Ocean Energy Policy Brief

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Summary:

South Africa has an exploitable wave energy resource that compares well with other sites in the world as well as the potential to extract energy from the Agulhas Ocean Current. At this time there are no wave energy converting technology available that can compete on a commercial basis with electricity generated from conventional or most other renewable energy resources. A number of wave energy converting devices are being developed worldwide that may eventually be appropriate for deployment in South Africa, for instance the Pelamis and PowerBuoy devices. It is more difficult to extract energy from the ocean current and the development of suitable technology for this application will take even longer. The cost of electricity generated using wave power could be as high as R 5/kWh which, even compared to electricity from solar and wind energy, is too expensive considering the South African context where electricity from renewable resources is available in a range of 90c/kWh (wind) to R 2,50/kWh (solar thermal).

At this time it is suggested that South Africa focuses on studying the available ocean energy resources to identify suitable deployment sites as well as investigate the potential impact of the devices used to extract ocean energy. The development of both wave and ocean current technology in the rest of the world should continuously be monitored to identify systems suitable for South Africa's conditions. Investing in locally developed technology should be carefully considered and only after a proper evaluation of the technology has been made.

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1. Introduction to Ocean Energy

The energy available in the ocean that can be harnessed to generate electricity mainly consists out of:

- Wave energy, i.e. the energy in the waves that travel along the surface of the ocean;
- Tidal currents, the currents in estuaries and around prominent land masses caused by the changing tides;
- Ocean currents, the more consistent, major currents in the ocean;
- OTEC (Ocean Thermal Energy Conversion) where the temperature difference of the water at different depths in the ocean are used to drive a thermal process; and
- Salinity gradients where osmotic pressure between very salty and fresh water is used to drive a turbine.

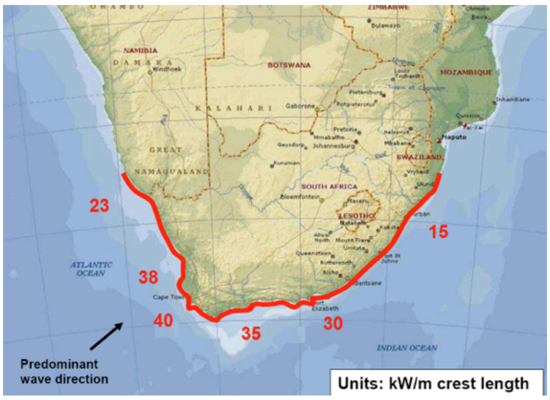
Ocean energy is widely distributed over the world with different resources being more available than others in any given location. In South Africa the main ocean energy resources available are wave energy along the west and south coasts and the Agulhas Ocean Current along the southeast coast. With a relative small tidal range and not many accessible, non-sensitive estuaries South Africa have virtually no exploitable tidal currents. Suitable salinity gradients and OTEC sites have also not been identified in SA to date.

In the rest of the world ocean energy has been an area of research and development for many decades. Over the last few years the United Kingdom, and in particular Scotland, took a firm lead in the development of the technology and projects to extract, in particular, tidal current and wave energy. Other European countries that have been active include Portugal, France, Denmark and Sweden with the last permanently deployed wave energy device the Mutriku OWC in Spain. In the USA Oregon State University and the Florida Atlantic University took the lead in wave and current technology development respectively. In the East Japan, China and more recent South Korea have also invested in r&d and demonstration plants in this area.

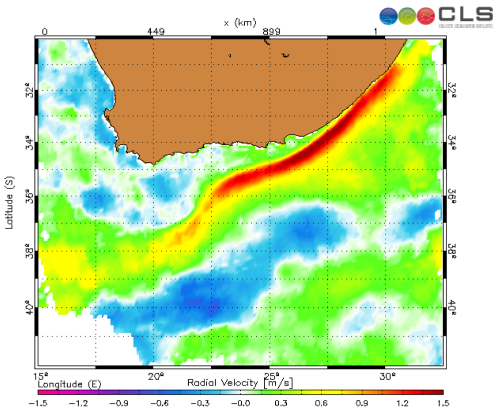
Although there are may different devices that have been proposed and tested to extract energy from the waves and currents over the years there are to date no commercial installation where ocean energy is extracted at a cost that can compete with other conventional or renewable energy resources. There is also not a clear convergence of technology with a diverse range of technology still under development.

2. Ocean Energy Resources in South Africa

The main ocean energy resources available in South Africa are wave energy along the west and south coasts and the Agulhas Ocean Current. The strength of the wave energy resource is expressed in power (kW) per meter crest length of a wave. Along the coast of SA it varies from 15 to 40 kW/m when averaged over a year.



The coastlines with the highest resource are the west and south coasts. Further north, on both coastlines, the wave energy resource rapidly reduces. The available wave energy can vary from less than 10 kW/m in the summer months to over 100 kW/m after a winter storm passed through. The averaged wave energy resource of over 30 kW/m in South Africa is sufficient to be considered an exploitable wave energy resource. The best locations to deploy wave energy devices will depend on the type of technology that will be used and the available sites for their deployment.



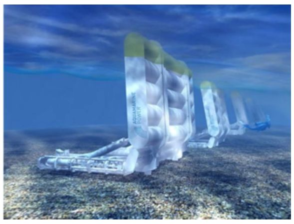
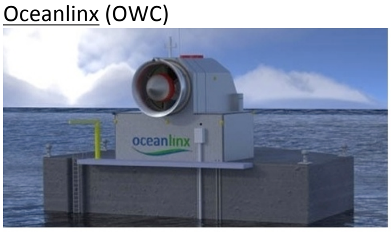
The Agulhas Ocean Current is a surface current that flows down the eastern coast of South Africa in a south-westerly direction. Close to East London the current is the fastest and closest to the land (approx. 10 km offshore) and flows with an average velocity of 1,5 m/s. There are however times when the current at a specific location will stop, or even reverse, due to the meandering nature of the current and the so-called Natal-pulses, or eddy currents, that breaks of the main current and move with the current down the coast. The best locations found to date to deploy ocean current devices will be close to the surface at locations typically 10 km offshore in 100-200 metre water depth.

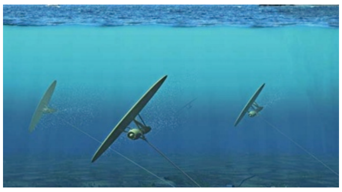
Ocean currents usually flow much slower than tidal currents. In the case of the Agulhas Ocean Current the average flow of 1.5 m/s is probably too slow to make use of the existing technology that has been developed for tidal steam applications where velocities are usually much faster than 2 m/s. However, this resource remains attractive due to the size of the current and the fact that it is fairly consistent.

3. Technology to Convert Ocean Energy

There are a large number of devices that have been proposed to convert wave energy to electricity. Only a few of these have progressed to an advance stage of development and testing. In the South African context the following devices may be the most appropriate currently available. There are however few, if any, devices presently available that can be used to extract energy from the Agulhas current. The following list of devices could be considered for deployment in South Africa and they are suggested as they all have a track record of development and deployment at sea at a reasonable scale, which is an indication of the status of development of the technology.

Technology	Description	Status & Motivation
Pelamis Wave Power (Attenuator) 	Five tubular floating structures that can articulate relative to each other as waves pass over the device. At each joint hydraulic rams absorb the energy from the waves to drive hydraulic motors and generators to generate electricity.	Pelamis Wave Power (PWP) is arguably the company that could be the closest to a commercial WEC. PWP has already manufactured and deployed 3 full-scale P1 and 2 full-scale P2 machines which are currently undergoing testing in Scotland (EMEC) rated at 750 kW each. Pelamis WECs could be deployed off the west or south coasts of SA but the dimensions will have to be adapted to suit SA's wave climate. Survivability

		during large storms still needs to be demonstrated and the overall cost of manufacturing, deployment and o&m need to be reduced before PWP will have a commercially viable solution.
Aquamarine Power (Terminator) 	The Oyster device is an articulating flap that is fixed to the seafloor. As it moves to and fro it pumps water onshore in a closed circuit to drive an impulse turbine that turns a fly-wheel connected to a generator.	Aquamarine Power (AP) has also produced two full-scale prototypes, one 315 kW and the other 800 kW, that were/are tested in Scotland (EMEC). Although the company is also developing projects that will consist of a large number of these devices in arrays they are also still proposing many changes to the next generation indicating that the technology has not matured and it will be a number of years before a commercial unit will be available.
PowerBuoy (Point Absorber) 	PowerBuoy is a spar buoy that floats on the ocean surface with a power take-off device making use of hydraulic cylinders and motors to drive an electric generator.	Ocean Power Technologies (OPT) is a private company listed on the NASDAQ in 2007 that has deployed a number of prototypes in the ocean with the US Navy as a primary client. Their Mark3 866 kW buoy has been tested in the North Sea and a larger Mark4 of 2,4 MW is under development. PowerBuoys could be deployed along the west or south coasts of SA. Tuning these devices for SA wave conditions may not require structural changes, only in the controller.
Wave Star ("Point Absorber") 	Wave Star is a platform with articulating arms connected to floats on the water surface. As the arms are forced upwards by the wave motion hydraulic rams convert the force into hydraulic pressure that drives a hydraulic motor and electric generator.	Wave Star AP has deployed a ½ scale prototype that can generate up to 110 kW in September 2009 and connected it to the grid in February 2010. The device has been now in operation for 3(?) years. Wave Star commercial unit will have 20 floats and produce up to 6 MW but such a device at full-scale still needs to be deployed and demonstrated. Wave Star AP predicts cost to be below R 1/kWh by 2019.
Wave Dragon (Overtopping Device) 	The Wave Dragon Is a floating structure that gathers waves to run up a ramp into a reservoir. From the reservoir the water runs out through low-head turbines back into the ocean to generate electricity.	The development of Wave Dragon has not progressed in recent years. The largest prototype at ¼ scale was deployed in the ocean with reasonable results. The Wave Dragon will probably be at more risk off the South African coast where it will have to endure storms with waves in excess of 20 metres. At this time it is not clear what the future of this device is.
Oceanlinx (OWC) 	Oceanlinx's greenWAVE technology is a floating oscillating water column (OWC) device driving a bi-directional turbine that turns the generator.	Oceanlinx deployed a full-scale 0,5 - 2 MW prototype in 2005 gaining valuable experience. This has led to the design of the fourth (?) generation units rated at 1 MW. Although these units could be deployed along the South African coast the survivability of these floating devices need to be demonstrated in similar wave conditions.

CETO (Point Absorber) 	The CETO device consists out of a buoy that floats just below the surface that is connected to a hydraulic cylinder that pumps water under high pressure to shore where it can be used to drive an impulse turbine and electric generator.	Carnegie Wave Energy Ltd (CWE) deployed an 80 kW CETO 3 device in 2011. A 240 kW system is currently under development for a project off Reunion Island. Although CWE claims that the submerged buoy has unique properties to ensure survival in storm conditions this still needs to be demonstrated in the ocean on full-scale prototypes.
Minesto (Ocean Current Turbine) 	The Minesto “Deep Green” technology consists out of a “kite” with a turbine that “flies” in an ocean current to generate electricity. By “flying” in the country the device creates a higher relative velocity through the turbine and hence more electricity.	Minesto has been testing a ¼ scale prototype in the Chalmers University towing tank and Strangford Loch in Ireland. Minesto plan to offer systems ranging from 120 kW up to 850 kW in due course, mainly for the tidal current market. With the advantage of increasing the relative velocity through the turbine the Minesto solution may be the only viable technology to extract energy from the Agulhas Ocean Current at this time.

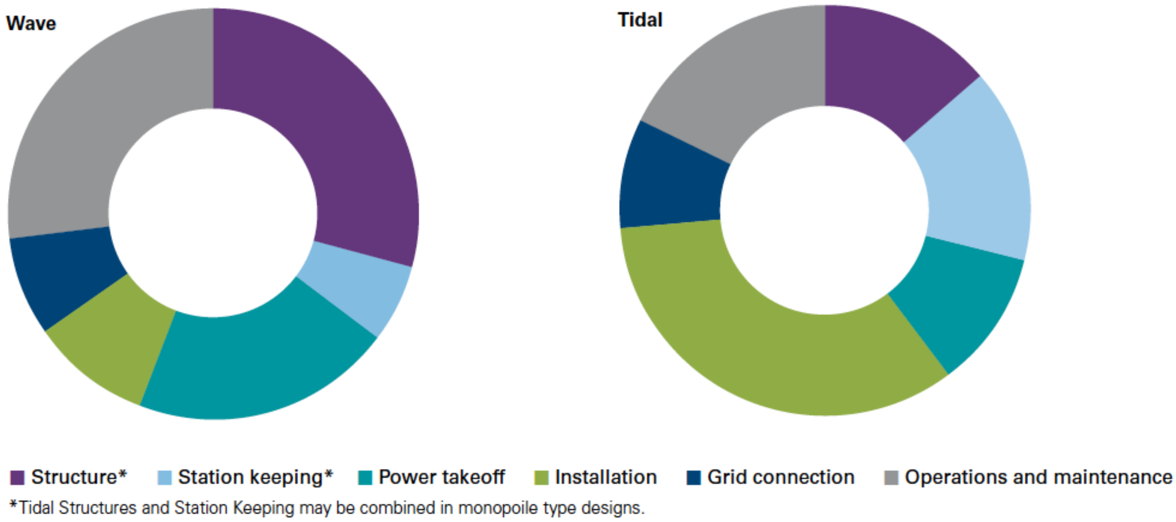
4. Cost of Ocean Energy

At this time it is very difficult to establish the cost of electricity from wave energy. There are some projects in the UK under development that will make use of subsidies available as Renewable Obligation Certificates (ROCs), which will come in with a levelised cost of electricity at close to R 4/kWh. Many technology and project developers claim that their cost will reduce in due course to about R 1,50/kWh in the UK. To reach this level they agree will take a number of years, 5 to 10, and a significant uptake, 1 GW or more, to ensure that significant economies of scale are reached. A report by the UK’s Carbon Trust estimates the LCOE range to be between R 5,70/kWh and R 7,20/kWh for the first wave farms to be deployed along the coast of the UK over the next 5 to 10 years.

The price of electricity from ocean current devices are impossible to determine accurately at this time as there are no technology available to harvest large ocean currents such as the Agulhas Ocean Current. At best one can use the cost of tidal current projects, where the technology is well developed and the deployment in many respects easier. The Carbon Trust predicts the cost of electricity from the first tidal current projects to be between R 4,35/kWh and R 4,95/kWh but it should be pointed out that these devices and the cost of deployment may differ significantly from that required in the Agulhas current.

The cost components of wave and tidal energy converters are shown in the figure of the Carbon Trust report below from which it is clear that the installation, grid connection and operation and maintenance costs comprise a significant part of the cost of ocean energy systems. The main reason for this is that the oceans are a hostile environment to install and operate these devices requiring specialised materials, construction methods and deployment vessels.

Figure 7a and 7b Indicative levelised cost of energy components for wave and tidal energy converters in an early commercial farm. The coloured segments are capital costs, while the grey segment represents O&M costs and includes all other spend including insurance and leases



5. Environmental and Social Impact of Ocean Energy

Ocean energy devices will have a positive environmental impact in the sense that they will generate clean electricity with a small carbon footprint. There are however a number of other environmental aspects that should be considered before these devices can be deployed. The devices may have an adverse effect on marine life ranging from the disturbance of the seabed during installation, noise and other flow disturbances to possible trauma to sea mammals and fish trapped or hit by moving parts. The extraction of energy from the waves and currents may also affect other natural processes such as sediment transportation. All the possible environmental impacts still need to be considered and studied as none of these projects have been implemented in South Africa.

South Africa has an existing offshore/marine engineering industry that currently serves the offshore oil and gas and diamond mining industries. Most of this industry is based in Cape Town but the potential exists to develop satellites in the Saldanha Bay and even in Port Elizabeth or East London. Most of the skills required for an ocean energy sector have already been developed in this industry. Therefore, South Africa is well positioned to do most of the manufacturing of these devices locally that will result in new job opportunities in the so-called Green Economy. The deployment, operation and maintenance activities will create additional scope for permanent job creation. The impact of these devices on other human activities, both commercial and recreational, should be small. The impact on fishing and shipping should be studied and measures put in place to limit any adverse effects.

6. Technical and Practical Potential of Ocean Energy

Not many studies have been done on the available ocean energy resource along the South African coast. One recent study on wave energy identified suitable areas for the deployment of wave energy converters but did not report on the total technical or practical resource available. In one past presentation the potential of the technical wave energy resource was estimated to be as high as 80 GW. The potential that can be exploited in the Agulhas Ocean Current is more difficult to estimate since there is currently no device available that can be deployed to extract the energy.

7. Conclusions and Recommendations

The following conclusions are clear from the information above:

- South Africa has a recognised, exploitable wave energy resource along the west and south coasts.
- The technology to exploit this resource is not commercially competitive with conventional or even other more expensive renewable energy sources at this time.
- The negative impacts of deploying wave energy devices still need to be studied in the South African context but they should be manageable.
- The Agulhas Ocean Current is an exploitable source of renewable energy, although not as attractive as it may sometimes be presented.
- Technology to extract energy from ocean currents are not currently available and a significant amount of research and development will still be required to develop a reliable, cost-effective ocean current energy system.
- South Africa does have a number of distinct advantages to pursue ocean energy systems, namely: a sufficient resource, a need for renewable energy, and a research and industrial base to support the development of an ocean energy industry.
- The primary challenges that technology providers in this sector need to overcome is to ensure that their devices will survive the storm conditions along the South African coast and to reduce the cost of their devices to compare more favourably with the other renewable energy resources available in the country.

It is recommended that at this time South Africa focus her ***research and technology development*** efforts in ocean energy on the following aspects:

- Study and document the available ocean energy resources, mainly wave and ocean current, but also salinity and temperature gradients.
- Identify a number of suitable sites to deploy ocean wave and current devices along the west and south coasts.
- Investigate the possible environmental impacts of wave and ocean current devices at the identified sites as well as the procedures to follow to obtain the necessary consent and approvals to deploy ocean energy devices in South African waters.
- Monitor the development of ocean energy technology and projects in the rest of the world and adapt it to South African conditions where necessary, i.e. different wave characteristics.
- Carefully evaluate any locally developed ocean energy technology and/or devices before investing in their further development.
- Investigate the use of ocean energy for community-based electricity supply and desalination.

JL van Niekerk, Edinburgh/Stellenbosch, April – July 2013