merits and has been used successfully in other offshore applications. However, there are various difficulties associated with their application to tidal turbines. Gravity bases are, in theory, the simplest and should be the easiest to deploy. To secure a turbine of 1MW capacity with a blade diameter of approximately twelve metres in tidal velocities of approximately 1.75 m/s, it is likely to require ballast weights of approximately 700tonnes. This is approximately 91m^3 of steel, or a 4.5*4.5*4.5m block.

Mono piles require driving into the sea bed to a suitable depth to allow them to withstand the over-turning moment and support the weight of structure above. The pile size for a 1MW capacity turbine will require approximately 14m penetration with a maximum diameter of 914mm. The driving operation generally requires some form of jack-up or spread moored vessel. These vessels can generally only work in tidal velocities of 0.5m/s for jacking or piling and 1.5m/s for other working. This results in a very short working window through each tidal cycle requiring vessels to be on site for long periods with the potential for long periods of weather downtime.

Tension mooring of devices that are semi-submerged in the water column is a complex solution. The dynamic forces are difficult to quantify and so assumptions to ensure the design is safely engineered must err on the cautious. Each mooring leg will need expert design but is likely to be made up in sections to deliver the required properties. These are likely to consist of a clump weight or Bruce type anchor, length of chain and then a flexible link. Clump weights are likely to be in the region of 30 to 50 tonnes with the full anchor leg being anywhere from 10 to 80m in length depending on the device attached.

Gravity bases are the design aim as they should, in theory, require simply lowering to the sea bed from a suitable vessel. The operation requires no or limited sea bed preparation and less time to perform the actual installation. The large masses involved mean that deployment often cannot be achieved in a single lift and it therefore must be done in stages at each slack water period and could take up to six lifts to complete.

4.3 *Wave Energy Conversion (WEC) technology*

There is a diversity of WEC device designs currently under development. These can be divided into four main categories, based on the principle of energy extraction employed: attenuators, overtopping, point absorbers and oscillating water column (OWC).

- **Attenuators** are floating WEC devices which have their main axis perpendicular to the wave front. They operate in parallel to the wave direction, riding the waves. The Pelamis device is an example of this type of device (http://www.pelamiswave.com/)

- **Overtopping** devices store the water from the incoming waves in a reservoir above sea level, using it to drive low-head turbines for energy generation. The Wave Dragon is an overtopping WEC device, using this principle of operation (http://www.wavedragon.net/).

- **Point absorbers** are floating WEC devices which extract energy in all directions through the vertical movement of a moving part in relation to a fixed base. Examples of point absorber devices include the Ocean Power Technology's PowerBuoy and the Fred Olsen's FO3 device (http://www.oceanpowertechnologies.com/).

- **Oscillating Water Column (OWC)** devices are open to the sea below the water line and enclose a column of air. Moving waves cause the water column to rise and fall, compressing and decompressing the trapped air column. The moving air column drives a turbine to generate electricity. The onshore Wavegen and offshore Energetech are two examples of OWC devices, along with the Superbuoy concept (http://www.wavegen.co.uk/ and http://www.oceanlinx.com/ previously known as Energetech Australia Pty Ltd.).

In terms of their installed location, WEC devices can also be sub-classified as shoreline, near-shore or offshore. The trend in all types of Offshore WEC device design is for deployment in water depths of up to 100m, with typical depths of approximately 50m. Offshore design is mainly preferred due to the higher annual wave energy available.

This study focuses on an area with a water depth of 20-50m which is suited to 'offshore devices'. However, it is important to note that shoreline and near-shore devices are available and may be suitable for deployment within the region. Aquamarine Power's Oyster and Neptune Renewable Energy's Triton are two examples of devices operating in shallower and near-shore waters (http://www.aquamarinepower.com/ and http://www.neptunerenewableenergy.com/).

Large scale applications of WEC devices will involve the installation of large arrays or wave energy farms. It is anticipated that for an array footprint of 4 km^2 (7 to 100 devices) the potential generating capacity will be in the order of 15 to 50 MW [1].

4.4 *Wave Energy Convertor Mooring*

The different types of wave energy convertors all require a slightly different approach to mooring system design. The amount of positive buoyancy involved, the required motion and depth of water will dictate the system design.

In general, in areas of high energy seas, the sea bed tends to be hard rock or mobile shoals of pebbles/shale. Large boulders are often reported to move along the seabed through such areas. It is unlikely that a simple short length of chain attached to a Bruce or fluke type anchor will obtain sufficient purchase alone. The mooring systems will therefore be of a composite leg type with clump weight or anchor, length of chain and flexible section. The number of legs will be dependent on the device.

Pelamis machines currently use two to three nose anchorages leading into the prevailing wave direction with a single stern leg that is long enough to allow the device to pivot and align with the predominant wave direction within suitable limits. The current devices are 3.5m in diameter with an overall length of 120m for a power output of 750kW.

Point absorbers such as OPT's Power Buoy are more likely to use three or more equally spaced legs. The clump weights and design of moorings will be dependent on the device but a rule of thumb is that mooring lengths should be at least three

[1] Scottish Marine Renewables Strategic Environmental Assessment (SEA), Environmental Report Section D: Energy Resource Assessment and Cumulative Effects, March 2007

and a half times the water depth, so for 50m depth this gives 175m per leg. Clump weights will be in the region of 30 to 100tonne depending on the device. The new PB150, a 150kW device will be 10m maximum diameter with an overall height of 44m (34.75m of which is submerged).

One device known to use tension leg moorings, similar to that used by semi-submersible vessels in the oil and gas industry, is being developed by Orecon. This is a 1.5MW wave energy device with a large surface structure. It can therefore be assumed that the sub sea weight required will also be large, possibly thousands of tonnes as opposed to hundreds.

4.5 Infrastructure Equipment

Since each tidal turbine or wave energy convertor is of relatively low capacity in relation to anticipated demand it will be beneficial to connect several together offshore and then to transmit the generated power ashore via either a single cable or two or three smaller ones. A method of isolating either single turbines or small groups is probably required to allow flexibility in operation and to provide a means to isolate machines for maintenance or repair without having to shut down the whole farm. This all requires the deployment of additional equipment either to the marine energy converters or to a connecting hub-structure.

At present sub-sea connection and hub infrastructure for power systems is not fully developed. The systems will need to take from the offshore oil and gas industry which does deploy much of the required building blocks, albeit with lower capacity ratings that will be required for large marine energy schemes. In particular the development of subsea transformers to step the voltage up for efficient transmission to shore is required. Currently they have and are being deployed in similar capacities for the Ormon Lange oil field in Norway. These devices are relatively large, potentially with an 8m diameter footprint, and can weigh in the region of 35 to 50tonne in air. Additional mass for adequate ballast or foundation to retain them in high energy seas such as those around Guernsey, Herm and Sark is also required. Depending on the type and profile of the sea bed this could require complex structures and installation techniques adding to cost and time to deploy.

The requirements of the various developers are likely to be mixed and so requesting data from them as to facilities they would like, whilst necessary, can lead to a complex picture that is difficult to turn into a realistic industry-wide set of specifications. Bearing this in mind and the stated aim of providing input to the REA study, the following list of minimum requirements is given;

- A transmission cable from the offshore site with a path to a grid or transmission network;
- An area of sea consented and marked appropriately as a marine energy zone;
- A form of SCADA system capable of providing a sufficient level of control to satisfy the requirement of MGN 275 in an emergency situation;
- A set of metering equipment which will accurately measure both power produced and power used;
- Suitable control and safety switch gear for connection to either a local transmission network or private consumer dependent on scheme adopted;
- Appropriate buildings to house the shore-side equipment and control stations as required by the scheme adopted;
- Appropriate structures and housings for any sub-sea equipment required in the scheme adopted;
- Appropriate transformers and associated equipment offshore to step up the generated voltage before transmission to shore to reduce losses.

5 Logistics and Port Facilities

5.1 Logistic Scenarios

In installing any marine energy conversion devices the offshore logistic requirements are very much dependent on the nature of energy farm to be installed and the local port facilities available. It should also be noted that Guernsey has no heavy industry of the sort associated with subsea engineering. It is therefore necessary for the majority of devices and other equipment to be imported to the islands ready for installation. However, some tasks and components will remain common to all types of development with respect to their logistics and their impact on the Island of Guernsey. In particular this includes transmission cable installation, large mooring or foundation deployment and shore control equipment installation.

The transmission cable requirements will be dependent on the final capacity of site to be developed. Large capacity transmission cables will be required for the capacities currently envisaged. It is common practice to load this type of cable directly onto the vessel which will lay it. The vessel will then transit to site, complete the installation, and returns to a convenient home port to de-mobilise. Additional facilities are thus unlikely to be required from any ports in Guernsey.

However, the installation of foundations, moorings, sub structures and turbine nacelles will require the use of port facilities at a conveniently close location. Many of the turbine manufacturer's have recognised and wish to establish techniques where prefabricated sections of structure and turbine can be completed close to the deployment sites to reduce transportation costs and ease logistics difficulties. Their sequence of activities would thus be to ship pre-fabricated sections to a vessel mobilisation port, complete assemblies, load installation vessels (probably three at a time), transit to site, deploy and then return to collect more.

5.2 *Port Facilities*

The type of port facility required during each stage of installation and operation of a marine energy site varies with the different types of vessel involved at different stages. The port facilities are currently fully utilised with the major limitation on deep water berths already a concern. The largest vessels at St Sampson are currently small tankers that are used to supply the island's Heavy Fuel Oil for the power station on the North side and other fuel requirements on the south side. The limitation of the berths at St Sampson harbour are that they dry out completely and vessels must therefore be Not Always Afloat but Safe Aground (NAABSA) to use them. The photograph below shows berths 1 and 2 on the north side.

Figure 5.2.1 St Sampson Harbour North Side

More modern offshore support vessels tend to be fitted with azimuth thrusters for propulsion and are not generally NAABSA in construction. Therefore this precludes the facilities on the island for use in servicing the installation activities unless significant improvements are made.

5.3 *Installation Vessel Requirements*

Early stages of the project will require detailed sea bed and resource survey work to be undertaken with relatively small vessels. Benthic ecology, birdlife and marine mammal surveys are achievable from relatively small vessels which can be accommodated within the current harbour facilities on the east coast of Guernsey, although it is recognised space is at a premium.

Sea bed bathymetric surveys are generally done from slightly larger vessels capable of twenty four hour operation. This increases efficiency over the large areas considered for marine energy farms. This work will cover potential cable corridors and the whole of a prospective deployment area. Correct specification and quality control of this work and the data produced is required to ensure that it is suitable for use by archaeologists and those who will be designing the energy farm. It is achievable from vessels under 30m in length, again which should be readily accommodated, space permitting, in either port.

Greater difficulties in accommodating vessels will commence once any type of mooring or foundation structure deployment commences. If the main installation activities are to be completed using barges on spread moorings, Anchor Handling Vessels (AHVs) are required, and these vessels are generally 75m plus in length with a draught of 5m to 7.5m. They are unlikely to have deck space to carry all the anchors/ clump weights and so may request temporary lay down areas on shore. If the harbour facilities have not been improved before the work commences then the nearest alternative ports in UK or France will need to be utilised for handling, thus introducing transits between, handling and storage charges at other ports.

The two main types of installation vessel that would be considered for this work are either a Dynamic Positioning 2 (DP2) installation vessel with heave compensated deck crane or some form of heavy lift barge. The DP vessels range in length from 80 to 120m with a draft of 6.5 to 7.5m. They are therefore too large for the islands berths. The typical lift barges required for a lift of approx 200tonne are a length of 61m, beam 23.5m and a draft of 5.6m. These would also need the support of some form of AHVs.

Whilst some jack-up type vessels can just operate in a 30m depth of water they would be limited by tidal velocity. The time taken to position and then deploy legs is likely to exceed available working windows in the areas of sea under consideration for tidal energy sites. The depth of water required for the wave energy sites is generally quoted to be 50m. This is above the depth of currently available jack-up type vessels.

5.4 *Other Ports*

A desktop study of alternative port locations, with suitable depth of water, available crane-age, bunker facilities and lay down areas was undertaken. This resulted in the following possible locations, with rough order transit distances in nautical miles. As an example, the relative cost of fuel for a return journey for an AHV and an installation vessel at a speeds of 11kts and 12kts respectively has been included between each port. This shows the financial impact of using remote ports to service the installation of tidal turbines or wave energy convertors.

Port	Distance nm	AHV (@15tonne/ day)	DP Installation (@29tonne/ day)
Cherbourg	52nm	£12 100	£22 100
Portland Port	86nm	£20 000	£36 550
Plymouth	88nm	£20 480	£37 400
Portsmouth	106nm	£24 670	£45 050
St Malo	52nm	£ 12 100	£22 100

Table 5.4.1 Transit Cost

To install a tidal energy farm of 27 turbines without storage locally with most vessels only having a deck capacity of three sub-structures would require 9 transit trips by either a supply/ AHV or the installation vessel with a minimum cost of £198 900 or possibly rising to £328 950 with the additional risk of weather down time. This does not include any port tariffs for pilotage, berthing or storage of equipment.

Due to the extended periods vessels will need to remain on station they will need to refuel partway through the installation activities. The ports have no capacity to accommodate this type of requirement at present. Refueling at Sea is strictly prohibited within the territorial waters of Guernsey, Sark and Herm. The vessels will therefore need to bunker in the nearest port with facilities. The time this takes will be at the cost of the scheme.

6 Grid Connection

6.1 Grid Overview

The description of the grid on the Island of Guernsey is included in documents available to the public on the Guernsey Electricity website, such as the *Statement of Opportunity* were referenced in compiling this document.

6.2 Potential Supply Points

The map and information supplied by Guernsey Electricity highlighted the following bulk supply points; two at Guernsey Electricity's North side site, Les Amballes, Belgrave, and at Kings Mills. All of which serve the north and east of the island with the exception of Kings Mills. No value of available import capacity was given but it was assumed this would vary and could be substantial due to the sophisticated nature of the grid operation and stability practised on the island.

The site at Kings Mills is closest to the possible sites for development as Wave Energy Farms with the North Side site, Les Amaballes and Belgrave being closer to the main potential tidal resource areas. The tidal resource area to the south of Guernsey may benefit from the proposed upgrade at Ville au Roi, depending on the planned works at this site.

6.3 Potential Cable Routes

It is obvious that minimising the length of cable helps to reduce costs and improve system efficiency. However other factors also dictate viable cable routes such as;

- Site location
- Available grid/ distribution network points
- Sea bed type

- Beach landing point

The site and direction of incoming waves or tidal streams will determine the layout of device arrays and subsequently the cable routing into the area. This will be further complicated by avoiding such things as local rocks, wrecks, fishing grounds or other zones which will mean that the route is not a straight run between the selected landing site and the device array. The detailed route engineering will require a full seabed survey to show the depths, seabed type and identify wrecks to be avoided.

In general it is preferred to bury cables across the selected beach and along the route to the offshore site using equipment deployed from the cable lay vessel during the lay process. The simplest form is termed a "plough"; these are towed behind vessels whilst the vessel moves along deploying cable along the route. They have the advantage in that many of them can land cables and allow them to be pulled up the beach to commence burial. A depth of burial of approximately 2m can be achieved in this way in soft sand or clay. Regular beach profile survey data is essential to ensure that the required minimum depth of burial is maintained throughout the life of the cable.

Shore landing sites must be selected carefully and will be dependent on the type of installation vessel proposed. Most large DP class cable vessels for un-coilable cable require a minimum water depth of 10m to operate in. Therefore, the closer that this depth is reached to the low water mark, the better. Anything above 2km is probably prohibitive as floating this length of power cable to shore is difficult. If used, a barge or pontoon can be beached on certain types of seabed to perform the shore pull in, but they can only deploy cable at a relatively low rate. In general, sandy beaches that allow for relatively easy cable burial are preferable. Although pebble beaches can be more stable whilst still allowing burial with more conventional techniques. This is due to the possibility of sand washing away in certain wave climates and thus leaving the cable either nearly or actually exposed and thus susceptible to damage. Rock trenching equipment for cable burial is available but this is slow and therefore expensive to use with additional complexities in operation when compared to traditional cable ploughs.

The Island of Guernsey currently has five subsea cables shown on Admiralty chart 807. The Interconnector with Jersey, a telecoms cable into Saints Bay, a power cable to Platte Fougere, and two into L'Ancresse Bay assumed to be telecoms by their indication on admiralty chart 807. This indicates that deploying and landing cables is perfectly feasible along the coastline, including large power cables. There are no cables, power or telecoms indicated between Guernsey, Herm and Sark on chart 807.

The following photograph shows the difficulties that would be faced in trying to bring cables ashore on many of the beaches on the west coast. It shows the rocky sea bed, with the photograph taken at a time close to low water to illustrate that burial of the cable would require some form of rock trenching tool. It also indicates how it would be difficult for cable vessels to move to within an acceptable distance to float a cable ashore due to the numerous rocky outcrops and shallow slopes toward deeper water. The photograph shows L'Eree bay, which is close to the sites of interest for wave energy farms.

Figure 6.3.1 L'Eree Bay

The photograph below illustrates the reverse and shows how some of the beaches on the island are actually ideal for cable landing. With good sand coverage and water depths that allow cable vessels to approach to a relatively close range for cable pull in. L'Ancresse bay on the northern coast has a good sand coverage, with a depth of water close enough to make cable pull in possible. There is also good access on the landward side with the main roads from St Peter's Port. Unfortunately there are already two cables marked as coming ashore on the beach, meaning, at best, careful survey and deployment would be required. At worst, it will not be possible to use the beach for landing cables whilst the others are in service.

Figure 6.3.2 L'Ancresse Bay

The photograph below of Saints Bay which has telecoms cables and illustrates how cables can be brought ashore on beaches consisting mainly of pebbles and buried for protection with no visible effect other than a small jointing pit and cable marker.

Figure 6.3.3 Saints Bay

From the limited data available at the time of writing, the most promising or obvious beaches for landing power transmission cables from marine energy sites are Saints Bay, Havelot Bay, L'Ancresse Bay, Vazon Bay, Cobo Bay (Although local knowledge would suggest Cobo has some constraints). There is also some potential, through an angled drilling, at Pleinmont Point on the south side. Other beaches along the south coast have potential but are either more remote from the offshore sites or have limited landside access. The limitations of this are illustrated by the photograph below of the road leading to Saints Bay, one of the better served sites. It shows the difficulties of moving land drilling rigs or the size of winch that will be required for pulling ashore power cables of the size envisaged.

Figure 6.3.4 Saints Bay access road

Obviously this list includes beaches which already have cables crossing them and so careful consideration and detailed planning of routes will be required to avoid impacts to existing cables.

The cables would then need to be routed to the nearest bulk supply point or small substation capable of accepting the power import to the Island network.

6.3.1 *Wave Sites*

For the wave sites to the west this is likely to be the sub-station at Kings Mill close to the water treatment plant. The cable could then be landed at Vazon Bay, buried under the beach passing through the sea defences via a duct installed in a directional drilling to a jointing pit. The cable could then be run in a similar fashion to other cables in ducts underneath the road to the substation.

6.3.2 *Tidal Stream Sites*

The majority of the tidal energy appears to be at the southern end of the Big Russel and so the cable landfall would be located at the southern end of the island or if possible in Havelet Bay. Although, it must be recognised that a full risk assessment, to ensure damage to the island interconnector is avoided, would be required before this route is taken.

6.4 Cable Size

The initial assessment of cable size would be based on the power to be transmitted, transmission voltage and distance to grid connection point. For the purposes of the cost estimation that accompanies this report, a cable from the Big Russel to Saints Bay on the south of Guernsey has been considered.

In general the overriding controlling factor in installing a cable of this nature is the temperature rise when at full capacity through the splash zone transition. This is because , due to the heat generated by the cable, it is usual to place the cable in some form of ducting, and direct burial is preferred.

For comparison purposes the cable scenarios were investigated to provide size and rough order cost estimates. A cable length of 8.65km is assumed, operating at a voltage of either 11kV or 33kV, and transmitting power of 15MW or 40MW respectively.

Since the sea bed is aggressive in most locations, with a high energy coastline the cable is likely to require double helical galvanised steel armour for protection. A typical cross section of an appropriate cable construction is given below.

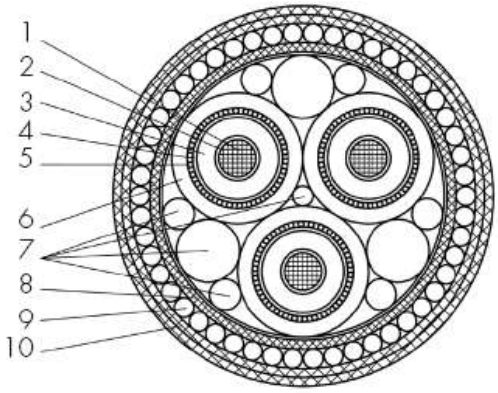

Figure 6.4.1, typical cable cross section

The table below illustrates the results of rough calculations on the cable dimensions and cost. This cost is for the main transmission cable only and does not include connections or installation. It does however highlight the impact of scheme design and transmission voltage on project cost.

Parameter	11kV, 15MW	11kV, 15MW	11kV, 15MW	33kV, 40MW	33kV, 40MW	33kV, 40MW
Length Required	3*8650m	3*8650m	3*8650m	8650m	8650m	8650m
CSA mm	240mm²	300mm²	630mm²	240mm²	300mm²	630mm²
Losses %	26.83%	22.7%	16.1%	7.91%	6.96%	4.77%
Weight in air, approx kg	19kg/m	24.1kg/m	39kg/m	19kg/m	24.1kg/m	39kg/m
Cost £	£4,18398	£5,128,758	£8,946,263	£1,394,466	£1,709,586	£2,982,087

Table 6.4.1 – Cable parameters

Further calculations on the temperature rise through dunes or beachheads would be required but from the above data transmission to shore at 33kV, 40MW with a copper Cross Sectional Area (CSA) per conductor of 300mm^2 is a suitable starting point. This allows some capacity for either increase in scheme power output and a safety margin for temperature fluctuations. The probable outside diameter of this size cable is somewhere in the region of 120 to 150mm dependent on the armour and insulation packages. To complete the ambitious target of 100MW by 2020 it is likely that three or four cables of this size will need to be landed.

7 Installation

7.1 Required activities

To install either a Wave or Tidal energy farm a fairly common sequence of activities is required. The overall process will take several years and is very much weather and tide dependent. In addition to the environmental and consenting aspects, the steps below are generally recognised as the basic building blocks of a suitable installation programme;

1. Sea bed survey, bathy and geomorphology, cable route and site
2. Landfall survey with route to grid connection point
3. Scheme design, including required shore facilities
4. Procurement and manufacture
5. Shore-side construction
6. Deploy foundations, moorings
7. Lay cables, main transmission and interconnect
8. Deploy sub-structures
9. Deploy nacelles/ turbines
10. Cable pull-in to turbines
11. Commission and test
12. Handover

The size and complexity of the scheme impacts on the length of time each task takes to complete. Careful scheduling to ensure installation time and cost is minimised is therefore critical to ensuring successful completion.

The following two approaches listed, with a Rough Order Costs, are based on installation of a typical 40MW tidal energy farm located in the Big Russel with cables running ashore at Saints Bay. This gives, on current state of technology the following rough list of equipment to be installed offshore, with cable lengths being very approximate.

Scheme A

Assuming tidal turbine technology has advanced to the production of 1.5MW machines by 2014, this would then require the installation of 27 turbines in the Big Russel. These could then be connected to three hubs, each of 15MVA capacity, with step up transformers, which in turn would be connected to a single Point of Common Coupling (PCC) to transmit the power ashore at 33kV.

This would then require approximately 13.5km of interconnect cable rated at 1.5MVA and 11kV in various lengths with three lengths of 15MVA, 33kV cable and a single length of approximately 8.65km of 45MVA, 33kV shore transmission cable.

Scheme B

Again assuming turbine technology has advanced to the production of 1.5MW machines and a 40MW site is envisaged. This would thus again require 27 turbines to be installed.

Instead of stepping up the voltage, the "hubs" will act as a PCC for nine turbines again and then three cables, each with a capacity of 13.5MVA at 11kV will be run to shore at Saints Bay. This gives 13.5km of 1.5MVA interconnect cable and three 8.65km lengths of 13.5MVA shore transmission cable.

Two alternative approaches to the installation of these schemes were then developed with Rough Order Costs calculated for each to result in four overall cost options.

Scheme	DP Vessel Installation	Moored barge Installation
A	£47 860k	£48 810k
B	£50 806k	£51 756k

Table 7.1.1, Cable Cost Comparison

However it must be borne in mind that the cost of deployment covers the vessel mobilisation, transit to cable factory, loading of cable and transit to site. Depending on where the cable is purchased from this is likely to involve transit from Hartlepool, Rosyth, or Oslo Fjord in Norway.

8 Operation and maintenance

8.1 *Operational Approach*

The operations approach will considered in reference to a typical 40MW tidal site. Some form of engineering management will be required to ensure a safe and economically successful operation. This is likely to include personnel to observe condition monitoring equipment, perform basic operations to connect, dis-connect and vary power produced etc.. Whether or not these tasks are performed on the island is dependent on the final scheme owner and their company operating procedures/ philosophy. Some form condition monitoring and maintenance activity of the shore-based equipment with the ability to perform some tasks offshore will be required.

In addition, depending on the device characteristics, there may be a requirement for devices to be removed from the sea from time to time for cleaning or replacement of parts.

It is therefore reasonable to assume that some employment opportunities on the island will be created. The more senior roles are likely to require personnel with a reasonable degree of training and academic qualification.

8.2 *Emergency Response*

If the States of Guernsey legislative body decides to adopt Marine Guidance Note (*MGN) 275* then a remote means to safely shut down the energy farms in the event of a marine incident will be required. This response must be immediate at the request of the local emergency services and so a physical means to perform this on the islands is likely to be required along with suitably trained personnel who can also coordinate effectively with the emergency services dealing with the incident.

9 Economic

9.1 *Cost Comparison*

The initial costs have been calculated using the Carbon Trust cost of energy spreadsheet to obtain costs per kwh. The basic assumptions are given in the tables included as part of Appendix A. It is assumed and that available resource exists for the size deployment. However, to build a business case, the resource will obviously need confirmation through detailed site resource assessments.

9.2 *Risk and uncertainty*

There are several factors which will make it difficult to apply cost certainty at this stage. This is obviously easier to accurately predict out-turn cost the closer a project progresses to a final scheme design.

None of the schemes in this document have been developed to sufficient level of detail to form a basis of design for quotation. This will be a time consuming activity to be undertaken by a developer. Small changes to a concept design at this stage can have sufficient impact on overall costs. In particular, decisions on the capacity of system to provide will influence both the initial capital purchase price and can vary the day rate of the installation vessels by as much as £65k per day.

Allowance for standing time due to weather risk can be the biggest single cost component. The areas selected for renewable energy sites tend to be high energy seas with relatively short windows in which to perform the offshore construction activities. Generally, for lifts >50tonne, a significant wave height below 1.5m is required, even with heave compensated cranes. The initial resource assessment highlights that the western coast does not normally experience this for much of the year. The opportunity to install heavy equipment is therefore limited and if missed can lead to delays of months or even up to a year. To avoid onerous heavy vessel charges, they need to be booked in advance to meet these windows and everything must be in place. However the weather can still be unpredictable and the potential to have a fully mobilised and loaded vessel costing £115k to £145k per day waiting for four to five days is very real.

In capital purchase for such a system, some of the biggest fluctuations can be caused through raw material prices. In particular, copper is traded as a commodity on the London Metal Exchange and cable suppliers are averse to giving a firm price until an order is placed, quotations generally include a formula linked to the trading price value to allow them to accommodate price variations incurred between the date of quotation and placement or signing of contract. The graph below illustrates the variation in price of copper per tonne for the past twelve months.

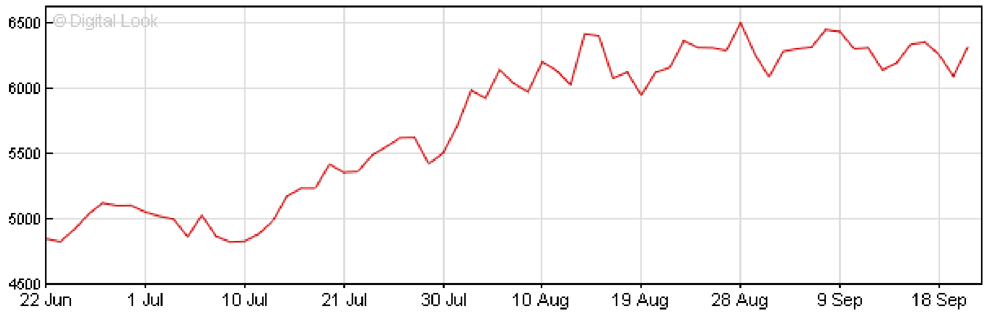

Figure 9.2.1 Copper per tonne 3 month fluctuations (BBC website 22/9/09)

The total weight of copper included in a cable suitable for transmission of 10MW is in the region of 58t, and so this could translate to a variation in price of the cable in excess of £100k.

The use of offshore installation vessels also trades very much as a commodity, with times of high oil price and high demand leading to high charter rates, typically in excess of £115k a day for vessels capable of performing the work required. However, this day rate can drop as low as £50k a day with careful selection and flexibility in approach on both time of installation and vessel specification. This means ensuring, wherever possible, that the equipment does not require a specialist vessel or that equipment for deployment is not vital to timing.

The fluctuation in oil price can affect vessel rates significantly, immaterial of demand, as large cable lay or lift vessels will burn approximately 25t of fuel oil per day. This equates to approximately 180 barrels and so the cost can vary considerably on a week by week basis.

A major influence on cost certainty for offshore projects is which party accepts or is responsible for the weather risk. Vessel operators and installation companies, in times of buoyant markets, generally are reluctant to accept the risk. If they have to, they will simply include a large contingency fees within their quoted figures to attempt to cover their exposure.

10 Conclusions and Recommendations

10.1 Conclusions

The seas around Guernsey, Herm and Sark have potential commercially exploitable resources in the form of wave and tidal stream energy.

With regard to tidal energy, there is likely to be an initial focus on potential high-energy sites, with Mean Peak Spring velocities between 2.5 and 4m/s. Any sites with velocities in excess of this could experience challenging engineering constraints. Conversely, sites with lower intensities are unlikely to be exploitable using current technology.

Much of the information and data on wave resource is either anecdotal or based on data from measurements taken at a reasonably remote location. Proper targeted resource assessment and measurement with the placing of sensors and buoys is required as soon as practicable to provide evidence to potential developers.

If the Islands are to benefit economically from installation and maintenance activities, future plans must take into account the need for deep water berths, bunkering facilities and lay down areas with suitable crane capacity.

A study of skills and training requirements is required to ensure they are in place before development starts. This would help to maintain knowledge and a sense of ownership within the community.

The commercial risks are diverse and can be high with a project of this nature. Correct assignment of risk should be made at an early stage to the parties best able to manage and minimise it.

To take advantage of the maximum number of vessels available and optimise installation, selecting equipment that does not require specialist vessels or a great deal of equipment modification would be prudent.