Power developed from the Sea

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Energy is all around us and there are many ways in which mankind has tapped into it and used it for purposes such as generating electricity. This article discusses how the energy in the waves and the tides of the sea are used to generate electrical power

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Introduction

In previous OTN articles, various power sources were discussed which have been used to generate electricity. Many were what have been called renewable energy sources, such as the wind, the sun, and heat from the depths of the earth.

How they derive the name 'renewable energy source' is not too clear. Early schooling taught that energy can neither be made or destroyed. In using energy, we tap into its source or convert it from one form to another. It seems that if the energy is defined renewable, there is no source material which has to be mined, such as as coal, oil, gas, or uranium, and there is no residual combustion ash or radio active component to bury or pollute the atmosphere.

There are sources of renewable energy all around us including radiation from the sun and from the wind. Also wherever there is moving water there is energy which can be tapped, such as by the many hydro electric systems installed around the world. But our article concentrates on generating electrical power from the energy of the sea.

Such systems are planned, or installed, world wide and samples of these will be discussed. There are two distinctly different sources of energy extracted from the sea. In the first, the energy is taken from the waves of the sea, using a float which sits in the water and follows the rise and fall created by the waveform. In the second, energy is extracted from the incoming and outgoing tides.

There are also two methods used to extract energy from the tides. In one method, tidal water is stored in an estuary or dam which is filled when the tide is rising and held by a barrier at the dam entrance. The energy is generated by the release of the water when the tide is falling or has reached a low. It is also generated by the water movement when the dam is filling from the rising tide. In this system, the release of the water is controlled by gates so that the time of energy generation can be regulated. One might consider this as a form of energy storage.

In the second method, there is no estuary or dam and energy is extracted from the flow of water when the tide is rising or the tide is falling.

The power systems using the two different sources of energy will be discussed under the headings of "Wave Power" and "Tidal Power". Also, the two methods of extracting power from the tides will be discussed under the sub-headings 'Tide Level Systems" and "Tide Current Systems".

Wave Power

Waves in the sea are generated by wind passing over its surface imparting energy into the water. The waves cause the water particles on the surface to oscillate in elliptical paths as shown in figure 1. Maximum kinetic energy occurs as the height of the wave passes through the mean sea level. This energy is tapped from the movement of a floating object on the surface of the water and coupled into an electricity generating turbine or some other plant such as that used for desalination of salt water.

Wave height, and hence energy produced, is determined by wind speed, the duration of time the wind has been blowing, the fetch (or the distance over which the wind excites the waves) and by the depth and topography of the seafloor which can focus or disperse the energy of the waves.

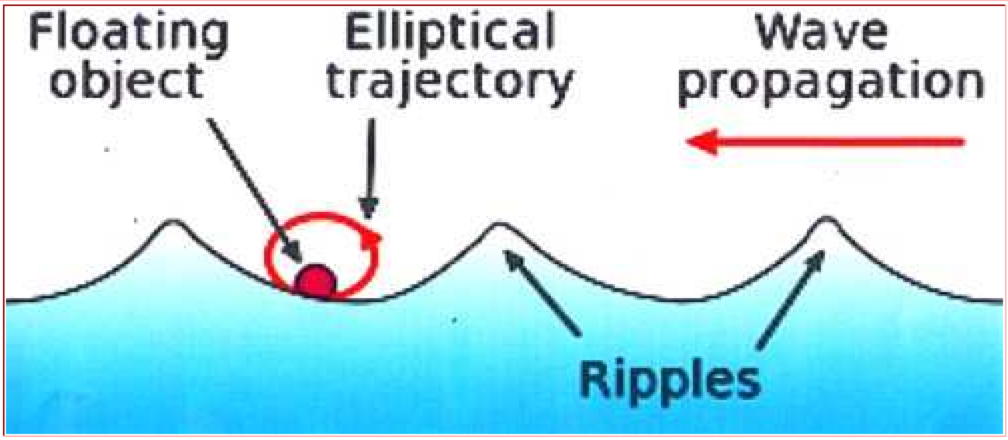

Figure 1
Elliptical trajectory of a floating object on the Ocean surface

Two wave power generators (or converters) will be discussed; The first, under development by the Carnegie Wave Energy Limited since 1999, is now in operation at Garden Island, Western Australia and will later be connected to the mainland power grid. The second generator project was founded in 1997 by Dr. Tom Denniss, as Energetech Australia Pty, later to become Oceanlinx. The version to be discussed was built at Techport, Port Adelaide. This was completed early in 2014 and it was intended to be put in operation and connected to the power grid at Port Mcdonald. But there were problems on its journey attempting to get there.

<u>Garden Island and the Carnegie Wave Generator</u>

Garden Island is a slender island about 10 kilometres long and 1.5 kilometres wide, lying about 5 kilometres off the western coast of Western Australia, adjacent to Cockburn Sound, and south of Fremantle (refer figure 2). It is linked to the coast by a man-made causeway.

Figure 2
Garden Island is located south of Fremantle
& adjacent to Cockburn Sound

The largest fleet base of the Royal Australia Navy (RAN) is located on the south-eastern section of Garden Island, facing Cockburn Sound. The base is called Fleet Base West or HMAS Stirling. The base is home to more than 2,300 service personnel including 600 Defence civilians and 500 long-term contractors.

Power for island including the RAN base is supplied from a recently installed wave array developed over 10 years by Carnegie Wave Energy Limited. The project has had the support of Australian Renewable Energy Association (AREA) and was officially turned on in February 2015. As shown in photo 1, buoys are tethered to seabed pump units which are actuated from the motion of passing waves. The pump pressurises fluid which is then sent onshore through a sub-sea pipeline and the pressurised fluid drives hydroelectric turbines onshore to generate electricity. The resulting low-pressure water is returned to the ocean in a closed loop system.

The power initially supplies the RAN base but it is proposed to expand the system to four times its capacity and connect to the onshore grid. It is claimed to be the world's first grid-connected wave energy array.

The project utilises Carnegie's 100 per cent owned and invented CETO wave energy technology. One has to wonder what the name CTEO represents. But it appears that the name is simply that of Greek ocean goddess. The CETO Unit, consists of the fully submerged buoy (or buoyant Actuator) tethered to the pump on the seabed.

The initial Garden Island installation consists of three type CTE5 units, each able to supply 240kw of power. The system is illustrated in figure 3. Planning and design work has begun on Carnegie's next generation CETO 6 technology, supported by 13 million dollars of ARENA funding. These larger units are aiming to deliver around four times the capacity of CETO 5 units (about 3 Mw), improving efficiency and reducing energy generation costs.

A further proposal is to also use the high pressure water to feed an onshore desalination plant which will supply fresh water back to the RAN base.

As the world's first grid-connected wave energy array, it will be generating enough electricity to power between 1,500 to 2,000 households in Western Australia. The project will also deliver Carnegie's first power revenues through the sale of green electricity to the Department of Defence for HMAS Stirling.

The CSIRO, Australia's peak science body, estimates that wave energy is at least three times more predictable than wind. Carnegie claims that the system is different from other wave energy devices because it operates underwater where it is safer from large storms and is invisible from the shore.

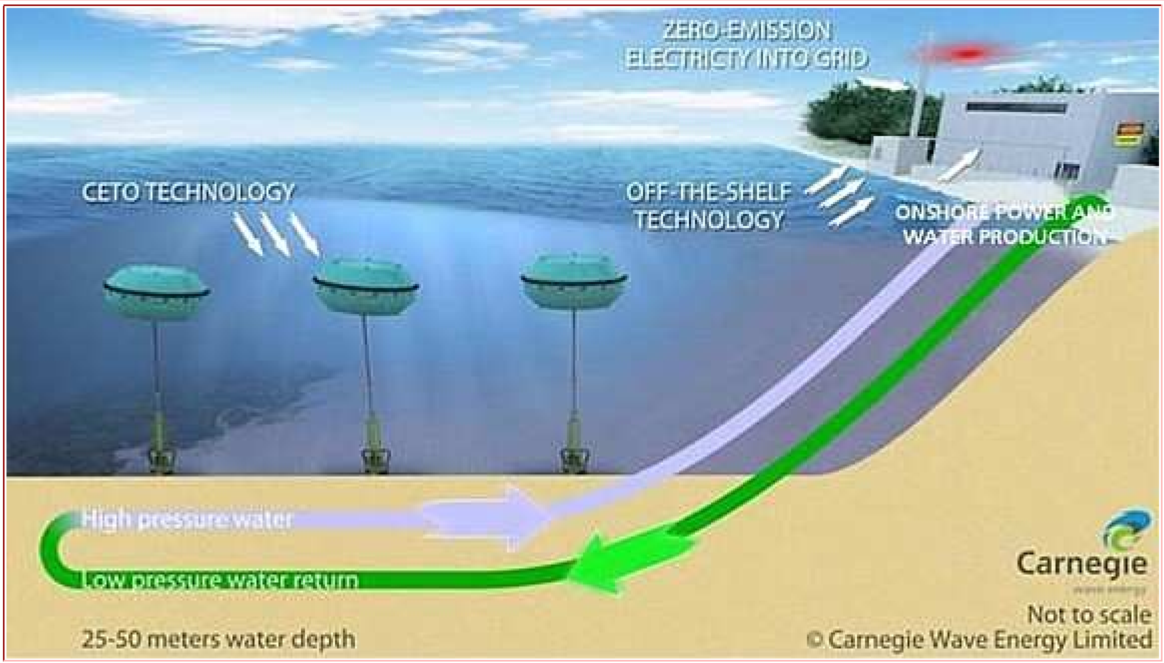

Figure 3
Wave Power System, Garden Island

Photo 1
The Carnegie CETO unit
showing the buoy tethered to a pump on the seabed

The Oceanlinx Wave Generator

The company Oceanlinx was formed more than 15 years ago by University of Wollongong graduate Tom Denniss, who had built a number of prototypes of wave energy units, including three at Port Kembla. The project had received financial support from both overseas and the Australian Government through ARENA.

Oceanlinx's Wave Generator combined their patented wave device with air turbine technologies to provide a highly efficient energy converter with no moving parts under water. The energy of the wave drives a column of air to a turbine which generates electricity. The device was designed to sit in shallow water, using oscillating water column (OWC) technology (Ref.20). The commercial wave energy demonstrator is a 3,000 tonne structure measuring approximately 21 metres wide by 24 metres long and can generate 1Mw of peak electrical power output. The device is made of simple flat packed prefabricated reinforced concrete that makes the structure heavy enough to anchor itself to the seabed, in approximately 10-15m of water, without the need for destructive seafloor preparation.

The Commercial demonstrator was assembled in Techport, Port Adelaide (Photo 2). In February 2014, construction of the device was complete and it was intended to transport the device from Port Adelaide to Port McDonnell for connection to the power grid for 12 months of loaded operation and testing. If all went well, the initiative plans were to follow up with a 10 megawatt version of the device. Transportation to Port McDonnell commenced on 1 March 2014 and it was expected to take approximately four days to arrive.

Photo 2 - Oceanlinx power converter is towed out from
TechPort, Port Adelaide, on its way to Port MacDonnell

The structure was to be lowered into the seabed at Port McDonnell and connected to the power grid by sub-sea cable. But alas! It didn't get to Port Mcdonnell. The 3000 tonne piece of machinery, supported by airbags, was being towed on its way by a tug boat when it experienced problems with the buoyancy of the airbags. Around March 4th, it sunk in 16m of water, 1500m offshore and had to be towed to shallow water at Carrickalinga.

When writing this article some 12 month later, mid 2015, the structure was still stranded, sunk off Carrickalinga beach (Photo 3) . It has been estimated that salvaging would cost about $3 million. It has been considered as a navigation hazard to shipping and a danger for snorkelers, divers and swimmers at Carrickalinga. The Company seems to be in limbo as to whether the project can proceed, and if so, when that might take place and how it might be continue to be financed.

Photo 3
The Oceanlinx Wave Generator
on the Ocean floor at Carrickalinga

In fairness to the Oceanlink project, an important thing to emphasise is that the set back in the project is because of a failure in the transport method in moving the generator to the operational site, and not an engineering failure in the design or construction of the structure.

Tidal Power

A number of quite large power systems powered from tidal energy are installed around the world. For 45 years, the installation at the estuary of the Rance River, in Brittany France, was the largest tidal power station in the world, with 240 Mw of peak power. The Rance River station was opened in November, 1966. However, in 2011, the Sihwa Lake Power Station, in South Korea, became the largest with 254 Mw of peak power.

Proposals for several tidal power installations have been put forward in Britain and some of these will be discussed . But initially, the basic operation of some of the tidal systems will be examined.

The tides of our oceans cause the sea level reaching our shores to change over periods of the day. Tides are the rise and fall of sea levels caused by the combined effects of gravitational forces exerted by the Moon, the Sun, and the rotation of the Earth.

Some shorelines experience two nearly equal high and low tides each day, called a semi-diurnal tide. Some locations experience only one high and low tide each day, called a diurnal tide. Some locations experience two uneven tides a day, or sometimes one high and one low each day and this is called a mixed tide. The times and amplitude of tides at a given shore location are influenced by factors including the alignment of the Sun and Moon, by the pattern of tides in the deep ocean, and the shape of the coastline.

Certain parts of the world are renowned for their extreme tides where large potential energy could be tapped. The Bay of Fundy in Nova Scotia is known for having the highest tidal range in the world. Other large tidal locations are Ungava Bay in northern Quebec, King Sound in Western Australia (WA), Gulf of Khambhat in India, and the Severn Estuary in the UK. King Sound is recorded as having the second highest tidal range in the world and which can reach up to 11.8 metres. (see figure 4)

Figure 4
King Sound in Western Australia is one of the world's higher tide ranges

Tidal power exploits energy drawn from the movement of ocean tides to produce electricity. As briefly discussed earlier, there are two ways in which tides have been be tapped to obtain energy. For the purposes of identification in the article, the first method has been called the Tidal Level System. The method is to tap into the changing sea levels which occur from the advancing and receding tides on the shorelines. With the help of water storage and hydro turbines, incoming tides can be manipulated to generate electricity over a wide daily time scale. In the Tide Current System, tidal energy is extracted by sinking turbines to the sea floor where fast-flowing currents from the tides turn generator blades much like wind does with a wind turbine. So electricity is generated over the periods when the tide is rising or the tide is falling.

<u>Tide Level Systems</u>

The first method, concerning the change in sea levels, involves constructing a barrage, a dam, or some other sort of barrier to store water at the level of the high tide. Power from the water is harvested from the height difference created between the high and low tides . Photo 4 shows a typical barrage at Rance River estuary France, which holds the water, and contains the turbines.

Photo 4
Tidal power barrage at the estuary of the Rance River,
France (From EnergyBC, Ref. 6)

In hydroelectric power schemes, the power is generated by running the water through turbines to a lower level. In the tidal energy system, the technology is similar except that the water currents run in two opposite directions through the turbines.

Where a tidal barrage blocks off an entire estuary, a tidal lagoon impounds an artificially created area of the sea or estuary. As the tide goes out, the barrage flood gates remain closed and the lagoon remains full until the sea level stabilises. The flood gates then open to let the water out until water levels on each side of the lagoon wall are even. As with the hydro schemes, the running water releases energy to drive the turbines, When the tide comes in, the water runs back into the lagoon and the process in driving the turbines is reversed. The operation is demonstrated in the drawing, figure 5.

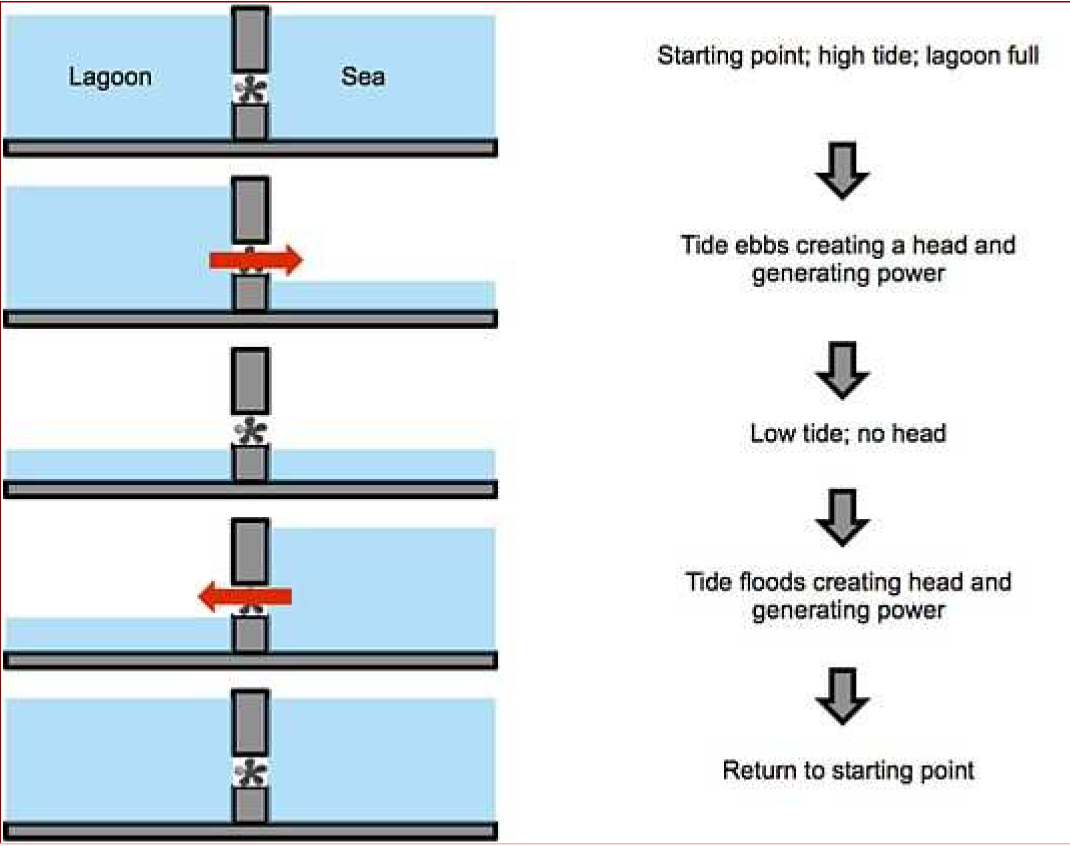

Figure 5
Operation of Hydro Electric Turbines from the Tides

When the level of water on one side of the barrage is greater than that on the other side, a form of potential energy or energy storage is provided and electrical power can be continually generated whilst that condition is maintained. It would seem that providing the amount of water movement either way is carefully regulated, the cessation of power generation would be limited to when the two levels are near equal and the sea level is stationary. However it appears that if more than one storage dam is used, each with separately regulated water flow, their time frames for this condition can be staggered to achieve continuous power generation.

<u>Proposals for Tidal Power in the UK</u>

Swansea Bay is located in the Bristol Channel on the South Wales coastline (refer figure 6). As part of the Severn Estuary it experiences one of the world's largest tidal ranges, often reaching 10m.

Swansea Bay was suggested for a tidal lagoon previously in 2004. Later proposals suggest a larger structure than before. The structure would cover 11.5 square km including a long breakwater, cost £913m to construct, and have an installed power capacity of 320 Mw. The installation would be capable of generating 495 Gwh per year, enough energy to power 155,000 homes. The breakwater (apparently including what we called a barrier) would be 9.5 km long. There has been some scepticism in the UK concerning the proposed project because of the failure of a previous barrage power generator in the region, and of the high cost.(Ref 9).

According to the BBC's Environment Analyst, Roger Harrabin (Ref 9), the Tidal Lagoon Swansea Bay project would be the world's first man-made, energy-generating lagoon.

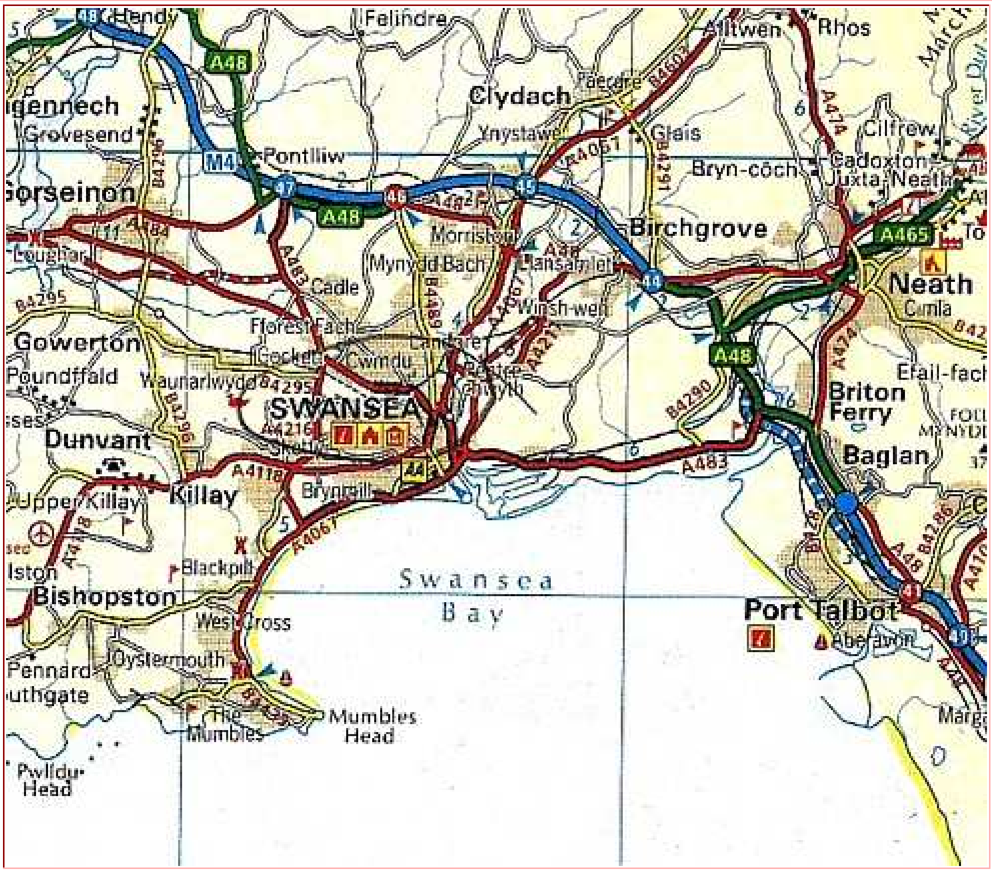

Figure 6
Map showing Swansea Bay in Wales
Proposed site for Tidal Power

The following UK tidal power proposal was reported in the Adelaide "Advertiser" on May 4, 2015 (Ref 2) "A British firm has launched plans to build a giant lagoon off the Welsh coast that would harness the tide to provide electricity for all of Wales. If the scheme goes ahead, a lagoon would be built between Cardiff and Newport in the Severn estuary, featuring 90 turbines in a 22km breakwater. The scheme, being planned by Tidal Lagoon Power, would have a capacity of between 1800 and 2800 Mw, enough to provide electricity for every home in Wales." Reference 9 noted that this installation would be able to generate power for about 14 hours each day.

Roger Harrabin also reported in March 2015 that there were six proposed lagoon sites, including Swansea as well as Cardiff, Newport, and Colwyn Bay in Wales, Bridgwater in Somerset, and in West Cumbria. The cost of generating power from the Swansea project would be very high, but the company behind the proposal plan had stated that subsequent lagoons would be able to produce electricity much more cheaply. Mr Harrabin also stated that the series of six lagoons could generate 8% of the UK's electricity for an investment of £30bn.

It could be assumed that the multiple of six lagoons would stagger the periods when each generator source was able to feed power to the common grid and maintain continuous power.

Proposals for Tidal Power in King Sound, WA.

Tidal power has been proposed in the Kimberley region of Western Australia since the 1960s, when a study of the Derby region identified a tidal resource of over 3000 Mw. However, in 2013 ,the West Australian government approved plans to build a 40Mw tidal power station in King Sound, part of the West Kimberley. This paved the way for the development of the state's first utility-scale ocean energy plant. King Sound is recorded as having the highest tide levels in Australia.

The proposed plant, which is being developed by Tidal Energy Australia (TEA), is earmarked for Doctor's Creek, near Derby. At this location, the extreme tidal movements are expected to be able to generate enough electricity to power between 10,000 and 15,000 homes.

The tidal power project aims to build two barrages, or dams, across the two arms of Doctors Creek. These arms have been formed by the tides from the King Sound and which lead into Derby. It is proposed to build a $360 million, 48 Mw hydro-electricity plant which will rise to 72 Mw. To take advantage of the high tidal location, 500km of transmission lines will be built to provide power for much of the north/western area of Western Australia.

The proposed plant is to be situated at the head of the two adjacent inlets off the King Sound. The inlets would be connected via an artificial channel. By erecting dams at each inlet, differences in water levels in each basin can be controlled to enable flow via the connecting channel. Power take-off would be achieved from a bank of six 8Mw turbines housed in a structure built in this channel. These would provide power output of 200 Gwh/annum. The system of barrages and reservoirs, built around the tidal creek network, would allow water to continuously flow through turbines and generate continuous power.

To achieve the operational system, 5 km of barrages would have to be built. A number of parties have raised objections to the changes of topography , essentially on environmental grounds. Their concerns included damage to the nature reserve, the mangrove habitat, the fish population, and other threatened species.

Tidal Current Systems

A tidal current turbine, works a lot like an underwater windmill. The in-stream turbine uses the flow of the tides to turn an impellor, just like a windmill uses the flow of air to turn its blades. The rotation in turn drives an electrical generator. The turbine sits on the seafloor and operates in both directions, either when the tide comes in or when the tide goes out. On this technology, there is a great deal of experimental work being carried out in Canada and in the following paragraphs we will describe some of this work. An artist picture (figure 7) from EnergyBC, Ref 6, illustrates the scheme.

There is a predicted potential of 42 000Mw stored in tidal energy off the coast of Canada which remains widely untapped by the energy industries. The first tidal current generator was built and installed in Canada in 2006. It was deployed north of the Middle Islands in the center of the Race Rocks Ecological Reserve, off the coast of British Columbia. The prototype generator was a 65 Kw tidal current turbine, shown in photo 4. The venture was part of a six year joint research venture between Clean Current and the Race Rock project. The project aided an alternative energy technology policy to minimize the environmental impact on the facilities in the reserve. It was also used as an experiment for testing structural design of the turbine. The tidal current machine replaced two diesel generators,

Figure 7 - Energy from tidal currents
Artist's rendition of a tidal fence (From EnergyBC Ref. 6)

Photo 4
Tidal Current Turbine before installation at Racerocks, British Columbia, Canada (From EnergyBC Ref. 6)

As discussed earlier, the Bay of Fundy in Novia Scotia (figure 8) is known for having the highest tidal range in the world with a mean spring range of 14.5 metres and an extreme range of 16.5 metres. Clearly, the Bay of Fundy is an excellent choice for research and development of tidal power systems and in 2009, the Fundy Ocean Research Center for Energy (FORCE) was incorporated. The non profit corporation would operate a tidal turbine demonstration facility, which would enable public and private research into tidal energy extraction and its effects. (Reference 11).

The project would construct and operate the facility in the Minas Passage of the Bay of Fundy where devices will be demonstrated by up to four developers. Using new technology, one developer, Open Hydro, would deploy a 4Mw tidal array by 2015. A second group, Black Rock Tidal Power (BRTP), formed with both Canadian and European partners, would introduce a 2.5 megawatt turbine system using technology developed in Germany. The projects would work towards Canada's Renewable Energy commitments aimed at a full scale demonstration of tidal turbines and arrays by a 2020 year target.

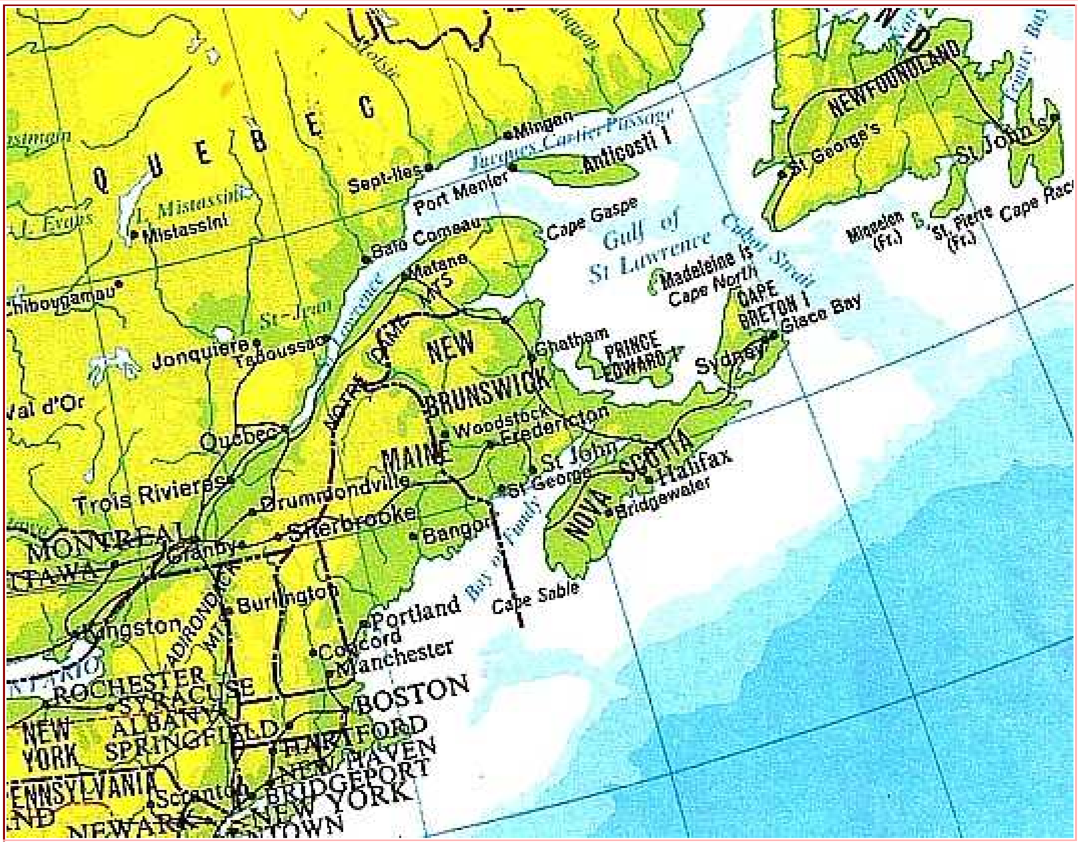

Figure 8
Bay of Fundy in Nova Scotia has the highest tide range in the world and is potential for tidal power generation

OpenHydro would proceed with plans for the deployment of a fully grid connected 4Mw tidal array to be in place later in 2015. The array would consist of two 16m (2.0Mw) commercial scale turbines. On successful completion, this project has the potential to be the world's first multi-megawatt array of interconnected tidal current turbines, providing energy to over 1,000 customers in Nova Scotia.

A group led by OpenHydro together with Nova Scotia based energy company Emera, would deliver the project. The group has ambitious future plans for tidal energy in the region and are looking to use this initial demonstration project as the first phase of a commercial scale project in the Bay of Fundy. Subject to regulatory approvals, the aim would be to see the turbine array grow to 300Mw. This higher power output would be comparable with the larger tidal level systems, installed elsewhere in the world, and which used water storage held by a barrage or dam.

The second group (BRTP), contracted by FORCE, would use a different form of tidal current turbine. Most of the existing tidal current energy systems (including those of OpenHydro) are single turbines designed to rest on the seabed. BRTP says that this type of single-turbine approach requires enormous machines to operate and that significant capital is required to construct, transport, and maintain the turbines.

BRTP is directly addressing these cost drivers with a new approach. This combines a unique Triton platform, developed by TidalStream Ltd, with inexpensive small and robust tidal turbines developed by ship propulsion manufacturer Schottel.

In the BRTP assembly, a gravity base foundation is used to anchor the platform system. This would be lowered down to the seabed prior to the final installation. The whole structure would be is assembled on shore and then towed out to the installation location.

The Triton platforms support 36 lightweight horizontal axis turbines and related electrical power conversion equipment. The 36 turbines would ultimately supply 2.5Mw of electrical power in high tidal flow velocities. 16 of these turbines would be deployed in 2015 and after testing, the installation of the remainder would commence in 2016.

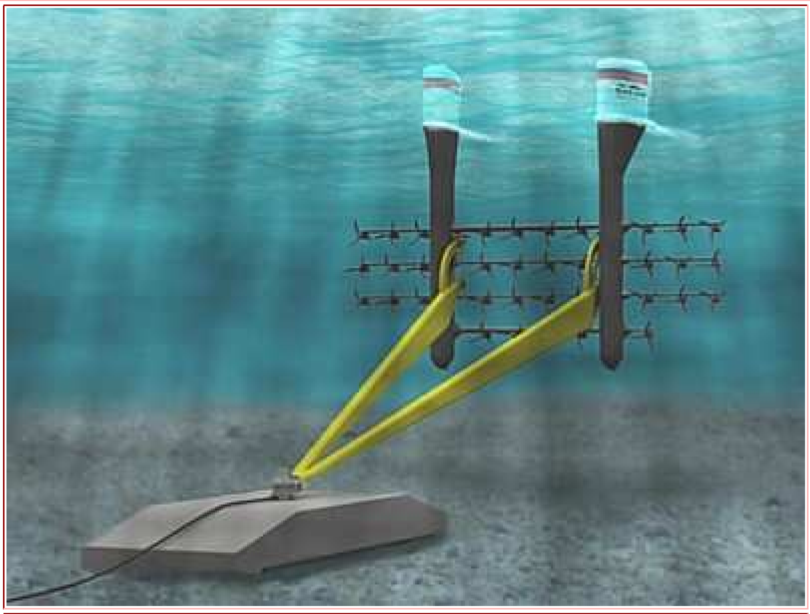

Figure 9
Black Rock Tidal Current system using Triton Tidal Current Technology

The complete system is illustrated in Figure 9 and described as follows: The turbines are connected in a grid pattern across the crossarms and the entire structure is tethered to a foundation with 2 rigid arms. The arms are attached to each of the spar buoys and meet at a sub-sea hinge that allows pitching, rolling and self-alignment to the flow direction by passive yawing.

Electrical power is fed from the turbines via frequency converters, whose outputs are paralleled to feed a transformer. The electrical equipment is located in a room in one of the spar buoys. The output of the transformer is fed from the floating structure to a slip ring unit at the sub-sea hinge and then via a connector that connects the device through undersea cables to the Nova Scotia power grid.

To carry out maintenance on the turbines and the electrical equipment, the floating platform is tipped 90 degrees so that the turbines are above the surface of the sea and the turbine blades are parallel with the surface as shown in figure 10.

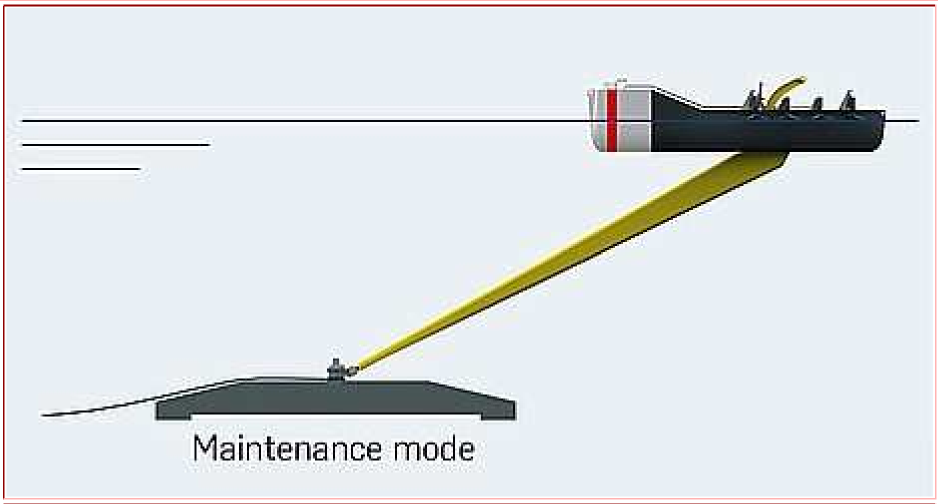

Figure 10
Triton platform in Maintenance Mode

<u>Sea Water as an Energy Store</u>

There is a problem with generating power from some renewable sources in that there is not always energy available 24 hours per day. The wind doesn't always blow, the sun doesn't shine at night and there are periods between when the tides are not rising or falling. So back up power for those periods is needed, at present essentially available from the burning of coal or gas.

On the other hand, there can be an over supply of power. On a windy night, South Australian wind farms, on their own, can supply most of the State's needs. With the addition of the 600 Mw wind farm in progress for Black Point on York Peninsular, over supply of power can be anticipated. Wind farms also continue to be installed in the eastern Australian states and it can be expected that a similar over supply of power might ultimately occur in those states..

Existing base source power stations (such as coal), are not designed for efficiently ramping up and down of the power loads. There seems to be a concern that the need to operate these stations in this way will lead to rising costs in their operation, and hence rising costs to the consumer.

The renewable power sources generally have desirable characteristics. For example, there is no source fuel to dig out of the ground, and there is no disposal of residue or pollution of the atmosphere. But they need to operate in conjunction with some form of energy storage to iron out the variations discussed above.

One way to store energy and release it later, is to pump water into a lake or dam and later release the water to drive a turbine. (In an earlier OTN article [Ref.1], one such a system was described at Tumut 3 Power Station in the Snowy Mountains). In earlier paragraphs, tidal water dams for storage of sea water were discussed. It is suggested that the experience gained overseas with those tidal water dams, could well be put to use as energy stores to control loading of our renewable energy supplies.

Australia has a long coast line where deep valleys might well be found, close to the sea, and with an entrance which might be suitable to trap water with a barrage. The dam, could be used to store sea water, pumped in when there was a surplus of electrical power. When there was insufficient power to meet demand, water could be released from the dam, back into the sea to drive a turbine and generate the power needed.

Summary

There are certainly ways of extracting energy from the sea. Looking around the world, there are plenty of examples of where electrical power has been generated from energy of the sea, or where proposals have been prepared for power engineering plants at suitable sites.

We have examined several examples of how power is generated from energy in the waves and how it can be extracted from energy in the tides. Quite large power sources have been built overseas using energy from the tides, and making use of large dams to store the tidal water. Typical of these are the operating installations at Rance River, France and Sihwa Lake, South Korea. Planned projects in UK, such as at Swansea Bay, also look interesting. We look forward to the possible development in Australia of the King Sound project.

The Bay of Fundy in Nova Scotia has the highest tides in the world. But planned tidal systems for the Bay will use the tidal currents rather than storage of high tide level water. Perhaps the topography of the bay does not provide a suitable lagoon, or similar, which can be controlled as a dam with a barrage.

The question must continually appear with renewable energy systems: How is power maintained when nature has a rest? The sun doesn't shine at night, the wind doesn't always blow and there are days when the sea is calm. Maybe expensive to initially construct and perhaps unfriendly to the beauty of the coastline, the best answer for continuous power seems to come from the tide level system using the storage dams. It is notable that for the system of dams envisaged for the King Sound proposal, 24 hour supply of power is anticipated.

One must wonder how the power at Garden Island is maintained when the sea is calm. This must rely on back up from the mainland grid.

The sea can become quite a wild beast in the presence of extremely stormy weather, such as a cyclone, a submarine earthquake or a volcanic eruption. One might give some thoughts about which type of energy installation described might best withstand the wild battering the sea might sometimes produce. The solid structure of a tidal barrage might be expensive to build, but it might withstand the rage of the sea better than the floating platform structure of the Triton tidal current array.

Power systems described may require back up of base load power for times when the natural resources have a rest. The sub-section "Sea Water as an Energy Store"discusses this condition and how it might be controlled with a storage dam..

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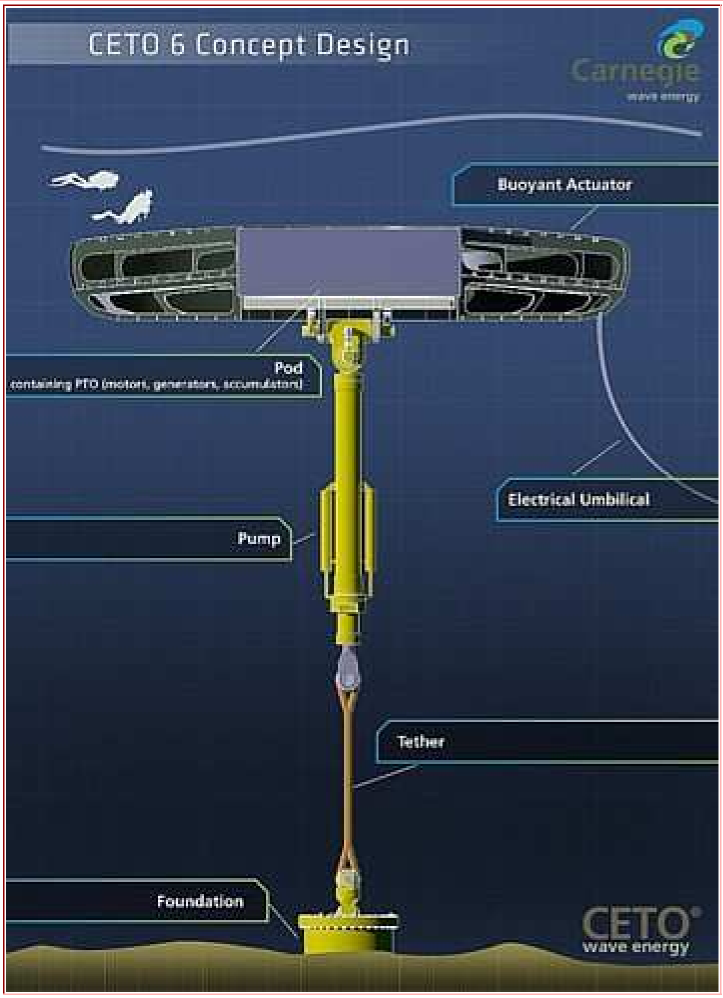
Addendum - Update of Power From the Sea (As at July 2016)

Garden Island and the Carnegie Wave Generator

In 2016, company Carnegie advised that it had completed the full 12 months of phase of the CETO5 Perth Project as required in its Government grant funding agreements.Payment had also been received for the concept design milestone of its CETO 6 Project. The upgrade from the CETO5 units (total 750 kw) to CETO6 technology will increase output capacity by around four times (3 Mw).

In April 2016 Federal Minister for the Environment, the Hon Greg Hunt MP, announced that University of Western Australia (UWA), and Carnegie Wave Energy Limited (Carnegie), in partnership, will soon start investigating the optimal number, size, arrangement and location of wave energy converters in order to minimise the cost of installation and infrastructure while maximising power output.

It is likely that Carnegie will build its biggest wave energy project to date in Hayle, Cornwall UK, and connect to existing sub-sea cables and power grid. The planned 10MW-15MW project will use CETO 6 technology, using the full-size 1MW machines and will occur in two stages.



CETO6 Concept Design

Oceanlinx Converter from Wave Power

The 3000 tonne Oceanlink Power Converter, supported by airbags, was being towed on its way by a tug boat from Port Adelaide to Port McDonnell for mains load testing. Unfortunately it experienced problems with the buoyancy of the airbags. Around March 4th, 2014 it sunk in 16m of water, 1500m offshore and had to be towed to shallow water at Carrickalinga. As far as we know, the stranded the Power Converter is still there on the ocean floor at Carrickalinga. It was estimated that salvaging would cost about $3 million. The company Oceanlinx was put into Voluntary Administration April 2, 2014.

In November 2014, company Wave Power Renewables Limited, trading as Oceanlinx, acquired the Oceanlinx technology know-how and intellectual property, along with its key scientists and engineers. Since the acquisition, the new owners under a new management team, have continued with the research, development and promotion of the Oceanlinks technology. It is not clear what will happen to the stranded Power Converter.

King William Sound W.A. Tidal Energy Project

The 48 Mw Tidal energy project around Derby was approved by the Western Australian Government in July 2013. The proposal is being developed by Tidal Energy Australia (TEA).

The design and costing was completed in 2003, but at 2013, TEA was awaiting a suitable off-take contract before it could go ahead. TEA has stated that the project will use proven off-the-shelf equipment including six 8Mw turbines. It is not known whether an installation contract has been let or whether the project is on hold subject to approval of finance.

UK Tidal Lagoon Power System

The general planning application was expected in 2017. Planning permission for Swansea was granted in June 2015.

In February 10, 2016, the UK Government announced a review, to start in Spring, of the Feasibility and Practicallity of Tidal Lagoon Energy.

On May 16, 2016, it was reported that a majority of UK Councillors and Conservative MPs support the Swansea Tidal Lagoon project.

Black Rock Tidal Power experiment in the Bay of Fundy in Nova Scotia

This experiment makes use of the flow of the tidal current of the incoming and outgoing tides and does not use a storage lagoon. Black Rock, one of a number of contractors, has reached a financial close on the 2.5 Mw Triton project. The Triton floating platform will carry a number of Schottel turbines which are expected to be installed by Autumn 2016.

In May 18, 2016, it was reported that Black Rock Tidal Power Inc. (BRTP) has awarded the contract to fabricate its TRITON S40 tidal power platform to Aecon Atlantic Industrial Inc., a wholly-owned subsidiary of Aecon Group Inc. (“Aecon”). This will be the first full-scale fabrication of this technology in the world. It is anticipated that the instream tidal device will be installed in the Bay of Fundy in 2017.

OpenHydro Tidal Power experiment in the Bay of Fundy

The Openhydro experiment also makes use of tidal currents without a storage lagoon. Reported in September 2015, the first of two machines would be installed by the end of 2015. The machines would deliver 4 Mw. A second machine was proposed to be installed early in 2016. By 2019, it was expected that several more machines would produce a total of 50 Mw.

It was reported in June 2016 that the project had been put on hold in the light of criticism by local fishermen.