Marine Energy Sector

Report
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Clean Energy Council

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1. Introduction

This report has been prepared for the Clean Energy Council to present a snapshot of the Australian Marine Renewable Energy Sector in 2010.

The marine environment is a vast, largely untapped renewable energy resource. Two thirds of the earth's surface is covered with water and almost none of it is stationary or homogeneous in nature. These characteristics provide opportunities for harvestable energy. There are broadly three categories of potential marine renewable energy sources: wave energy, tidal energy and ocean thermal. This report will not deal with ocean thermal as there is very little activity if any in this sector within Australia.

Twelve companies participating in the Australian marine renewable industry were identified. Nine of these agreed to be interviewed and their views on the marine renewable energy sector are largely captured in section 6.

2. The Marine Renewable Energy Resource

2.1 The Wave Energy Resource

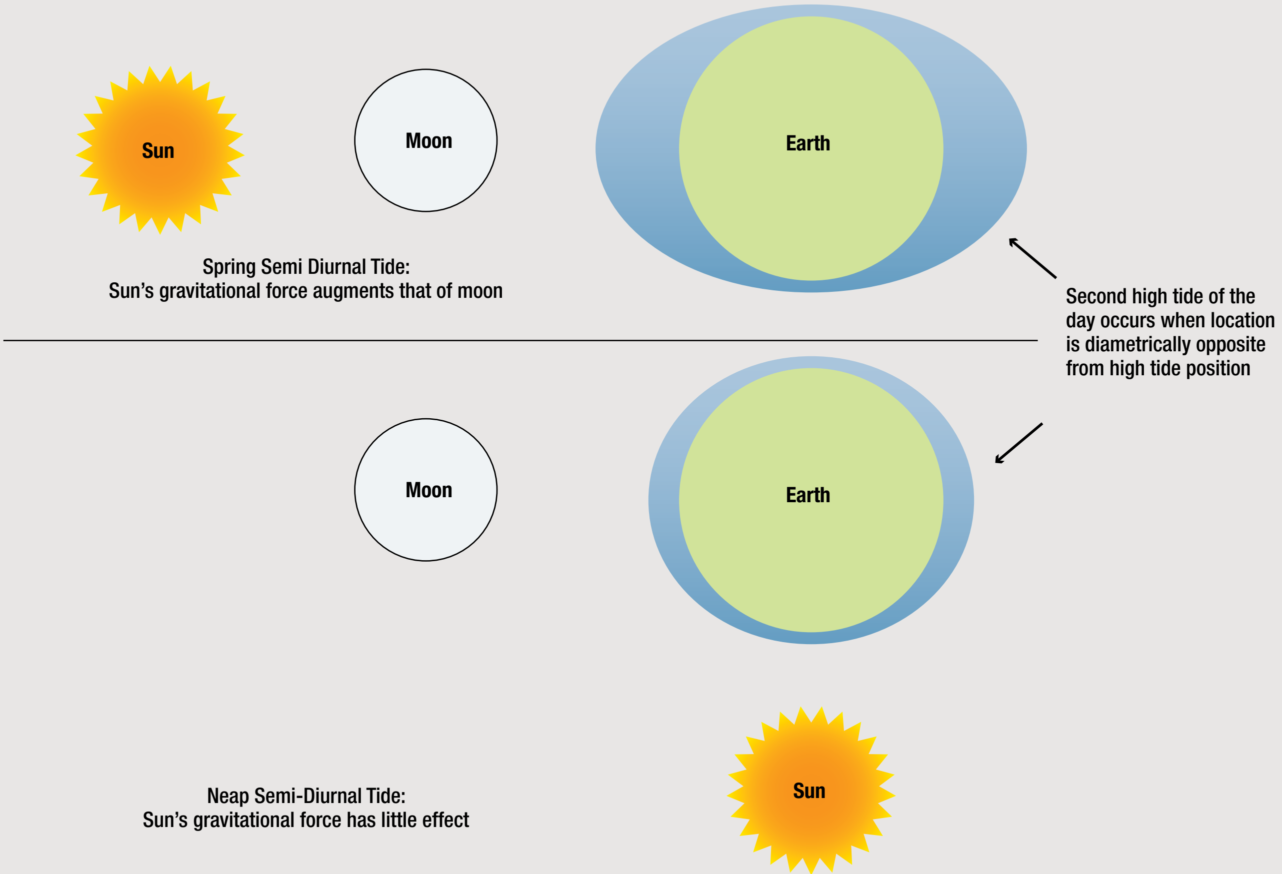
The wave energy resource is typically comprised of a combination of windwaves and long period swell. Wind-waves are created by the action of local winds on the surface of the ocean. They are generally short wave-length and lower amplitude. Swell is often created by storm activity hundreds of kilometres away. These strong winds also transfer some of their energy to the ocean surface. However, by acting over extended distances, termed 'fetch', the result is long wavelength relatively regular waves.

As the swell approaches a coast, the reducing depth steepens and accentuates the wave shape until ultimately the wave may break producing the familiar surf observed at many beaches.

Swell is the predominant wave energy exploited by wave energy technologies. Although relatively regular, the amplitude and to a lesser extent period of the swell will vary over time. Indeed the amplitude of the swell will vary from one swell to the next and therefore it is typical to describe swell in terms of averages. One commonly used measure of amplitude is the Significant Wave height (Hs). The significant wave height is the average height of the largest one third of waves.

The energy available for exploitation is typically expressed in kW/m of wave front and is a function of the wave period and the square of Hs. Cornett[1i] (Cornett, 2008) shows that the more energetic wave energy resources may be found outside the tropics on coasts adjacent to long fetches of ocean. This principally means that the west coasts of Europe, USA and Canada, Chile, South Africa, Australia and New Zealand.Australia is particularly well served in two respects. The Southern Ocean delivers its energy to the south and western coasts of WA, SA, Victoria and Tasmania. Also, and just as importantly, the seasonal and monthly variability is generally less than comparable sites in the Northern Hemisphere.

Figure 1: Earth Moon Tidal Diagram



2.2 Tidal Energy Resource

Tidal energy arises from the gravitational interaction of the Earth-Moon-Sun system on large bodies of water such as oceans. The primary action is to draw the body of water toward the moon creating a 'high' tide at the point on the earths surface directly below the moon. Most coastal locations experience two high tides each day. This arises because on the opposite side of the earth furthest from the moon, the gravitational attraction of the moon on the Earth is greater than of the moon on the water. Accordingly the earth moves toward the moon more than the water with the effect that, relative to the earth's surface, the water level appears to rise.

The Sun exerts a similar effect on the oceans although to a lesser extent as it is a much greater distance from earth. While the force driving the tides is relatively simple and regular, the impact locally in terms of timing and height of tide becomes dominated by the local near-shore bathymetry and its effect on the flow of water in response to the gravitational forces. Fortunately, as tides have a direct bearing on the safe navigation of shipping in and out of harbours, tidal predictions have been studied and refined for hundreds of years. Accordingly, accurate tidal heights can be forecast years into the future for all Australian ports and most ports around the world, thus making tidal energy a highly predictable energy resource.

Tidal energy extraction harnesses either the potential energy of high versus low tides or the kinetic energy of the resulting water flow (tidal stream). In Australia, the highest tidal ranges typically occur in tropical regions with tidal ranges in excess of 9m observed at Derby in North-West WA. However, harvestable tidal streams are available at many locations around much of Australia.

2.3 Scale of the Marine Energy Resource

With its long coastline and proximity to both the tropics and the Southern Ocean, Australia has an enormous marine energy resource available. The Department of Resources, Energy and Tourism (DRET 2010) estimated the total average tidal kinetic energy available at any one time on the continental shelf to be 2441.92 TJ and the total average wave energy available at any one time to by 3467.98 TJ. If all this energy was convertible to electricity it would deliver nearly 52 000 TWh per year. Compare this with Australia's electricity consumption in 2007-08 of 257TWh. Of course, such gross estimates at a continental level do not describe what portion could be technically converted nor what might be commercially feasible. Furthermore there is considerable variability between the marine energy available at one location from another. The only valid point that may be made is that marine renewable energy is an enormous resource with the potential to provide a material contribution to Australia's energy needs well into the future.

2.4 Technical Challenges

From an exploitation perspective, marine renewable energy has several advantages over other renewables

- Water is 800 times denser than air. Correspondingly, wave energy arrays or farms should have a much smaller footprint than wind farms of comparable size
- Marine energy conversion devices can be placed away from the coast line or are fully submerged reducing the potential for visual pollution
- Tidal energy is highly predictable allowing the scheduling of generation capacity on a network reducing the need for fossil fuel based redundant capacity or spinning reserve. While wave energy is not as predicable as tidal the average wave energy generation can be predicted several days in advance
- With about half of the world living within 100 miles of a coastline, there is the opportunity for marine energies to be supplying a significant proportion of the world's energy mix into the future.

The challenges for the technologies are however:

- The marine environment is hostile. Technologies de signed to convert average wave energies of 30kW/m must also be able to survive extreme events where the incident energy can be as high as 2000kW/m. Survivability loads can significantly drive the engineering design and cost
- There can be wide distribution of incident energy levels at any particular site. At the lower end of the distribution, the marine energy resource may not have sufficient energy to warrant operating the conversion device. Conversely at the upper-end of the distribution, the conversions device may need to be shut down to prevent damage. Thus the energy available for conversion may be somewhat less than the supposed average
- Marine surveys, sub-sea cabling, installation techniques and offshore engineering required for wave energy devices draws heavily on the skills, experience and capabilities of the offshore oil and gas sector. The market dynamics of offshore oil and gas drive equipment availability and costs with the marine renewable energy sector very much a price taker
- The development cycle (design, build prototype, test) for devices in open ocean conditions is lengthy and costly. Scale devices can be trialled with limitations in tank facilities. However, in open ocean conditions only full scale devices will provide representative data over a full operational range. Despite these challenges, the marine renewable energy opportunity has stimulated considerable interest and activity as a number individuals, universities and companies seek innovative solutions to harness this resource.

3. Wave Energy Technologies

Wave Energy technologies seek to harness the oscillating motion, horizontal and vertical, of the ocean. There are over 90 companies and organisations around the world trying to develop practical devices to harness this energy.

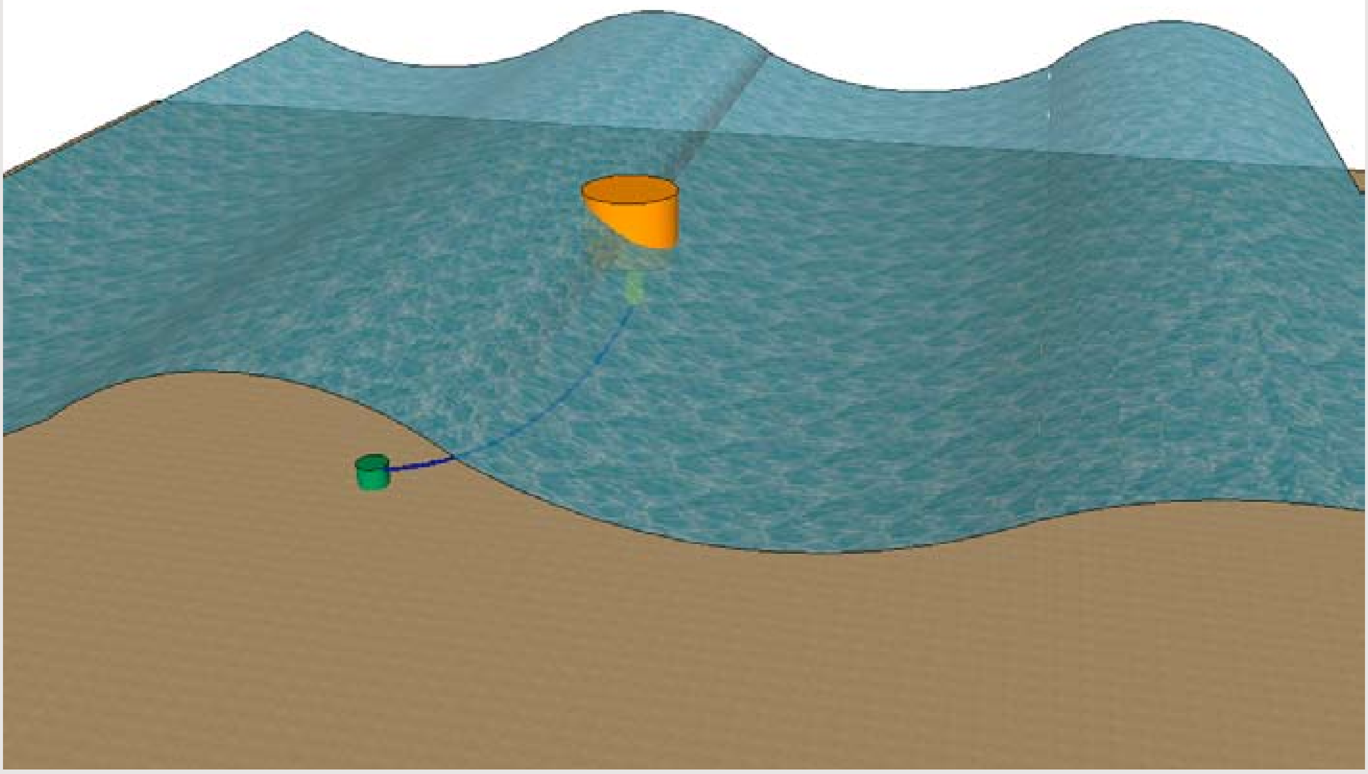
A wide range of devices and ideas has been conceived or are under development with no single concept having pre-eminence. Most devices fall into one of several categories of wave energy conversion:

- Point Absorbers
- Attenuators
- Oscillating Water Columns
- Overtoppers

3.1 Point Absorbers

Point absorbers, as the name suggests, seek to extract the wave energy at a specific point. Typically, point absorbers are moored buoys with the buoy following the wave surface. As the buoy rises with an incident wave, the distance between the buoy and its mooring point is increased. As the wave passes, the buoy descends, closing the distance between the buoy and its mooring. This oscillating motion can be harnessed to extract energy.

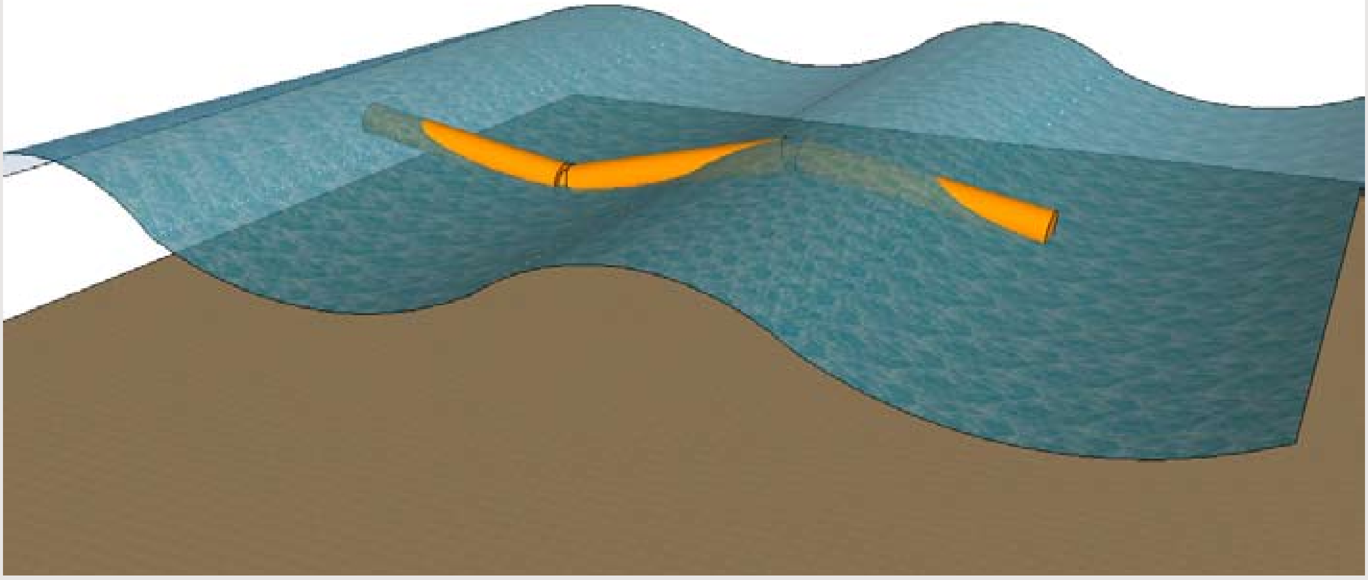
Figure 2: Point Absorber



3.2 Attenuators

Attenuators are elongated multi-segment devices with their longitudinal axis at right angles to the wave front. Attenuators may span one or more wavelengths and the derive their power from the relative motion between their individual elements.

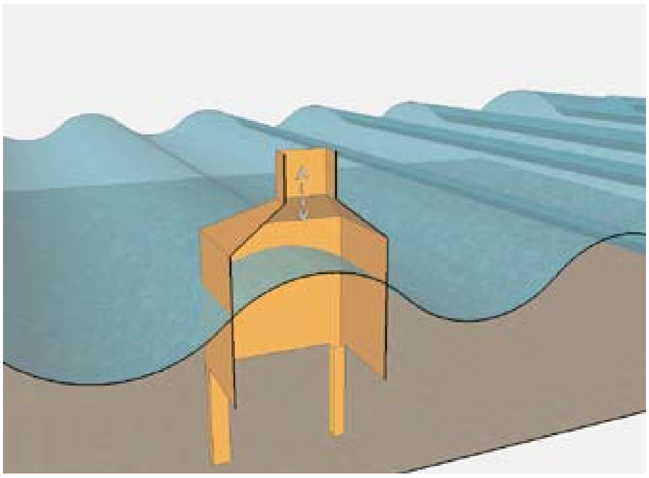
Figure 3: Attenuator



3.3 Oscillating Water Columns

Oscillating Water Columns may be characterized as an inverted chamber. As a wave rises in the box, it forces the column of air above it like the piston in cylinder. Generally this air is then passed through a turbine to extract the energy. As the wave falls the air above it is sucked back into the chamber and again energy may be extracted by a turbine in the air-flow. Optimised variants of the OWC seek to achieve resonance of the oscillation with the chamber such that the amplitude within the chamber can exceed that of the surrounding ocean.

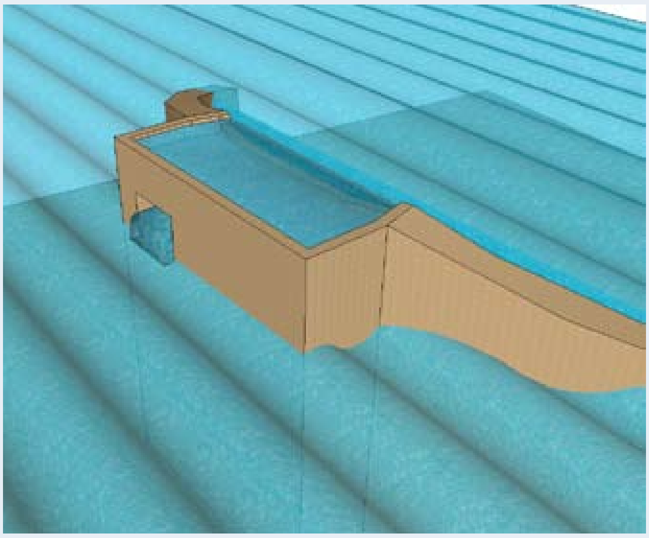
Figure 4: OWC

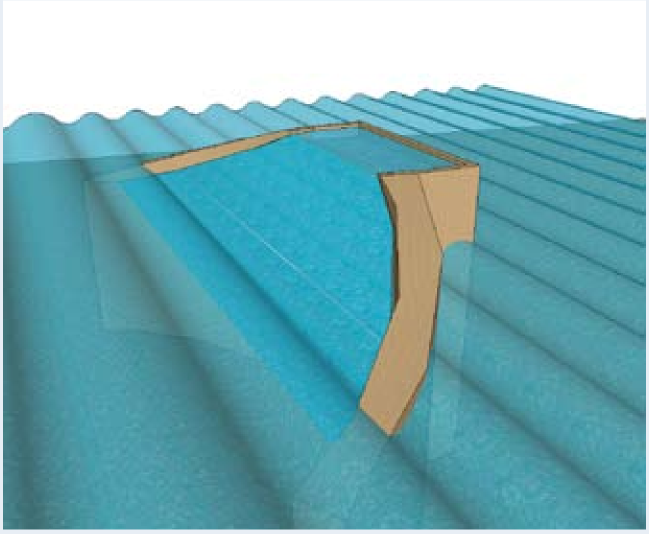


3.4 Overtopping Devices

Overtopping devices focus incident wave energy at a discrete point. This results in a localised increase in wave height which is captured in a holding plenum. The captured water is then allowed to flow back through a low head turbine down to the surrounding water level. An attraction of overtopping devices is that the holding plenum acts as a controllable buffer smoothing out the wave to wave variability.

Figure 5 & 5a: Overtopper





4. Tidal Technologies

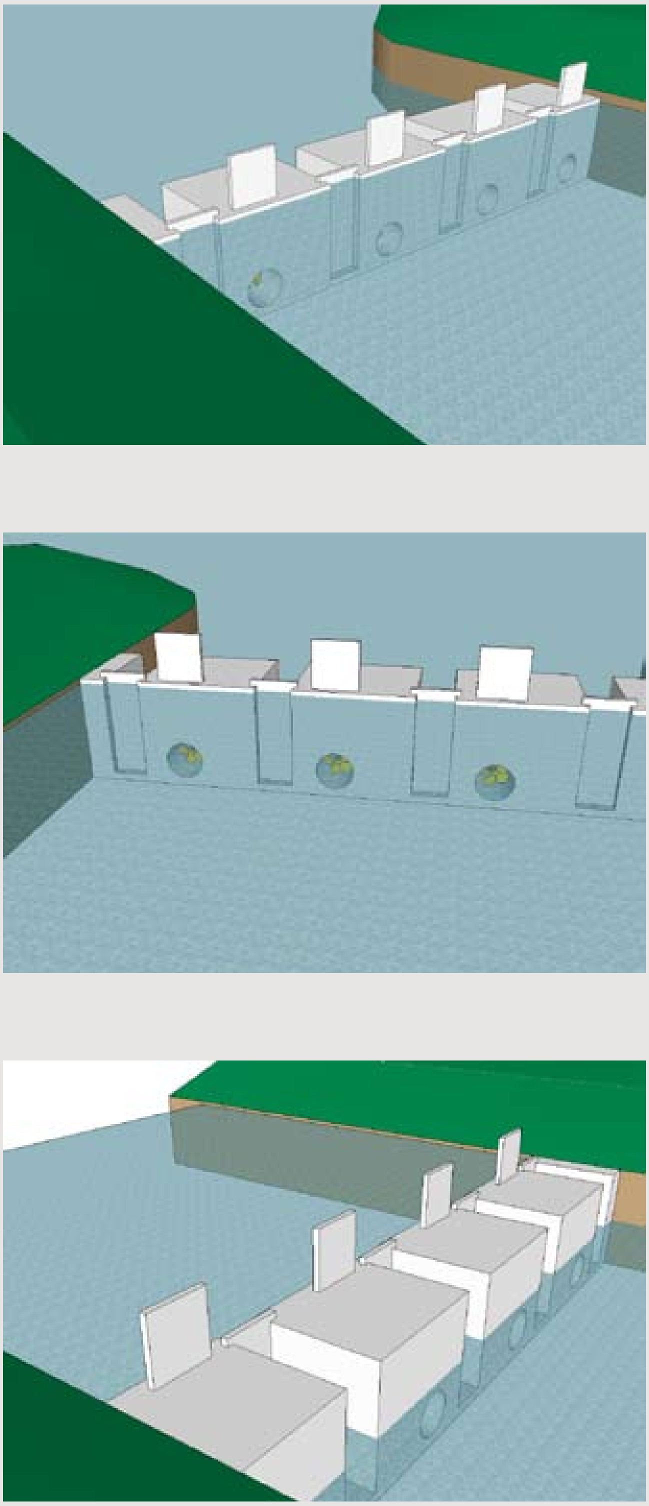
4.1 Barrage Systems

Barrage Systems aim to harness the potential energy of a volume of water at high tide compared with that at low tide. Most of the world's current marine renewable energy generation is created at two tidal barrage sites. A 240MW tidal barrage system at Rance, France has been in operations since 1966. A 20MW tidal barrage has been operating in the Bay of Fundy, Canada since 1984.

A barrage system is essentially a dam across a tidal basin or estuary. The operation is cyclic:

- The basin is firstly allowed to fill through sluices until high tide when the sluice gates and turbine gates are closed
- The tide is then allowed to fall until sufficient head is created across the barrage
- The turbine gates are then opened allowing water to flow across the turbines and generate electricity. This continues until the head differential becomes too small. The sluice gates are then reopened and the basin allowed to refill.

Figure 6, 6a & 6b: Barrage



The following diagrams show a stylised tidal barrage system comprising 4 axial flow turbines shown at the commencement of the generation cycle. There is a significant head difference between the basin in the foreground and the open water. Sluice gates are shut and turbine gates are open.

Barrage systems are a proven technology but require large-scale civil works and ideally a naturally occurring tidal basin or estuary. This tends to limit their application to a narrow set of locations with tidal ranges in excess of 4m. Tidal barrages inevitably disturb the normal ebb and flow of waters in the area and may cause silting, salinity increase and adversely impact on fauna such as seabed dwelling fish species.

4.2 Tidal Stream Devices

As the tides rise and fall, they create a flow of water called a tidal stream. Tidal stream devices seek to harness this flow in much the same way as wind turbines seek to harness the flow of air. However, contrary to wind turbines, tidal stream turbines are subject to relatively smooth and continuous flow.

There are a large variety of turbine styles under development ranging from direct analogues of wind turbines, to various horizontal and vertical axis impulse and reaction turbines. Some turbine sets are cowled; others operate in the free field. The Atlantis Resources AK series turbine (section 5.2) is an example of an open water tidal device.

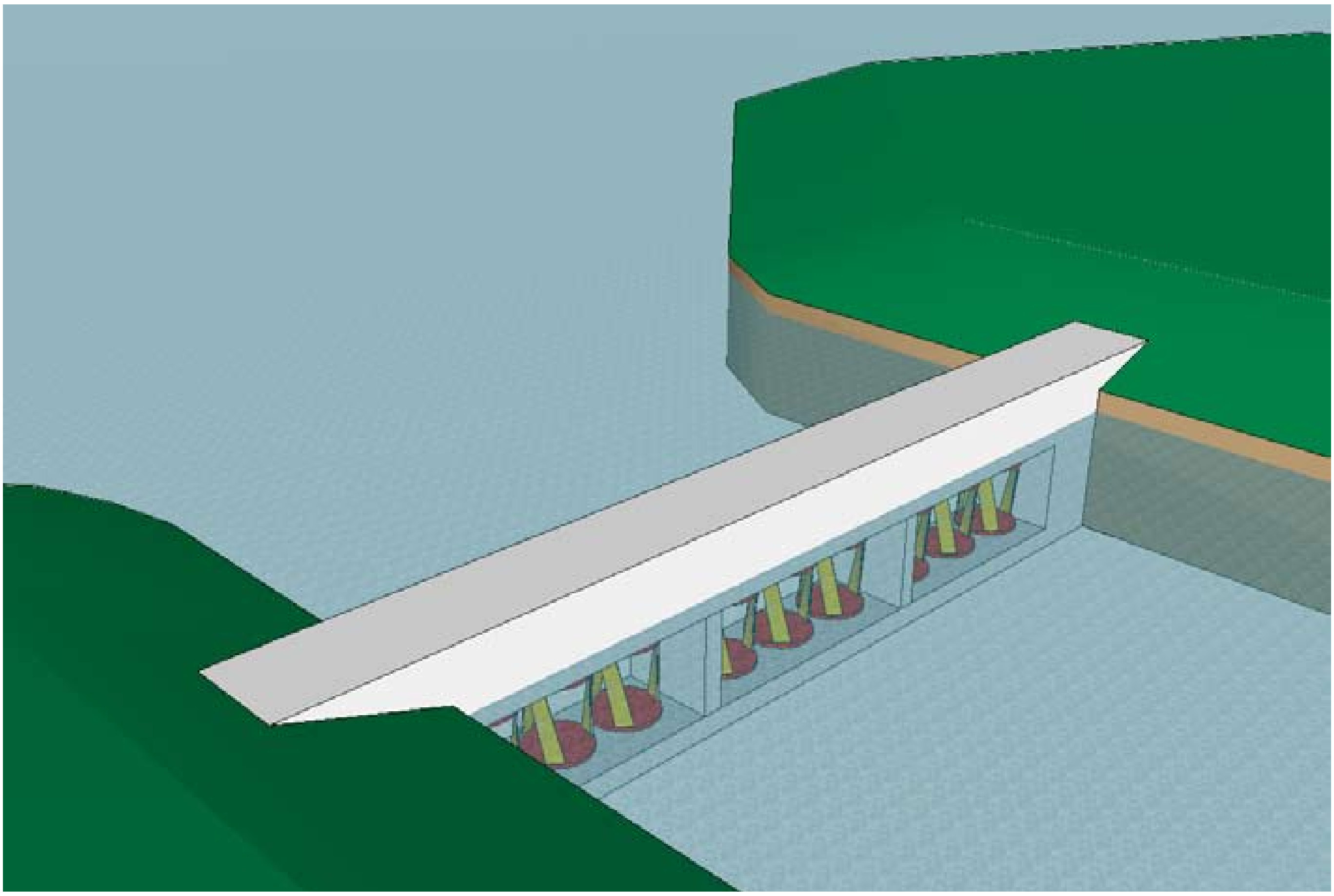
The advantage of tidal stream devices over barrage systems is that they can be sited wherever there is sufficient water flow. Typically, they will harness only a portion of the flow in the area and therefore have far less impact on the natural flow.

4.3 Tidal Fence

A tidal fence is something between a barrage and a tidal stream device. A tidal fence is typically a barrier with a series of turbines placed across a tidal basin or estuary that directly harnesses the tidal flow in and out of the basin.

The near normal flows in and out of the tidal basin or estuary typically mean they are less ecologically damaging than barrage systems although silting can still be an issue.

Figure 7: Fence



The above diagram shows a stylised tidal fence with vertical axis turbines. In contrast to the tidal barrage there is little to no head difference between the water in the basin and the water in the open water. For this reason, tidal fences are able to generate less energy than a tidal barrage at a similar location.

Tidal fences, like tidal barrages do require large scale civil works and an existing tidal basin or estuary.

5. The Australian Marine Renewable Energy Industry

Australia has been very active in the marine renewable sector for a number of years and there is a healthy, active and growing community of companies at various stages of maturity. It is testament to the potential of this renewable energy resource and Australia's characteristic innovation skills that the marine renewable energy sector is vibrant and overwhelmingly positive.

No attempt is made in this report to rate one company or one technology over any other. The paucity of information against some companies should not be interpreted as indicating a lack of substance or maturity. Interested parties should approach these companies directly in order to form an opinion as their relative merits.

5.1 Advanced Wave Power

Advanced Wave Power (www.advancedwavepower.com) is a Brisbane based developer of a wave energy conversion device and developer of projects based on their technology. Their Nautilus wave energy converter comprises of multiple Oscillating Water Columns (OWC) arranged in a longitudinal array. Each OWC discharges to a common air plenum via a valving mechanism with the energy in the resulting airflow extract by a turbine.

Figure 8: Nautilus

During the 2009, AWP successfully deployed and tested one array in Moreton Bay confirming the performance estimates of the University of Queensland. AWP plans to develop a 1MW project using the Nautilus wave energy converter at one of the Pacific Islands within the next 24 months.

5.2 Atlantis Resources

Atlantis Resources (www.atlantisresourcescorp.com) is a tidal energy company with several families of tidal turbine. Originally an Australian company it is now headquartered in Singapore and London. Their turbine families include:

- AK Series – free-flow horizontal axis turbine (two blade sets per axis)
- AS Series – ducted flow horizontal axis variable pitch turbine
- AN series – shallow water turbine with two shafts and chain mounted series of aquafoils that drive the chain and thence the shafts.

Figure 9: AK Turbine

Over the last 12 months, Atlantis Resources has:

- completed the design and development of its 1MW commercial AK series turbine
- completed open water tow testing of an AS series turbine in Tasmania with results verified by Black & Veitch
- completed 20 months of operation on the Nereus AN series turbine at San Remo, Victoria with no OH&S issues and maintenance expenditure below budget
- Been selected by the UK Carbon Trust as one of six companies to share in £22million in support thought the Marine Energy Proving Fund

Primary focus for 2010 will be the deployment of an AK series turbine at the European Marine Energy Centre in Orkney, Scotland at the end of July 2010. The final phase commercialisation of the AK series turbine is planned for 2011.

5.3 BioPower Systems

BioPower Systems (www.biosystems.com) is based in Sydney and is primarily a technology developer and services provider although they do participate in project developments.

BioPower Systems has two families of technologies: one for wave (bioWAVE) and one for tidal (bioSTREAM). An interesting aspect of their technologies is application of bio-mimicry. That is the mimicking of naturally occurring mechanisms in the particular environment.

bioWAVE is their wave energy device. It is a seabed mounted, bottom pivoted device that harnesses the surge (horizontal) component of wave motion. A feature of the bioWAVE device is its ability to lay flat on the seabed to protecting itself from damage during storms and extreme events.

bioSTREAM is an oscillating hydrofoil tidal current energy convertor, based upon the thunniform mode propulsion of sharks and tuna.

Figure 10: bioWave

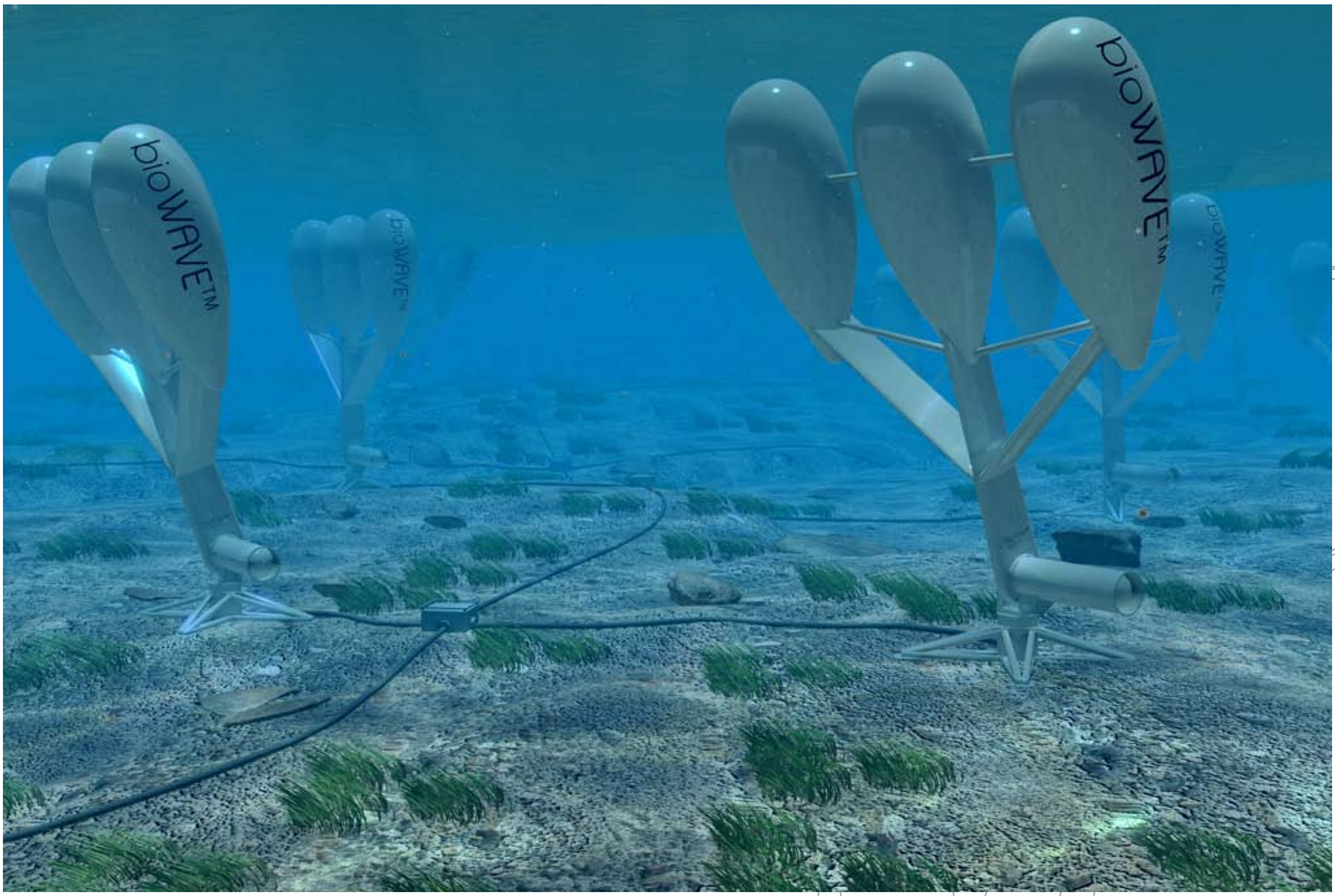


Figure 11: bioStream

Over the last 12 months, BioPower Systems has:

- Signed an MoU with Siemens to evaluate and develop joint opportunities for ocean power conversion.
- Entered into a collaborative agreement with the City of San Francisco to investigate and develop a 10-100MW wave energy project off San Francisco's western beaches
- Signed an MoU with Spanish Project Developer Elecnor SA that will lead to the development of wave energy projects in Elecnor's core business regions
- Secured land access, onshore development rights and project IP for a commercial scale wave energy site near Port Fairy, Victoria.

BioPower's plans for the next 24 months include:

- Developing 250kW bioSTREAM and bioWAVE prototypes
- Commencing the installation of a 250kW prototype bioWAVE device at Port Fairy
- Completing the engineering development and design of the 1MW commercial bioWAVE device
- Commencing deployment of a 750kW pre-commercial demonstration device with Elecnor in Spain
- Competing the feasibility study for the City of San Francisco.

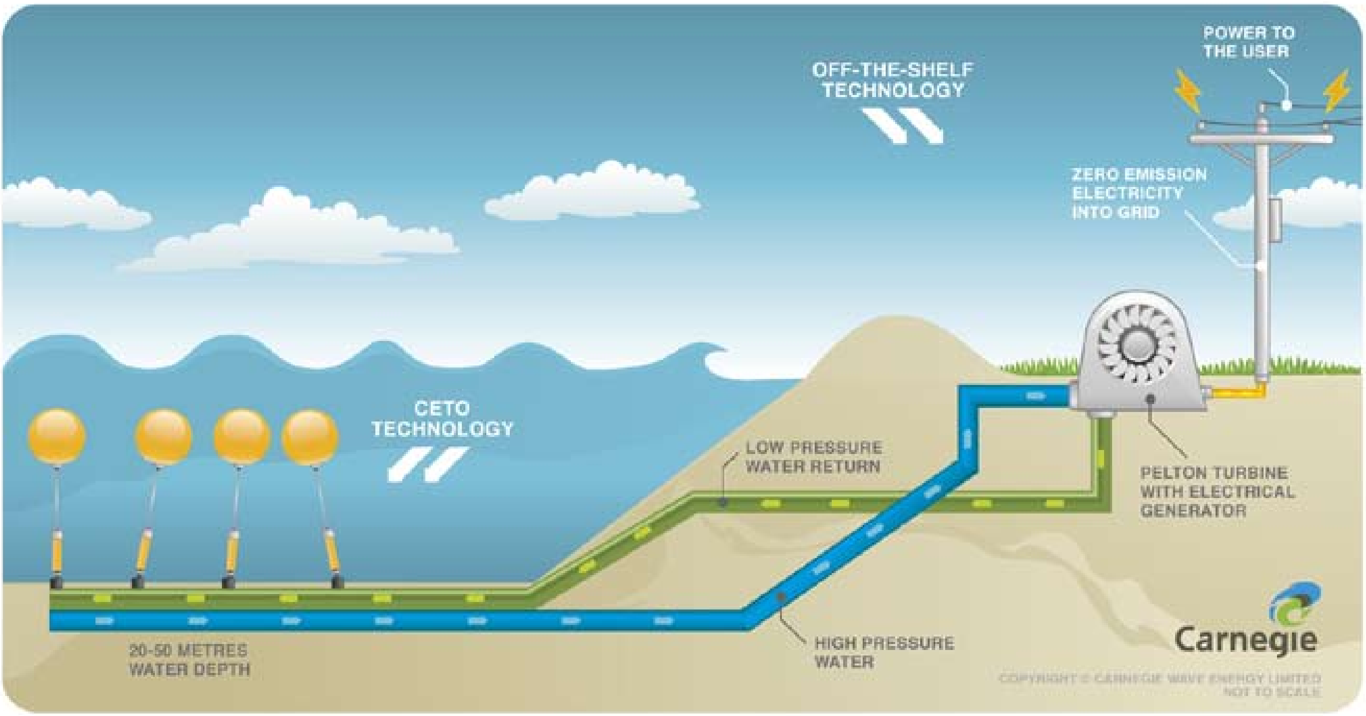
5.4 Carnegie Wave Energy

Carnegie Wave Energy (www.carnegiewave.com) is the only ASX listed public company of the marine renewable energy sector in Australia. Based in Perth, Carnegie seeks to develop its technology, develop projects based on its projects and also licence the technology to other developers.

Carnegie's third generation of technology (CETO 3) is a fully submerged point absorber. A submerged float drives a high pressure pump delivering pressurised sea water to a pelton wheel turbine located on shore which is coupled to a generator to create electricity.

Carnegie holds seabed licenses to investigate and develop wave energy projects.

Figure 12: CETO Schematic



During the last 12 months, Carnegie Wave Energy has:

- Completed pilot scale testing with CETO 2 devices
- Acquired 100% of the CETO intellectual Property
- Secured grants from the WA government ($12.5million), French and Canadian governments ($7million)
- Raised over $14.5 million through share placement to institutional and sophisticated investors.
- Gained access to potential project sites in Australia and the Northern Hemisphere (British Columbia, Ireland, Bermuda) and Reunion Island.
- Signed its first technology licence agreement allowing EDF EN to develop projects based on the CETO technology in the Northern Hemisphere and Reunion Island.
- Signed agreements with the Department of Defence to investigate the potential of CETO technology to supply HMAS SITRLING and the Harold E Holt Naval Communications Station at Exmouth.
- Signed anMoU with Synergy for the offtake of electricity from a 5MW demonstration project at Garden Island, WA.
- Commenced mooring foundation works for the first stage of the Garden Island project.

Figure 13: CETO2

Key events planned for 2010 and 2011 include:

- Deploy and quantify the performance of a commercial scale CETO unit in 2010.
- Construct the 5MW demonstration project at Garden Island by Q4 2011.
- Finalise a Power Purchase Agreement with potential offtakers: Synergy, Department of Defence or the Second WA Desalination Plant.
- Commence first international project with partner EDF EN in 2010.

5.5 Elemental Energy Technologies

Elemental Energy Technologies (www.eettidal.com) is the developer of a specialised turbine-generator designed for a very wide range of tidal stream flow rates (1.6ms-1 to 4ms-1) and locations. The turbine is axial flow and an integrated part of the generator – the turbine circumferential elements act as the generator rotor while a circumferential shroud acts as the generator stator.

Elemental Energy Technologies (EET) is a manufacturer and supplier of its turbines marketed through exclusive distributors and licensees in each geographic region.

During 2009 and early 2010, EET has been identifying and securing its key strategic partners to advance the product development, trialling and commercialisation of the technology. Over the next 24 months EET is planning to commence production of its (50kW) micro turbine by the end of 2010 followed by the commencement of production of its (50-200kW) mini turbine in 2011.

5.6 Oceanlinx

Oceanlinx (www.oceanlinx.com) is a Sydney based developer of a wave energy technology and renewable energy projects based on this technology. The third generation of their wave energy conversion technology has multiple oscillating water columns mounted in a floating lattice structure. Each OWC has its own bi-directional turbine and generator.

The highlights for the company in the last 12 months include:

- Securing the second tranche of funding from a European based investment syndicate.
- Achieved 500 operational hours in 2009 on Oceanlinx first generation (Mk1) full scale prototype at Port Kembla prior to decommissioning the device.
- Construction and deployment of a demonstration scale third generation device (Mk3PC) at Port Kembla.

Figure 14: Mk3PC

Over the next 12 months, Oceanlinx will trial the demonstration scale device and validate its performance before commencing commercial projects at one of its areas of interest: Namibia, Portugal, Victoria, King Island, Hawa[ii], Mexico, UK or Spain.

5.7 Protean Power

Protean Power is a Perth based technology developer of a floating pointabsorber type wave energy converter. A small-scale device of 1.5m diameter was trialled in 2009. Full scale devices will be 4.5m in diameter and rated at 300kW in open ocean conditions.

5.8 Tenax Energy

Tenax Energy (www.tenaxenergy.com.au) may be unique in the Australian marine renewable energy sector. Tenax is purely a tidal project developer and are essential technology neutral although have short listed 3 candidate system providers for their proposed projects.

Tenax is based in Darwin and over the last 12 months has secured tenure from the Northern Territory Government for its Clarence Straits project.

During 2010 and 2011:

- Tenax will complete the Environmental Impact Statement for the Clarence Straits project in accordance with recently developed guidelines issued by the NT Government
- Reach financial closure on the NT project
- Secure tenure over one of its other Australian project sites (Port Phillip Heads, Banks Strait).

5.9 Tidal Energy Pty Ltd

Tidal Energy Pty Ltd (www.tidalenergy.net.au) is the Gold Coast based developer of a Davidson-Hill Venturi turbine with a patented shroud design. They manufacture turbines to order and also licence the technology. In October 2009, Tidal Energy Pty Ltd signed an $18m combined supply and licensing agreement with a South American company that would see their technology deployed in that continent.

During 2010 and 2011, Tidal Energy Pty Ltd will:

- undertake their supply obligations to their South Ameri can partner
- finalise development and production of a demonstration scale turbine to be used as a proof-of-concept device by 3-4 project developers
- finalise a trial of the technology with Ergon Energy.

5.10 Tidal Innovations

Tidal Innovations (www.tidalinnovations.com) is an early stage tidal energy company based in NSW with headquarters in the ACT. Tidal Innovations technology development is focused on minimising capital and maintenance costs in the tidal energy sector. Details of their proposed technology have not been disclosed, pending patent application. Over the next 24 months Tidal Innovations will be deploying and trialling their technology at a series of sites in NSW.

5.11 Victorian Wave Partners Pty Ltd

Victorian Wave Partners (VWP) is a joint venture between Leighton Construction (www.leighton.com.au)(90%) and OPT-Australasia (10%) created to develop and operate a 19MW wave energy project at Portland Victoria. OPT-Australasia is itself a partnership of OPT Inc (88%) of New Jersey (www.oceanpowertechnologies.com), USA and Woodside (12%) (www.woodside.com.au).

VWP will deploy OPT's PowerBuoy point-absorber wave energy conversion devices and leverage off a trial project undertaken by OPT Australasia in 2000. 150kW devices are planned for the first stage of the project with the balance of the 19MW provided by 500kW devices currently under development.

The formation of the Joint Venture company and the securing of a $66.46 million grant from the Australian Government are the highlights of the last 12 months. During the next 24 months, VWP will complete all the requisite site permits and approvals and grant pre-requisites before the letting of contracts for procurement, fabrication, assembly and installation in early 2011.

Figure 15: PowerBuoy

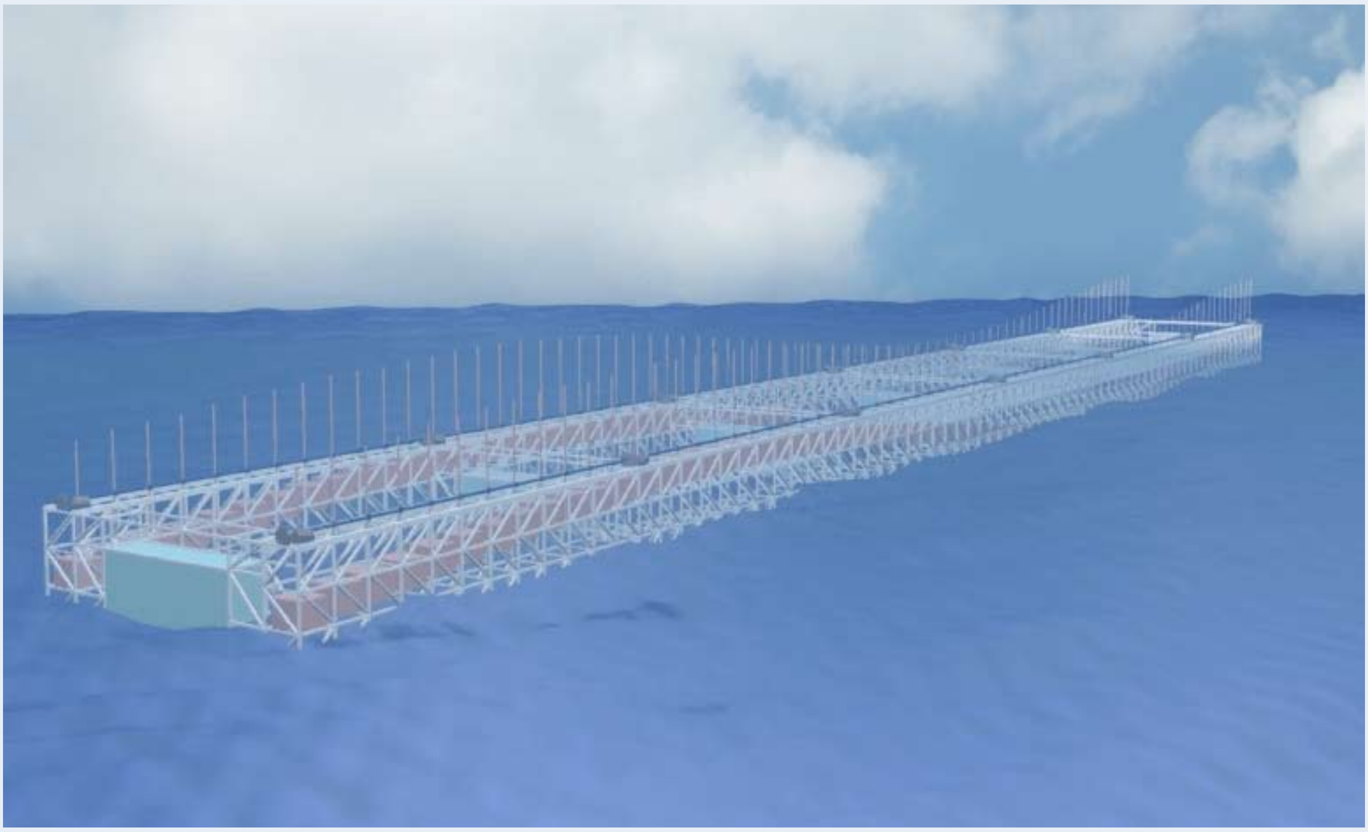
5.12 Wave Rider Energy

Wave Rider Energy (www.waveriderenergy.com.au) is a South Australian based technology developer. Their technology is a form of point absorber comprising and open frame structure containing a series of floats. These floats are mechanically linked to a shaft that in turn drives a generator.

In 2009, Wave Rider Energy received approval from the South Australian government to deploy a pilot device at Elliston on the Eyre Peninsula. They have subsequently been conducting a series of scientific and environmental studies required by the Department of Environment, Heritage, Water and the Arts with environmental approval expected in April 2010.

Construction of the 280 tonne, nominally 200kW, ~3/4 scale pilot device will commence in 2010 with deployment planned for Q1, 2011. A trial period of 12 to 18 months is envisaged.

Figure 16: Wave Rider



Source: CleanEdge

5.13 Woodshed Technologies

Woodshed Technologies is a Melbourne based commercialiser of environmentally responsible technical developments in energy, water and transport. Their principal marine renewable energy (tidal) activities are conducted in the UK through a wholly owned subsidiary CleanTechCom Ltd. Tests at the European Marine Energy Centre, Orkney, Scotland are planned for their tidal delay technology that employs an impulse turbine installed in a siphon pipe over/under a natural barrier.

6. Costs

As an immature industry sector there are few hard numbers available to assess the real and projected cost of marine renewables. Where such numbers do exist, they can be kept close to the chest to protect supposed commercial advantage.

One interesting observation from the survey of the marine renewable energy industry is that the more established companies are far less bullish than the more recent entrants. For example the more established would see comparability with offshore wind (~$6000-$8000/ kW installed) as an achievable near term target while the new entrants were looking towards comparability with onshore wind (~$2800/kW installed).

The UK's Carbon Trust (Carbon Trust, 2006)[ii] assessed the contemporary cost of wave energy to be between 12 and 44p/kWh with a central estimate of 22 to 25p/kWh. Tidal Energy was estimated to cost between 9 and 19p/kWh with a central estimate in the sub-range 12-15p/kWh. They projected that with government support during maturation and large scale installation marine renewable energy had the potential to become competitive with other generation forms while tidal stream could become competitive with the base cost of electricity (2.5p/kWh) at or near the estimated UK tidal economic resource limit.

7. Overseas Experience

7.1 United States

The Obama Administration's American Recovery and Reinvestment Act included more than US$80 billion in clean energy investments to build the clean energy industry and jobs of future America[iii]. Much of this US$80 billion is dispersed through the US Department of Energy and its US$16.8 billion Energy Efficiency and Renewable Energy (EERE) program and US$4.0 billion renewable energy loan guarantee.

However, while there have been dedicated programs for bio-mass, geothermal, solar and wind within the EERE program there is little support specifically for the US marine renewable sector.
The regulatory environment varies considerably from state to state compounded in recent years with turf wars between state and federal authorities and indeed between federal authorities.
In late 2008, the Federal Energy Regulatory Commission (FERC) and Minerals Management Service (MMS) reached an accord over federal oversight of marine renewable projects. FERC may issue permits up to the 3 mile limit of the shoreline while MMS may issue leases beyond the 3 mile limit to the limit of federal jurisdiction. FERC remains the licensor of all generating facilities irrespective of location.

In 2009 FERC introduced the concept of a pilot project permit for hydrokinetic projects, which includes marine renewables, in an attempt to arrest criticism over the prolonged period it can take FERC to issue a permit for hydrokinetic projects(up to 5 years). FERC aims to issue pilot projects within 6 months. The pilot project permits is, however, quite limiting. The project must be constructed, operated and decommissioned within the 5 year period and there is no opportunity to articulate a pilot project permit into a full 30 year permit.

The principal US based marine energy companies are the wave energy company OPT based in New Jersey and the tidal company Verdant Power based in New York. However, like Australia there are many smaller project and technology developers emerging.

7.2 Europe

The European Union has established its 20/20/20 by 2020 target. This calls for a reduction in greenhouse gas emissions by 20%, 20% renewable energy sources in the EU energy mix and an overall reduction in EU primary energy consumption by 20%.

The European Strategic Energy Technology Plan guides member states on how to address the challenge. However, in the main, marine renewables are considered secondary to other forms of renewable energy sources in meeting the 20/20/20 targets reflecting the maturity of the technology rather than the potential.

Several member states have greater emphasis on marine renewables than the EU though the provision of supporting mechanisms to promote marine renewables as part of the renewable energy mix.EU finance rules preclude grants to projects that would have the purpose or effect of producing a profit for the recipient. As profit is a primary motivation in attracting private investment, EU support strategies are typically focussed on market support mechanisms rather than grants.

These support schemes are listed in the following table:

Country	Direct Support Scheme
Denmark	Special tariff of 600 DKK/MWh for 10 years and 400 DKK/MWh for a further 10 years
France	Feed-In-Tariff of €150/MWh for 20 years Tender system for large projects
Ireland	Feed-In-Tariff of €220/MWH
Italy	Small generator (<1MW) may trade green certificatory or receive a Feed-In-Tariff of €340/MWh
Portugal	Establishment of a pilot zone specifically to promote wave energy to an installed capacity target of 200MW
	Sliding scale of Feed-In-Tariff for wave energy from €260/MWh for first 4MW installed down to €76/MWh for 20-100MW installed
Spain	Fixed Feed-In-Tariff of €65-69/MWh Premium Feed-In-Tariff of €30-38 MW

Source: European Ocean Energy Association presentation to WavEC Seminar 24 Nov 2008

7.3 UK

The United Kingdom is arguably the most active in the development and promotion of a marine renewable energy industry. With a well developed offshore industry servicing the North Sea and good wave and tidal resources, the United Kingdom views the marine renewable energy sector as a potential large contributor to their future energy needs.

The United Kingdom and Scotland in particular has initiated several strategies to promote the development of marine renewables. These include:

- Efforts to streamline and simply the planning and approvals processes for development projects
- The development of an Offshore Transmission regime to provide an offshore transmission network at 132kV or higher. Although largely driven by the need to support the offshore wind industry, this regime will eventually assist the marine renewable sector by shifting the capital cost burden of sub-sea cabling to Offshore Transmission System owners.

Marine renewable energy developers will pay either an annual usage fee or a wheeling charge to access the networks.

- The funding and support of several marine energy test centres and R&D programs including:
    - SuperGen Marine Research Program of the Universities of Edinburgh, Herriot-Watt, Lancaster, Strathclyde and Robert Gordon
    - The Peninsular Research Institute for Marine Renewable Energy - a partnership of the Universities of Exeter and Plymouth
    - The New and Renewable Energy Centre in Northum berland has large scale flume and tidal testing facilities
    - The European Marine Energy Centre (EMEC), Orkney, Scotland provided open ocean full scale test facilities for both wave and tidal devices. The EMEC has also been the focus for developing industry standards for the marine energy sector
    - Wave Hub in Cornwall aims to provide four separate berths for wave energy developers to demonstrate their technologies.
- Various grant programs including the £22million Marine Renewables Proving Fund created, in part, as a bridge to access the £50million Marine Renewables Development Fund
- An enhanced revenue support mechanism through tradeable Renewable Obligations Certificates (ROC) provide two ROCs for every marine renewable energy MWh produced in the United Kingdom. (One ROC is currently trading at around £44)
- A further enhancement of the ROC system in Scotland providing three ROCs for every MWh of tidal energy and five ROCs of every MWh of wave energy.

It is therefore not surprising that the UK has the largest concentration of marine renewable developers and has also attracted the attention of the major non-UK based marine renewable energy developers such as OPT, Atlantis Resources and Oceanlinx.

The presence of such a supportive environment has several impacts on the Australian industry. On the positive side, a critical mass of technical expertise and learnings is being developed in the United Kingdom that can be utilised by Australian industry to avoid previous mistakes. Secondly, the United Kingdom regulatory and industry support mechanisms provide Australian government with what works, what doesn't work and what can be achieved.

On the negative side, the favourable support environment attracts private investment at the expense of such investment in Australian companies. Furthermore, as Australian companies are attracted to developments in the United Kingdom the wisdom of remaining in Australia while managing projects in the UK comes into question creating the potential for relocating skills and intellectual property to the UK or Western Europe.

8. Critical Issues for Australia's Marine Renewable Energy Sector

Australia's marine renewable energy sector is in its infancy, both from a technology and from a business perspective. The potential has created an active and innovative group of companies and arguably Australia is punching well above its weight in the international stakes. Whether any of these companies can take the next step to commercial viability remains an open question.

Some common themes arose when discussing critical issues and impediments with members of the Marine Renewable Energy Industry. This are discussed in the following paragraphs.

Lukewarm Government Commitments

While the rhetoric in favour of renewable energy is being voiced by State and Federal Governments it is not being matched by action. The absence of firm and binding commitments by Governments coloured no doubt by concerns over damage to Australia's coal industry allows utilities, the public and investors to equivocate in their own actions. While this impacts all renewable energy sectors, it is felt more keenly by the less mature technologies such as marine renewables.

No Strategic Focus

To date, the marine renewables sector has received no particular focus in the political dialogue, despite Australia:

- Having one of the world's best marine energy resources
- Having developed several of the world's leading marine energy technologies
- Having around 80% of its population living within 5km of the coast.

This contrasts with the focus given by State and Federal governments to wind, solar, geothermal and Carbon Capture and Storage. Not surprisingly therefore, knowledge of the industryits potential and challenges, is not widespread within Government circles. Furthermore, what support that is available from Government is not as suited as it might otherwise be for the marine renewables sector.

Securing Access to the Resource

The approach taken to secure an area to conduct exploration for minerals and petroleum is reasonably consistent across the country. Exploration licences are issued providing the explorer with priority rights to any resources found. A subsequent licence is then required to develop the resource. The licences are issued on a use it or loose it basis to prevent permit banking. The exploration licences provide a level of certainty to the explorer that their investment in exploration will yield a return if a feasible resource is located.

There is no such certainty for developers of marine renewable energy. Each state government has approached the issue of licences differently and typically they develop the process in response to the first application they receive. Licences to explore or prove the feasibility of a project do not necessarily give priority access to a site for subsequent development. Thus all marine energy developers proceed at some risk when seeking to prove the resource at a particular location.

Grants v Market Support Mechanisms

The marine renewable industry has divided views the relative merits of grants and market based support mechanisms such as Feed-In-Tariffs. All recognise the need to support the industry through one or more mechanisms until it can stand on its own feet. Grants, particularly small grants, provided to support technology development and commercialisation activities were viewed favourably. However, grants for project development in isolation of market support mechanisms were viewed less favourably as they have the effect of 'picking the winner before the race is run'.

Market based support mechanisms such as feed-in-tariffs, production tax credits and guaranteed investment returns can attract private investment into marine renewable energy projects allowing all technologies access on commercially competitive terms.

Comparable International Support

Western Europe and the UK have invested heavily in the marine renewable sector. Their incentives and support mechanisms are very favourable which in turn attracts the project developers and project investment to opportunities in the region. All of which adds to the shortage of funding available to develop the marine renewable energy projects in Australia. It also shifts the focus of the Australian marine renewable industry toward projects in Europe and potentially the relocation of companies to Europe and the centre of their operations.

9. Advancing Australia's Marine Renewable Energy Sector

The following section, while guided by the comments of Australian Marine Renewable Energy companies, reflects the opinion of the author rather than an agreed position by this sector. The scope of this paper does not permit a detailed analysis of options for advancing the marine renewable energy sector and therefore the proposals are offered for consideration and debate only.

9.1 Why Advance?

No one renewable energy resource can provide all Australia's renewable energy capacity. Each renewable energy resource has its own limitations be it variability of supply, geographic distribution, poor matching of supply and demand cycles or other issues. Cost competitiveness will clearly be a factor in the supply mix but is not the only factor. A balanced mix of renewable energy supply that might vary from region to region is likely to offer the best opportunities for Australia to meet and exceed its renewable energy target.

In contributing to this optimum renewable energy mix, marine renewable energy should have a valuable part to play for several reasons:

- Marine renewable energy is a large and inexhaustible resource
- Marine renewable energy is accessible to the majority of Australia's population and energy demand as they are predominantly located within a few kilometres of the coast
- Tidal energy and to a lesser extent wave energy are among the most consistent of the intermittent renewable energy resources. They are therefore able to be a scheduled supply with the potential to contribute to base load
- Marine renewable energy can reduce the variability inherent in renewable energy supplies allowing a greater take-up of variable but relatively cheap renewable energy sources such as wind.

To elaborate on this final point, a study[iv] performed in the United Kingdom by the Environmental Change Institute of Oxford University addressed the issue of renewable energy supply variability on the grid. Several scenarios were considered for a 20% renewable, 80% conventional energy mix. The study concluded that a scenario involving wind, tidal and wave gave a much better variability outcome (2%) than wind alone (3.2%) or a mixed low carbon scenario of wind, wave, tidal, landfill gas, biomass and small hydro (3%). This lower variability translated directly to lower balancing costs. That is the cost of maintaining reserve conventional supply to overcome the additional supply uncertainty of utilising renewables in the total supply mix.

While this study related specifically to the UK grid it is not unreasonable to conclude similar advantages may accrue to the Australian electricity network with the inclusion of some marine renewable energy supply.

9.2 An Important Opportunity

An equally important aspect of marine renewable energy is that it represents an opportunity for Australia to take a dominant role in the development of this technology around the world.

It is tempting to look at renewable energy as merely a necessary mitigating action to climate change. Alternatively, one could view renewable energy as an opportunity to create a new industry and capability with Australia. Australia's opportunity to develop large scale industrial capacity within the mature renewables such as wind are limited. Arguably Australia has already allowed some of its technological advances in the solar sector to go offshore (AUSRA, SUNTECH).

Australia is developing some of the world's leading marine energy technologies. There is a clear and real opportunity for Australia to take a preeminent position in the marine renewable energy sector and become a market leader. Indeed marine renewable energy remains one of the few renewable energy sectors where the opportunity remains. The Danish became world leaders in the wind industry by early and decisive action. Australia could make similar advances in the marine energy sector.

9.3 Strategies to Advance the Sector

If we accept the merit of advancing the Marine Renewable Energy sector, it is tempting to look only at the economic tools available to government to promote marine energy projects.

- Reduce the inherent risk and uncertainty of the underlying technology. Unquantified risk is hard to price and therefore has difficulty in attracting private sector funding
- Ensure technology developers are not diverted into large scale commercial projects before they are really ready to take on these commitments

To a lesser or greater extent, the marine renewable energy technologies are still relatively immature. Until they are mature enough to realistically execute commercial projects, project oriented economic support mechanisms will not be as effective as desired. Therefore, the author believes two distinct sets of strategies are required:

- strategies to mature the marine renewable technologies (technology strategies)
- strategies to support the contribution of marine renewable energy into the total renewable energy mix (commercial project strategies).

9.3.1 Technology Strategies

As previously stated, Australia has some of the world's leading technologies in the marine renewable energy sector and yet none are realistically at commercial stage. To be commercial, the technology must be able to quantify the uncertainties associated with projects involving the technology. This generally means, among other things:

- The technology to be deployed has a stable configuration and will not be modified to any significant amount
- There is a high level of confidence in the construction cost of the technology
- There is sufficient operating history of the technology in its stable configuration as to provide a confident prediction of reliability and operational availability
- A credible model exists that can estimate the electrical output from the technology at its stable configuration given knowledge of the wave or tidal energy characteristics
- A comprehensive operations and maintenance program has been developed and tested
- Organisation capability has been established and exercised to develop, construct, operate and maintain the technology.

The federal government has initiated a new program of support for innovation called Commercialisation Australia grant program. The program is not well suited to support the marine renewable energy sector:

- The program must service all innovators and all sectors on a competitive basis. The merit criteria clearly favour innovations with short idea to commercialisation timeframes.
- The program only supports technologies in their final steps toward commercialisation. Specifically the Commercialisation Program provides no support for the research or development needs of the marine renewable energy sector.
- The $250,000 proof of concept grant is on the light side of providing sufficient funding to construct and deploy a device in open water conditions.
- The $2million Early Stage Commercialisation requires repayment through early revenues. For most technologies this scale of funding is well below the level necessary to install the technologies in a commercial application.

On the positive side, the Commercialisation Australia recognises the value of key personnel in progressing innovation and commercialisation. The $200,000 experienced executives grant is a welcome addition to the marine renewable energy companies seeking to attract executive talent when competing with the booming resources sector.

In the opinion of the author, the lack of any direct support for the research and development needs of the emerging marine renewables technologies and the long term strategic potential of the sector warrant a dedicated Government sponsored program. The solar industry has the Solar Flagships program and the geothermal sector has had focussed support via the Geothermal Drilling Program. A dedicated Marine Energy Flagship program that can nurture the industry in a manner that is conscious of the technology maturity, its strategic potential and the unique challenges of the sector could provide the impetus for advancing this industry that it sorely needs.

Although appropriate and targeted funding would be an element of a Marine Flagships Program, the program could be broader based and incorporate such measures as:

- Education and Information
- Concentration of available resources on the core technology
- Industry partnerships

Education and Information

Broadly speaking the level of understanding of renewable energy among government, the public and the investment community is quite low. Few appreciate the challenges or the opportunity presented. Of the various renewable energy technologies, the marine sector is one of the least well understood. Increasing the level of understanding leads to informed and involved participants willing to contribute the success of the sector or at least not unwittingly putting barriers in place to stymie the sector.

Contributing elements of this strategy could include:

- The publication of marine energy policies by federal and state governments to provide clear guidance to the marine energy sector and proposed investor participants. In this regard the recently published Victorian Government[v] discussion paper is a welcome step forward
- The acknowledgement of marine energy as a potentially large contributor to Australia future renewable energy supply in all relevant government publications and policies
- Regular communication and briefings by industry participants and representative bodies such as the Clean Energy Council to governments and investment groups to raise the level of awareness

By progressively increasing the general knowledge base, the potential and challenges of the industry will be better understood. Decisions can be made on objective assessments of risk rather than ignorance.

Concentration of Resources on the Core Technology

A surprisingly large proportion of the development, test and trial of a marine energy technology has little to do with the core of the technology. Marine construction, marine installation, cabling and grid connection are high cost elements using well understood techniques that don't add to the body of knowledge but do absorb considerable funds that might otherwise be deployed in the development and test of the actual technology. Could there not be a build once, use many times facility developed and in public ownership?

This was the philosophy behind the European Marine Energy Centre and the UK Wave Hub. The author is not advocating the development of similar facilities in Australia for the reason that they would require significant investment and that they drive development to be optimised for the trial site whereas marine technologies are being developed for a range of water depths, environments and incident energy levels.

However, the following activities would assist in this area:

- Public collection, ownership and publication of site re source data, sea-bed and environmental conditions at sites of interest to the marine energy industry
- Subsidies for shore crossing and grid connection infrastructure used for marine energy technology trials with the facilities reverting to public ownership on completion of use
- Government long lease of specialised installation vessels to undertake the installation of mooring foundations at a small number of site of interest. This would insulate technology developers from spot pricing while the resulting mooring foundations could be employed as and when required by technology developers on a lease basis.

Industry Partnerships

Marine renewable energy installations demand many of the skills and capabilities of heavy engineering and construction industry. Australia has a deserved reputation in heavy engineering and construction although to date has not participated actively in marine renewable sector.

The heavy engineering and construction industry is not generally noted for its innovation or appetite for risk, preferring instead well understood and relatively technically risk free projects in the resources and infrastructure sector.The one exception being the equity participation of Leighton Construction in the Victorian Wave Partners project at Portland.Leighton Construction is to be applauded for its courage and foresight in taking a leadership stake in this emerging industry.

Incentives to encourage the marriage of marine energy technology development with the skills and capabilities of heavy engineering and construction would have several benefits including:

- Influencing design for constructability and maintenances
- Shortening the learning curve of marine renewable energy participants by capitalising on existing knowledge
- Bringing engineering management rigor of the large scale construction into the generally SME marine renewable technology companies
- Providing future markets, particularly international markets, for Australian heavy industry and construction sector.

9.3.2 Project Strategies

At commerciality, each renewable energy source will have its current and projected production cost of electricity. There are likely to be those with a relatively low cost but limited scope for improvement; those with higher costs but a better prospect for future cost reductions and there will be those renewable energy sources that cannot be employed in a particular geographic area.

Achieving an ideal balance of a diverse mix of renewable energy sources is a multi-variant problem but worth solving to achieve Australia's renewable energy target. The ideal balance must be struck locally and at a network-wide level.

To achieve such a mix will inevitably mean supporting some renewable energy sources at a greater level than others. Initially, it is expected that the marine energy sector will fall into the camp of having high initial costs but with better prospects of future cost reductions. Thus one should expect the marine renewable energy sector will need support mechanisms for commercial projects until they progress down the cost curve.

It is considered that most forms of renewable energy including marine renewable energy will require some level of support in order to be sufficiently attractive to encourage investment. Governments will need to be able to adjust the support mechanisms over time to maintain the diversity of renewable energy supply and to accommodate improved cost structures in each renewable energy source. However, adjustments must be enacted in a measured manner conscious of project development timelines to avoid:

- Giving the appearance of market uncertainty as this erodes investor confidence
- Compromising projects currently under-development that suddenly become un-economic due to a change in the support arrangements.

10. Conclusion

The Marine Renewable Energy sector is in its infancy compared with many other renewables and the potential of the resource as a material contributor to Australia and the world's energy needs is significant. The United Kingdom leads the world in both the activities of its marine renewable sector and the supporting environment provided by its governments. While the Australian government may not afford the same levels of attention and support afforded to the UK industry, Australia has nevertheless created an active and innovative group of companies.

[i] Cornet, A.M (2008) "Global Wave Energy Resource Assessment", International Society of Offshore and Polar Engineers Paper 2008-579

[ii] Carbon Trust, 2006, 'Future Marine Energy: Results of the Marine Energy Challenge: Cost Competitiveness and Growth of Wave and Tidal Stream Energy'

[iii] website 'http://www.whitehouse.gov/issues/energy-and-environment' retrieved 18 March 2010.

[iv] Carbon Trust and DTI, Renewables Network Impacts Study, 2004

[v] Victorian Government Department of Sustainability and Environment discussion paper "Marine Energy in Victoria", March 2010 available from http://www.dse.vic.gov.au/dse/marineenergy

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