UNIVERSITY OF CAPE TOWN

Implementation Plan for the Stellenbosch Wave Energy Converter on the South-West Coast of South Africa

Masters Dissertation

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Abstract

Lack of experience in wave energy conversion locally leads to uncertainty in the implementation process for the Stellenbosch Wave Energy Converter (SWEC), which is the cause of many developmental hindrances in terms of determining cost estimates, the potential site specific environmental impacts and the required permits. Cost estimates based on assumptions of capacity factor, inflation extrapolated component costs, show that with significant learning rates and reduced risk the SWEC may become cost competitive with current prices of wind and solar energy. The establishment of a full array of SWEC devices carries significant threat to coastal process, marine flora and fauna, ecosystem dynamics and functioning. Mitigation is required to be incorporated into the design and layout of the plant particularly to conserve wave energy to drive coastal processes. A considerable number of permits and permissions are required for the Development of the SWEC, with the National Environmental Management Act forming the base for the majority of permitting procedures. Complexity is added through the coastal leasing policy relying on two different Acts, and policy reform is required to encourage the uptake of wave energy conversion technologies in South Africa as current energy policy acts as a barrier to adoption. Expected environmental impacts are ranked, required permits are listed resulting in the formulation of a simple implementation plan.

Keywords: wave energy converter, levelised cost of electricity, environmental impact, energy policy

Declaration

I, the undersigned, hereby declare that I know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own original work and that I have not previously in its entirety or in part submitted it at any other university for a degree.

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Abbreviations

c/kWh	-	Cents per Kilowatt Hour
CPV	-	Concentrating photovoltaic system
CRF	-	Capital Recovery Factor
CSP	-	Concentrating solar power
CSIR	-	Council for Scientific and Industrial Research
DoE	-	Department of Energy
DEA	-	Department of Environmental Affairs
DEADP	-	Department of Environmental Affairs and Development Planning
DEAFF	-	Department of Environmental Affairs, Fisheries and Forestry
DME	-	Department of Minerals and Energy
EMEC	-	European Marine Energy Centre
EEZ	-	Exclusive Economic Zone
FIT’s	-	Feed in Tariffs
GPS	-	Global Positioning System
IPP’s	-	Independent Power Producers
ICMA	-	Integrated Coastal Management Act (No. 24 of 2008)
IDC	-	Interest During Construction
IEP	-	Integrated Energy Plan
kV	-	Kilovolt
kW	-	Kilowatt (1 kW = 1000 Watts)
kWh	-	Kilowatt Hour
LCOE	-	Levelised Cost of Electricity
MW	-	Megawatt (1 MW = 1000 000 Watts)
MWh	-	Megawatt Hour
MEC	-	Member of the Executive Council
NERSA	-	National Energy Regulatory Authority of South Africa
O&M	-	Operations and Maintenance
OCW	-	Oscillating Water Column
POU	-	Publicly Owned Utility
PPA’s	-	power purchase agreements
REPS	-	Renewable Electricity Portfolio Standards
REBID	-	Renewable Energy Bids
REFIT	-	Renewable Energy Feed-in Tariff
REPA	-	Renewable Energy Power Purchase Agency
R&D	-	Research and Development
SSA	-	Sea Shore Act (No.21 of 1935)
s	-	Second
SA	-	South Africa
SANBI	-	South African National Biodiversity Institute
SWEC	-	Stellenbosch Wave Energy Converter
TW	-	Terawatt (1 TW = 1000 000 000 Watts)
TWh	-	Terawatt Hour
IRP	-	The Integrated resource plan for South Africa for the period 2010 to 2030
UCT	-	University of Cape Town
WEC	-	Wave Energy Converter

Definitions

Overnight Capital Cost	-	The total initial expenditure excluding extra expenses during construction (component, land, development, permitting, grid connection and environmental control costs).
Discount Rate (r)	-	The interest rate by which the present value of money is discounted
Interest During Construction (IDC)	-	The interest on the investment cost
Fixed O&M	-	Costs which occur regardless of how much the plant operates (Labour, equipment, overhead and regulatory permits).
Name Plate Capacity	-	The maximum output a generation system can produce (Given in MW)
Variable O&M	-	Costs which are a function of the number of hours a plant operates (yearly maintenance and overhauls, repairs for forced outages, consumables, water supply, annual environmental costs).
Tax	-	Taxes such as Ad Valorem tax (annual property tax), corporate and federal taxes. (Publicly owned utilities [POU] are usually exempt from such taxes).
Capital Recovery Factor	-	CRF converts a present value into a stream of equal annual payments to be received over “n” years at a specified discount rate.
Capacity Factor	-	Is expressed as a percentage and a measure of the amount of time a power plant operates. (Energy generated in a year divided by the amount of energy it would have generated at full capacity for the whole year).
Fuel Cost	-	Cost of fuel. In thermal power plants it is a factor of fuel usage, heat rate. The fuel cost (Is zero for renewables)
Efficiency/ Heat Rate	-	Is expressed as a percentage and represents the amount of energy from the feedstock fuel or energy source is converted into electricity
Diadromous	-	Migratory fish species, which migrate for feeding or breeding.
Anadromous	-	A type of diadromous fishes which spend most of their lives in the sea and migrate to fresh water to breed
Pelagic	-	Open water habitat/ecosystem based on phytoplankton located over the continental shelf. (Epipelagic zone – the sunlight zone)

Trophic level	-	The level at which a species feeds in the food chain.
Taxa	-	Scientific classification for a group of one or more organisms
Elasmobranch	-	Sub set of fishes where in sharks, rays and skates are all grouped
Ampullae of Lorenzini	-	Jelly-filled pores or electroreceptors used for detecting the weak electrical field generated by the contracting muscles of prey
Magnetoreception	-	A receptor or form of sense which allows an animal to detect a magnetic field to perceive direction or location
Invertebrates	-	Animal species which do not develop vertebra such as crustaceans and molluscs like crabs, crayfish and muscles
Molluscs	-	Are a group of invertebrate species which includes squid, octopuses, cuttlefish, nudibranchs, snails, slugs, limpets, sea hares, mussels, clams, oysters, scallops, as well as many less well-known animals.
Arthropods	-	Arthropod is an invertebrate animal having an exoskeleton, a segmented body, and jointed appendages.
Decapods crustaceans	-	Are an order of crustaceans, including many familiar groups, such as crayfish, crabs, lobsters, prawns and shrimp.
Benthic Organisms	-	A community of organisms living on, in or near the seabed or benthic zone. Comprising of both Phytobenthos (plants, algae) and Zoobenthos (animals)
Propagules	-	The material used for propagation by dispersal such as in benthic organisms.
High Water Mark	-	means the highest line reached by coastal waters during spring tides (excluding flooding)
Low Water Mark	-	means the lowest line to which coastal waters recede during spring tides
Minister	-	“Minister” in Environmental Policy refers to the Minister of the Department of Environmental Affairs (Currently the Department of Environmental Affairs and Development Planning)
Sinusoidal Wave	-	Describes a wave shape which varies according to a sine curve or an alternating motion
Cable Plough	-	A marine vessel which has a rig designed to dig trenches for the purpose of laying submarine cables.
Photic	-	A zone in the marine environment in which sunlight is able to

penetrate. There are different depths to which the sunlight penetrates and they are the shallow photic (<10m), deep photic (10m – 30m) and sub photic (>30m).

Abiotic - Chemical and physical factors in the environment which impact on ecosystem dynamics.

Nautical Mile - A unit of measurement for distance typically used in the marine environment. A nautical mile is equal to 1.852 kilometres (1nm = 1.852 km)

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Summary

Wave energy development is an emerging industry internationally offering many potential benefits if encouraged in South Africa. South Africa has a unique opportunity as the University of Stellenbosch developed the Stellenbosch Wave Energy Converter (SWEC) which is tailored to local conditions and a local site. However as an emerging technology wave energy development carries many risks both locally and internationally. Limited experience in the implementation of devices such as the SWEC introduces further uncertainty around any potential development. Thus it is imperative that experience from local experts and the few international examples are drawn upon to obtain an idea of what the implication could be for the deployment of a device in a predetermined site in South Africa. Key areas of uncertainty lie within estimating the cost of implementing the SWEC, determining the potential environmental impacts of the SWEC device as well as the permitting requirements for such a wave energy converter.

Immaturity of wave energy conversion technologies leads to large costs involved when deploying a wave energy converter. The SWEC device would have to carry such research and development costs as well as high rates of interest on the borrowed capital due to the lack of experience in deploying such a device. Lack of experience raises the costs of an already capital intensive technology. The other significant cost center is the operation and maintenance costs which tend to be greater due to a combination of uncertainty around methods, costly maintenance vessels and operating in a high energy marine environment. The major cost centers experienced by the SWEC are typical of immature wave energy converter technologies such as the Pelamis or the Oceanlinx MK1. Previous cost estimates exist for the SWEC device but they had previously only been modelled up until 2003. The cost estimates were extended until the current period based on annual inflation increases. Although a high-level cost estimate is utilised, it allows for a high-level comparison of the SWEC wave energy converter to traditional coal and other renewable technologies currently being implemented. The comparison displays the required reduction in cost of capital and potential cost reductions through high rates of learning that could make the SWEC device cost competitive with solar photovoltaic and wind technologies into the future. An in-depth component specific study would be the only method to accurately generate a cost estimate for the SWEC device. The levelised cost of electricity produced by the SWEC device is not economically viable in the current period but competitiveness will improve with experience and learning.

Whether a single unit SWEC of a 154 unit array is deployed on the south west coast of South Africa, a number of environmental impacts are expected. The severity of the impacts vary largely with the impacts of an array including local and ecosystem level impacts with a number of cumulative impacts experienced at all orders of the food chain. Deployment of the terminator type devices have two key direct effects; introducing a hardened surface into a typically sandy environment and reducing the wave energy behind the device. The physical presence of the device creates an obstruction to deep berthing marine vessels, diving and

hunting marine animals and larger migratory marine mammals. The deployment of a full array of SWEC devices would significantly reduce wave energy having a number of knock on impacts on coastal process leading to reductions in sediment transport, a dominance on less energy favouring kelp species, and an alteration of dynamic high energy coastal environments. A host of potential impacts exist that cannot be determined without in-depth study and onsite monitoring. Further site specific study would be necessary at the lower trophic levels through to the apex level of marine species, with particular focus on the large mid trophic pelagic fish populations which drive the ecosystem. The deployment of a single SWEC unit will have environmental impacts but they can be mitigated to a large degree. Conversely the impacts of a 154 unit array are difficult mitigate are more severe and further reaching.

Energy policy does not encourage the uptake of fringe technologies such as wave energy converters with the promotions of renewable energy technologies limited largely to established energy technologies. Coastal and marine legislation adds a further stumbling blocks to implementation as securing an off shore site is complex with multiple policies enacted for the same process. A full environmental impact assessment will be required due to the developments footprint size and being grid connected. A number of additional permissions are required; with 12 legislated and 7 non-legislated permits, totalling a minimum of 19 identified permits before implementation can occur. This leads to a long and complex implementation process to be followed adding to cost of project development. A simple implementation plan is created to clarify the development process and attempts to reduce the barrier to permitting. However novel solutions such as the Wavehub central marine connection and policy additions to include wave energy as a possible generation option in the REIPPP process are required to reduce transmission costs and encourage uptake of wave energy technologies such as the SWEC.

1 Introduction

1.1 Problem Statement

South Africa is reliant on fossil fuels for the majority of its electricity generation, as 93% is generated from coal (Winkler and Marquad, 2009). This has resulted in South Africa being the 14th largest greenhouse gas emitter from fuel combustion in the world in 2000. The 43rd largest producers of all greenhouse gas emissions in 2000, with our emissions per capita being on average 3.5 times higher than developed countries (Winkler and Marquad, 2009; Winkler et al, 2006). As such South Africa is attempting to commit to reducing greenhouse gasses. This is done by improving energy efficiency and increasing the amount of electricity that is generated from renewable energy technologies to replace coal fired power stations and reduce the country's impact on climate change (Winkler et al, 2006). South Africa has made commitments to reduce greenhouse gas emissions with a number of international organisations such as the UNFCCC (1997), Kyoto Protocol (2002), the Johannesburg Declaration (2002) and the Copenhagen Accord (2009). The share of electricity generation from renewables is being increased with a target of 10 000 GWh by 2013 according to the Renewable Energy White paper (DoE, 2012; Winkler et al, 2006).

The generation of electricity through renewable energy is possible through a number of different technologies (wind, solar, geothermal, ocean energy). All these renewables allow the production of electricity in a sustainable manner without the emission of greenhouse gasses. Wave power is a form of ocean energy that is a non-greenhouse gas emitting technology however it is more reliable and predictable than other renewable energy resources such as wind energy (Thorpe, 1999). It is available beyond the daylight hours (which limits solar energy), with the maximum energy output received during the time of year when energy demand is highest, thus allowing it to play an important role in the pursuit of energy targets and security (Thorpe, 1999). In addition South Africa is a developing country aiming to grow its economy, and reduce poverty through entrepreneurship, job creation and industry development. Development goals such as this are not easily achieved while trying to simultaneously encourage renewable energy technologies, as the majority of them have been developed overseas. Hence many renewable technologies that have been tried and tested require materials and components which have to be imported produced and purchased internationally along with the technologies property rights (Winkler and Marquad, 2009; Winker et al, 2006).

However, there is a local option for renewable wave energy. Professors from Stellenbosch University undertook the design of South Africa's own wave energy converter during the oil crisis in the 1970's (van Niekerk, 2009). After the technology was designed and patented, the research and development (R&D) was discontinued due to the reduction in the oil price and hence rendering the project an unnecessary substitute for oil. Since there is now again a major demand for renewable energy supply and energy security, with the oil price rapidly increasing; wave energy technology has come to the surface as a possible source in the renewable energy generation mix (van Niekerk, 2009; Joubert, 2008).

Currently South Africa is attempting to introduce renewable energy technologies into the generation mix. The majority of these technologies are not of South African design and hence we have to incur the costs of importing the technology as well as many components. Ocean energy and wave energy in particular are not being utilised as one of the new renewable technologies in the generation mix despite South Africa having developed its own wave energy converter (van Niekerk, 2009). It would also be logical to implement wave power due to the large wave power resource available in South Africa (Joubert, 2008). This technology is being investigated due to its unique benefits of enabling predictable, emission free energy production beyond daylight hours, while employing entirely local labour and manufacturing in its production. It may be an important opportunity for South Africa as the local production will benefit the economy. Little is known about the implementation of this technology as there are only a handful of commercialised devices operating in the world (van Niekerk et al, 2011; Cameron, 2007). Even less practical experience exists in South Africa. Experience in the impacts, legislative and permitting requirements involved in implementing such a technology locally are scarce. Consequently there is a need for an investigation into the processes to be undertaken in order to implement this technology. The potential stumbling blocks and barriers to the processes that may hinder the development of a marine energy industry in South Africa will need to be determined. Hence a greater understanding of the permitting process would be highly beneficial. The permits required would have to include: inter alia

a) Electricity generation permits
b) Environmental permits
c) Ocean safety permits
d) Varying oceanic and land use permits

The economic costs involved in establishing such a technology locally would be the pinnacle of such an investment decision, and clarity on this subject is required. Advancing the process of developing a marine energy industry would be fast tracked by the compilation of a robust Implementation plan which assists the developing industry through the political, legal and environmental red tape.

1.2 Key Questions:

a) What commercialised wave energy technologies exist which are appropriate for South African wave energy resources?
b) What are the associated costs of these technologies?

c) Are these costs competitive with internationally available WEC's that could potentially be utilised in South Africa and other renewable technologies currently being developed in South Africa?
d) Where should wave energy technologies be located in South Africa, specifically where in the Western Cape? Why should they be located here?
e) What are the environmental receptors in the marine environment?
f) What policies and regulations impact the implementation of the SWEC?
g) Are there policies and regulations which hinder the implementation of the SWEC?
h) What can be done to improve potential implementation strategies for wave energy technology in South Africa, specifically with regard to the SWEC?

1.3 Hypothesis:

To determine if the Stellenbosch Wave Energy Converter (SWEC) is environmentally, practically and financially feasible for deployment in South Africa.

1.4 Aim:

To develop an implementation plan for the Stellenbosch Wave Energy Converter to be built on the south west coast of South Africa between Langebaan and Grotto Bay.

The implementation plan for a wave energy converter will specifically explore the possible utilisation of the South African design for a wave energy converter; the Stellenbosch Wave Energy Converter (SWEC). The implementation plan will be developed for a 40km stretch of coastline between Langebaan and Grotto Bay on the west coast of South Africa (Joubert, 2008; Retief, 2007). The SWEC was designed for this stretch of coastline and would be at its most productive in this wave climate.

a) Research will be carried out to determine the economic competitiveness of locally designed and produced Stellenbosch Wave Energy Converter as opposed to foreign commercialised wave energy technologies and locally established renewable energy technologies. This will be done by investigating the comparative levelised costs of electrical production for the local (SWEC) and competing technologies.

b) Determining the potential environmental impacts of the technologies at the location where the wave energy potential has been proven to be the most significant. The environmental barriers, policy barriers, legislative and practical barriers to the implementation of these technologies will be researched, including the permitting structures and red tape which challenges implementation. This will be necessary in order to determine if a wave energy industry may be feasibly implemented in South Africa and be beneficial as part of the generation mix.

1.5 Main Aims:

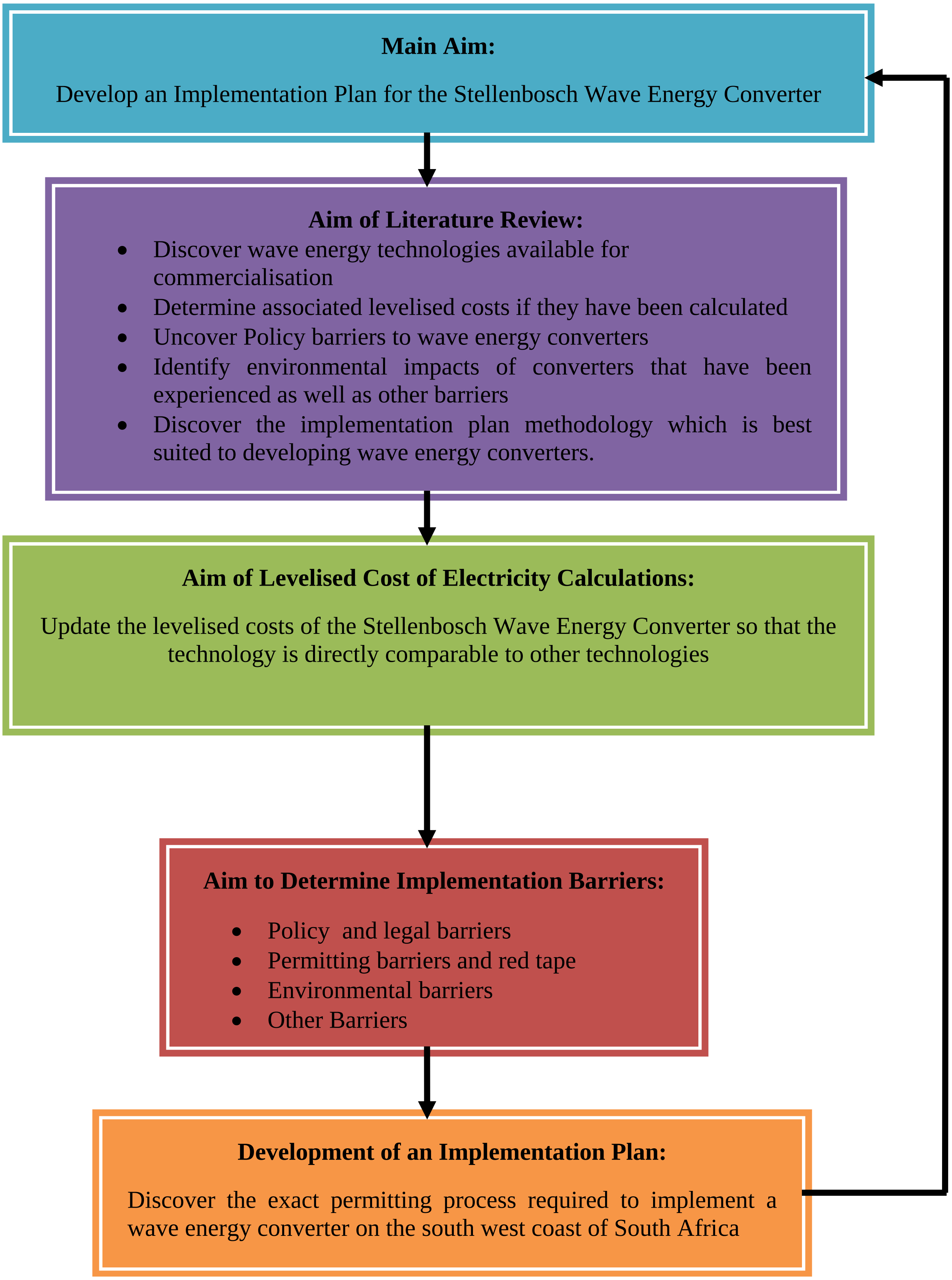


Figure 1-1: Flow Chart displaying the main thesis aims

1.6 Objectives:

a) Assess the wave energy converters appropriate for South Africa currently at the commercialization stage internationally. Determining their associated levelised costs.

b) Update the levelised cost of electricity (LCOE) [the R/kWh cost] for the Stellenbosch Wave Energy Converter (SWEC). I shall compare the Wave Energy technology costs of the SWEC to commercially available renewable energy technologies, traditional coal power and commercially tested international wave technologies such as the Oceanlinx MK1.

c) The barriers to implementation of the Stellenbosch Wave Energy Converter (SWEC) will be investigated. Such barriers will include:

   The potential environmental impacts of a single SWEC unit or an array in the proposed deployment area, focusing on potential environmental degradation.

   i. Environmental assessments which are triggered by activities involved in establishing a wave energy plant in the offshore environment.
   ii. Policy, legislative and permitting constraints preventing the implementation of a single unit SWEC or a full 154 unit SWEC array in South Africa.

d) Consequently an implementation plan will be developed for the Stellenbosch Wave Energy Converter, concentrating on the EIA regulations needing to be overcome, as well as other permitting issues, political and practical barriers to the implementation of the technology. To be considered:

   i. Relevant permissions
   ii. Permit Requirements
   iii. Any alternative notifications that would assist in developing a wave energy converter

e) In conclusion, I would like to determine the current state of affairs in South Africa; specifically the Western Cape, with regard to the potential development of the SWEC and its implications and opportunities for the wave energy industry. In order to ensure that a South African renewable energy technology does not go unutilised but is utilised in a practical and transparent manner.

1.7 Methodology

Literature Review

a) Comprehensive literature review of local and international wave energy technologies was undertaken to determine:
   i. The devices in the commercialization stage of development.
   ii. Which devices are available and will assist in a comparison for use in the relatively long period waves experienced in South Africa?
   iii. The cost involved with wave energy converters and the associated levelised costs for the current period.

b) Literature was used to determine the known environmental impacts, focusing on negative impacts, of WEC's based on international, practical experience. Focus is given to South African sources whether with sources being largely government commissioned studies and reports as well as device developer inputs.

c) Review South African policy and legislature, for the environment, electricity production, land use and marine and coastal management that may impede the development of a wave energy converter. Determine non legal barriers to implementation of a wave energy converter. Discover what is known about implementation and the permits required of the implementation of a wave energy converter in South Africa.

d) Literature review was used to determine a robust method for the structure of an implementation plan, referring to case studies and theoretical guidance for such implementation plans for a wave energy device. The barriers both legal, political and practical will also be investigated.

Personal Communication

a) Estimates were obtained for the levelised cost of electricity calculations. Personal correspondence via face to face meetings and email with industry experts and academics in order to obtain the required figures and expected figures required for the calculations. As well as figures from literature where available. Questionnaires and interviews where the methods used to facilitate the personal communication and are the most commonly used methods in developing an implementation plan according to Li et al, (2008). The four step Strength Weaknesses Opportunities Threats (SWOT) model was utilise for the design of questions and targeting areas of research required, as it is recognised as a robust tool in business environment (Elfring and Voelbreda, 2001).

b) Estimates acquired for cost calculations are:
   i. The capital and investment costs required
   ii. Fixed and variable operational and maintenance costs

iii. Expected life time of the plant
iv. Expected interest rates
v. Production of electricity

e) Personal interviews and electronic correspondence with industry experts with regard to policy and environmental impacts of wave energy converters.
    i. The potential environmental impacts of WEC's, and specifically the SWEC for deployment area of Langebaan to Grotto Bay in the Western Cape of South Africa. This site will be studied as it has the highest energy production potential from waves in South Africa (Joubert, 2008).
    ii. Environmental assessments which are triggered by activities involved in establishing a wave energy plant in the offshore environment. These activities will be assessed using the National Environmental Management Act (Act 107 of 1998) (NEMA) as a base and incorporating any other applicable policies.
    iii. Policy, legislative and permitting constraints preventing the implementation of Wave Energy Converters (WEC's) in South Africa. Such policy, legislation and permitting will include:

        - Electricity Regulation Act, Act No. 4,2006
        - Generation License Issued by NERSA
        - Land Use Permissions
            - Offshore - Marine and Coastal Management
            - Onshore - Below the High Water Mark - Sea-Shore Act (Act 21 of 1935) and Draft Integrated Coastal Management Bill (2006)
            - Onshore - Above the high water mark – purchase and lease agreements.

f) Personal consultation with experts will be used in combination with literature to determine the environmental impacts of WEC's as well as barriers to implementation. From this answers will be formulated for the different devices in order to build up an implementation plan.

Cost Calculation and Comparison

a) Levelised cost calculations for the Stellenbosch wave energy converter and comparative devices were established from SWEC specific research and international literature respectively. Costs of comparative devices are used as substitute data in the event of SWEC specific data not being available. Substitution is based on devices operating on the same principle and both in early stages of development. This lead to costs being used from the Oceanlinx wave energy converter which is extensively analysed from an economic standpoint by Previsic, (2004). Assumptions are detailed in Section 3.1.

b) Costs are updated using the inflation based levelised cost of electricity model constructed by Kenneth Pederson of PRDW and were based on the original costing of the device in 1984 (Pederson, 2006). The costs in the model are extrapolated to the current period using an average inflation rate for the period 2003 to 2013. Results are provided and discussed in Section 3.2. Method details are as follows.

Cost estimates for the SWEC device originally prepared by Pederson, (2006) based on the original unit requirements published by Retief, (1984) were updated and formed the basis for the cost estimations of this study. A simple LCOE model was then designed utilizing the standard LCOE formula:

$$\mathbf{LCOE} = \left\{\frac{(\text{Overnight Capital Cost} * \text{CRF} + \text{Fixed O\&M})}{(8.67 * \text{Capacity Factor})}\right\} + \left(\frac{\text{Fuel}}{\text{Efficiency}} * 3.6 + \text{Variable O\&M}\right)$$

Equation 1: Equation for Levelised Cost of Electricity (Pederson, 2006)

Where:

- CRF – Capital Recovery Factor is the ratio of constant annuity to the present value of receiving that annuity for a given length of time. $CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$
- 8.67 – Time conversion
- 3.6 – is a heat rate which is multiplied to zero as renewable do not require fuel
- O&M – are the operation and maintenance costs both fixed (known) and variable (unknown) costs.

Table 1-1: List of Parameters and Assumptions (StatsSA, 2013; DOE, 2012; Sinclair, 2012; Carbon Trust, 2011; PIER, 2009; Whittaker and Folley, 2007; Dresner, 2006; Pederson, 2006; Retief et al, 1984)

Basic Wave Data and Economic Assumptions	
Mean power available	30 kW/m length of wave crest
Device data (1 Unit)	
Water Depth	~ 15-20m
Distance off shore	~ 1.5km
Design Wave Length	12s
Conversion Efficiency	75%
Mean absorbable Power	30%
Unit Max Rate Design Power	5 MW
Mean Power Generation	2.55 MW
Average Power Generation (Winter; Summer)	2.9 MW; 2.2 MW
Device Array data (154 Units)	
Devices in an Array	154

Array Max Rated Design Power	770 MW
Array Winter Peak Mean Power	450 MW
Economic Assumptions	
Economic life time of all installations	30 years
Operation and Maintenance Cost (Fixed)	2.5% (of Capital)
Operation and Maintenance Cost (Variable)	2% (of Capital)
Rate of Interest (Discount rate)()	7.5%; 15%
Inflation rate (SA Reserve Bank target 3-6%)	6.15%
All Prices include:	
– Normal contingencies (depending on component)	
– Interest on components during construction	
– Offshore installation costs (estimate)	
But exclude:	
– Subsea cabling costs	~ € 1 million/km
– Project development and basic design costs	
– Financing cost for long term projects	
– Various taxes (e.g. V.A.T.)	

c) Costs inflated to the current period are then inputted into the SNAPP model developed by the University of Cape Town. This allowed for a unit cost comparison of the SWEC wave energy converter under varying interest rates, learning rates and capacity factors against establish electricity generation technologies. The cost competitiveness of the SWEC is graphed against traditional, renewable and wave energy converter technologies in a South African context calibrated for the Integrated Resource Plan 2010 (ERC, 2013). Results are provided in Section 3.3.

Implementation Plan Development

The implementation plan will be focussed in functional implementation and focuses on areas of R&D implementation. A key facet of this strategy is to take a critical look at regulation, policy and politics as suggested by Li et al, (2008) and is undertaken in Section 2.5 and in Section 5. One of the most utilised methods for developing an implementation plan is the use of a questionnaire. More than half of the sixty peer reviewed articles studied by Li et al, (2008) use questionnaires or interviews to gain information to facilitate the implementation plan design. The selected method to design the questionnaire is the Strengths Weaknesses Opportunities Threats (SWOT) model, as recommended by Schmidt and Laycock, (2009) and

Elfring and Voelbreda, (2001). This is beneficial as it allows inclusion of the opportunities offered by the SWEC and the external threats from environmental impacts, costing realities and policy implications. As such the methods used to collect information are questionnaires and interviews detailed in Appendix H.

Due to the nature of the wave energy industry, a number of diverse factors will come into play including hard, soft and mixed factors. A number of the factors will be incorporated but no strategy can account for every factor available. The factors considered in this thesis are listed and reflect the framework detailed in Figure 1-2.

Hard Factors:

- Cost of device construction and scalability.
- Regulation surrounding renewable technologies
- Established environmental impacts
- Tight construction time lines and weather windows

Soft Factors:

- Investor confidence in a new technology
- Ecosystem dynamics altered by device implementation
- Uncertain environmental impacts
- Political buy in
- Social and economic impacts

Mixed Factors:

- Communication between governmental departments
- Understanding of realistic device impacts
- Government support

A number of factors were also excluded from the investigation and would render a complete implementation strategy incomplete. The focus is kept on permitting procedures to be able to implement a wave energy converter. Social issues and political and grassroots support for such a project is not addressed in this thesis. Additionally this thesis only addressees the pre implementation phase of the implementation plan (Noble, 1999) A full implementation plan would include a plan for the organizing-implementation, managing implementation and sustaining performance (Noble, 1999). Hence a number of factors are excluded from the implementation plan.

High-level Excluded Factors:

- Economic impacts on local communities
- Job creation and social benefits
- Stakeholder buy in
- Supply chains and suppliers

- Contractors
- Detailed designs
- Site layouts
- Project finance
- Investors
- Power purchase agreements

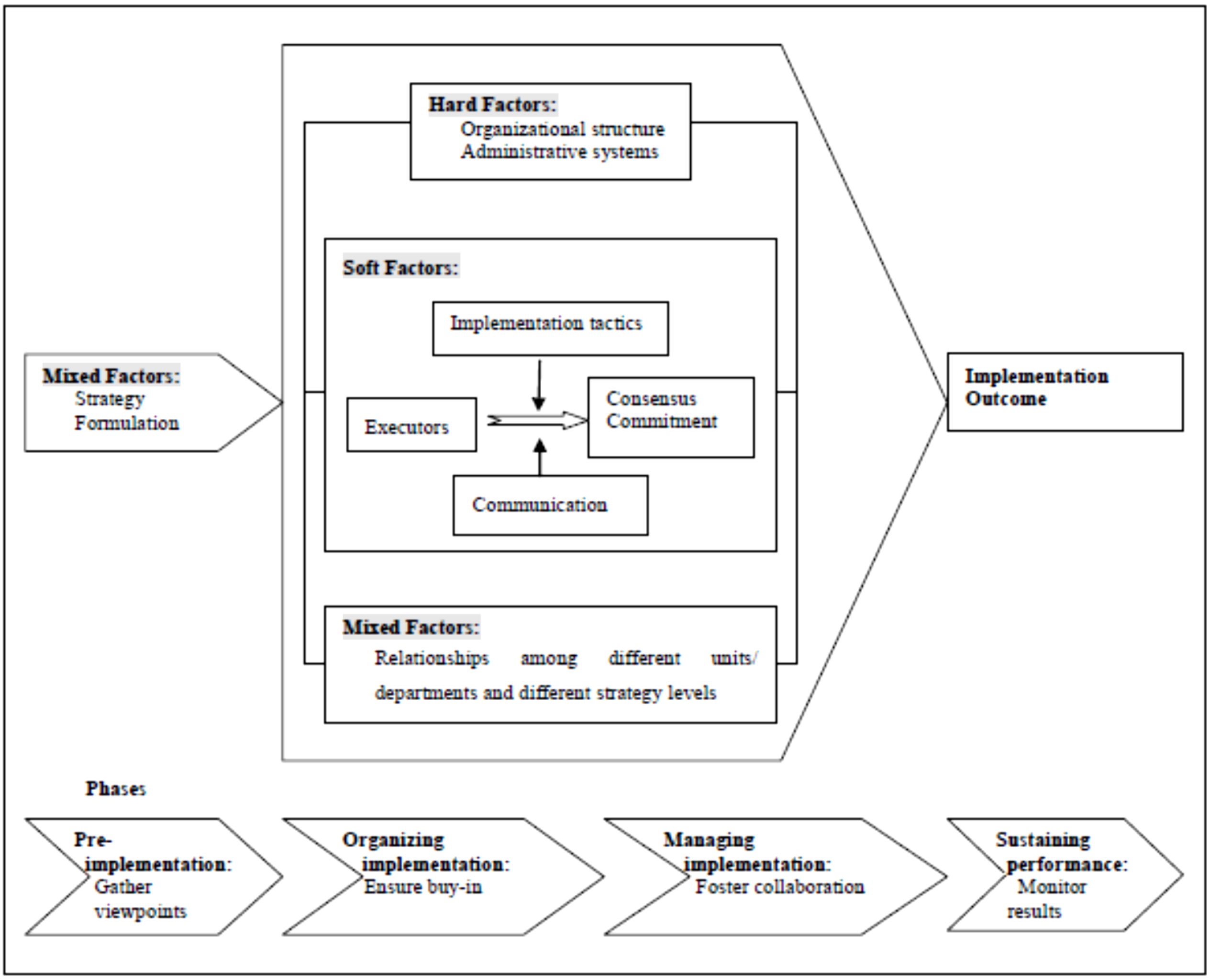


Figure 1-2: Structure and formulation of an Implementation Plan (Li et al, 2008)

Figure 1-2 details the framework followed in the design of the questionnaire and the structure of the interviews as well as research on different permit processes, costing implications and policy analysis. Ultimately the broad structure is used to compile the order of events of the implementation plan and what steps need to be followed. A number of further steps could have been included but social and socio-economic factors were purposely excluded from the analysis as they would require a further specialised study to address them competently. A further study on socio-economic impacts would be beyond the scope of this thesis.

1.8 Scope:

Policy Scope

The scope of this project is to investigate maritime policy that wave energy converters will encounter in South Africa. Hence only South African Policy will be explored and only international agreements which South Africa has entered into that have bearing on such a development will be considered. Only policy pertinent to the study site described in the geographic scope will be considered in this paper. The policy context of the selected site makes for a complex mix of overlapping policy boundaries due to the Marine Protected Area, sensitive biodiversity, productive fisheries and proximity to shipping lanes.

Scope of Devices

The study focuses on a South African device called the Stellenbosch Wave energy Converter (SWEC) as it is a local technology that has been designed to be appropriate for South African wave periods and wave heights. Therefore, theoretically there would be no need to optimise the device performance for local wave conditions (Retief et al, 1984). Whereas in the case of the Pelamis the design of the device is not suited to the longer wave periods experienced in South Africa as noted in Chapter 2.2.4. It also carries economic benefits, making use of skills which are all locally available. The study will consider a wave energy converter development of both a single unit and a full array of SWEC devices making up a power plant. International devices are considered but these are only considered as points of reference and comparison for the local device. In addition no untested international technology will be used as a comparison as grounded research will be used to draw parallels with issues faced by the SWEC device.

Scope of Costing

Costing will also be determined for the SWEC as the resources are available to make an up to date estimate that will be beneficial for the comparison of wave energy to other existing energy technologies. Estimates of international wave energy technologies costs will be used for the comparison of wave energy devices in South Africa terms.

Geographic Scope

The site is located approximately 80km's north of Cape Town, South Africa. The 40km stretch of coastline proposed for the SWEC site that lies between Langebaan and Grotto Bay is represented in Figure 1-3. The broad biogeographic region is the "cool temperate west coast" (CSIR, 2008). The site is described as part of the south west coast of South Africa. It forms part of the South-western Cape Bioregion which is endangered but well protected according to the 2004, South African National Spatial Biodiversity Assessment (CSIR, 2004). Geographic features include several exposed rocky headlands where beaches are exposed to intensive wave action (CSIR, 2008). Between the headlands, sandy pocket beaches are a common feature. Beaches vary between fine and coarser grained beaches (CSIR, 2008). The surficial sediments in the site made up of sand rather than gravel, mud or a combination (CSIR, 2008). This site will form the focal point of the research as this is one of the areas with the highest annual average wave energy in South Africa (Joubert, 2008).

The site would also be beneficial for power production as there are already 400kV transmission lines connecting this section of the coast with the grid, due to the Koeberg Nuclear Power Station Located along this stretch of coastline (Regional Action Group III, 2009). In addition the northern section of the site is a Marine Protected Area under the Marine Living Resources Act of 1998. Hence the full policy implications of a marine development are unclear for this site. Other protected areas that would be significant are Saldanha bay as a West Coast Rock Lobster Sanctuary, Melkbos to Hout Bay also as Rock Lobster sanctuary and finally Dassen Island Nature Reserve which protects marine birds and extends 500m seaward (du Plessis, 2012; CSIR, 2008).

The stretch of coastline on the south west coast of South Africa identified by Retief et al, (1982) is beneficial not only in its location for capturing wave power but also in its convenience in that it is located between two urban growth points, Langebaan and Atlantis, with Cape Town being in relative proximity to the proposed SWEC development area. In addition the site is close to a connection to the national electric power grid being within 15km between the closest point for wave generation and the connection (Retief, 1984).

1.9 The Investigation

This thesis will attempt to unbundle the implementation processes acting as barriers to the development of wave energy in South Africa. These will be studied according to environmental impacts of a SWEC unit or full array, policy and regulation implications for WEC development and financial implications of developing the SWEC. This thesis focuses on the negative environmental impacts only touching on some of the potential benefits where relevant. The barrier effect in each of these areas as well as proposed solutions will be considered in detail. As such a levelised cost of electricity estimate for the SWEC device in the specified site (Figure 1-3) will be produced and compared to the currency converted estimates for other devices produced internationally. An analysis of the expected environmental impacts will be conducted. Policies and regulations affecting WEC implementation will be unbundled. From these investigations an implementation plan will be constructed.

Figure 1-3: Location of the Site considered for deployment of the Stellenbosch Wave Energy Converter, Adapter from (Google Earth, 2012)

2 Literature Review

The study reviews the existing wave energy literature, investigating the source of wave energy and how waves are formed. The investigation considers harnessing wave energy for power production, locations in South Africa and the development of wave energy converters and prominent designs in the market. The levelised costing of electricity for wave energy converters is examined, along with the known environmental impacts of converters. The review concludes with the South African policy and legislation pertaining to wave energy converters and their implementation.

2.1 Wave Energy

The Source

The majority of energy generation is derived from the sun's energy at one stage or another. Wave energy is no different; in fact it is concentrated solar energy (Thorpe, 2010). Solar radiation warms the earth. The differential heating involved in this process causes temperature gradients thus, generating winds which blow across the surface of the earth and sea (Boud, 2003). Such winds blowing over the ocean surface transfers some energy to the water which creates water waves. These waves build and grow in size as the wind speed and the fetch (distance of sea surface over which the wind blows) increases (Boud, 2003; Thorpe, 2010). Once waves have been generated over the fetch, they persist in an irregular pattern even when the wind weakens and or changes direction. These irregular wave patterns continue to travel for great distances, in deep water, in the direction of their formation. However there is a predominant wave length and period to the wave formations. The waves are able to conserve much of their energy as they become more regular in their pattern and form smooth waves or 'swell,' travelling thousands of kilometres (Joubert, 2008; Boud, 2003). Wave energy converters; convert such swell near coastlines which are exposed to the prevailing wind. If the wind speeds are high and the fetch distance is relatively long, the coastline in question may receive high energy waves such as North and South America, Europe, Australia, New Zealand and South African, south west coasts (Thorpe, 2010; Joubert, 2008; Boud, 2003).

The Resource

Globally the total wave energy resource is estimated to be between 8 000 and 80 000 TWh/yr (1 to 10 TW) (Thorpe 2010; Boud, 2003). This could potentially meet the worlds electricity demand, which stood at 19 855 TWh in 2007 (IEA, 2009). However, only 140 – 750 TWh/yr is currently exploitable using existing technology at full maturity. The exploitable resource is significantly lower due to the appropriateness of the devices to the resource, accessibility of the resource and proximity to the grid. There is the potential for improvement to 2 000 TWh/yr if all designs can be improved to meet their expected potential (Thorpe, 1999). Figure 2-1 displays the global average annual wave energy resource. As seen in figure 2-1.

South Africa has a substantial resource in comparison to the rest of the world and this is due to the meteorological conditions experienced on the South African coastline (Joubert, 2008).

The high wave energy zone is found in the temperate regions between 30° and 60° latitude both in the Northern and Southern hemisphere. The wave conditions on the south west coast of South Africa are a function of the coastline being located within the high energy wave zone at a latitude of approximately 33° south. Wave conditions are stronger due to the many strong storms in these latitudes with wave conditions tending to increase toward the poles at higher latitudes such as at 60° south (Boud, 2003). Nevertheless high wave power is still experienced around the 30° latitude where regular trade winds are experienced as is the case on the south west coast of South Africa (33° S), seen in Figure 2-1.

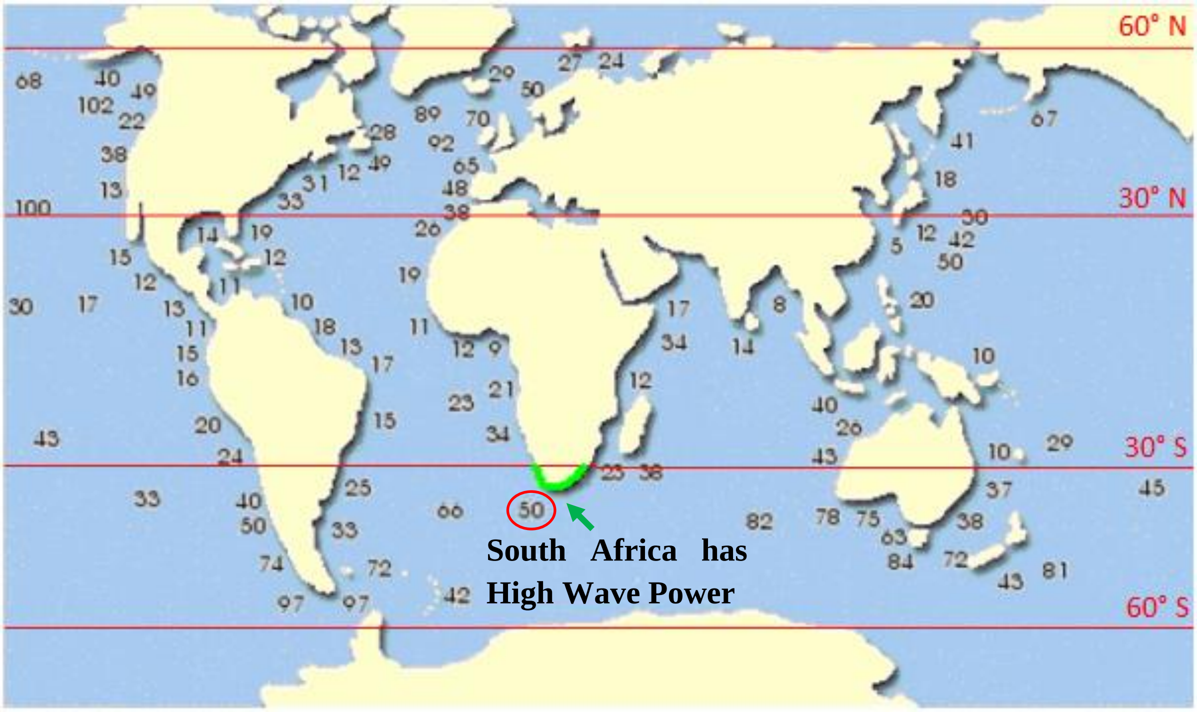


Figure 2-1: Global average annual wave power levels as kW/m of wave front (Source: Pelamis Wave Power)

Wave Energy in South Africa

The trade winds are a meteorological system that transfer energy into the ocean to form wave. The Trade winds are a function of large-scale meteorological systems such as the Hadley cell and the Ferrel Westerlies (Joubert, 2008; Rossouw, 1989). The Hadley cell forms the South Atlantic High and South Indian High pressure cells in which heated air descends southward from the tropics during the summer period (southern hemisphere) (Rossouw, 1989). The Ferrel Westerly system is a low pressure anti-cyclone where cold polar winds spiralling in an easterly direction move further north during the winter period, causing anti-cyclones to make landfall on the southern Cape and southern west Cape Coastlines of South Africa roughly every 3 to 5 days during winter (southern Hemisphere). Strong winds and gusts are the result of these strong cold fronts moving over the southern half of South Africa (Kruger, 2010). It is only occasionally that they make landfall in summer and they affect only the western, southern and southern-eastern coastal areas (Kruger, 2010; Rossouw, 1989).

Generally these systems result in more powerful waves in the winter and weaker waves in the summer months, with some variability depending on the meteorological systems at work in certain regions (Rossouw, 1989). Even if smaller waves are experienced at 33° south than 60° south, it is not necessarily a drawback as there is also less variability in wave crest height and thus less variability in wave power (Boud, 2003).

Wave length, crest height, and areas of the greatest wave energy

Wave power is drawn from progressive waves, which are waves that travel across the surface of the ocean and are categorised by wavelength, period, frequency, speed, crest height and steepness. The wave period (t) is the time between successive wave crests. Frequency (Ƞ) is the number of crest's which pass per unit time (Segar, 2006).

Equation 2: Frequency of a wave

$$\eta = 2\alpha/t$$

Wave speed (S) is equal to the wavelength (distance between subsequent crests) divided by the period (Segar, 2006).

Equation 3: Wave Speed

$$S = L/T$$

Wave height (H) is equal to twice the wave amplitude (α) (Segar, 2006).

Equation 4: Wave Height

$$H = 2\alpha$$

See Figure 2-2. These measurements can be used to calculate the wave power as described by Boud, (2003), "The power available is proportional to the square of the wave height and to the wave period."

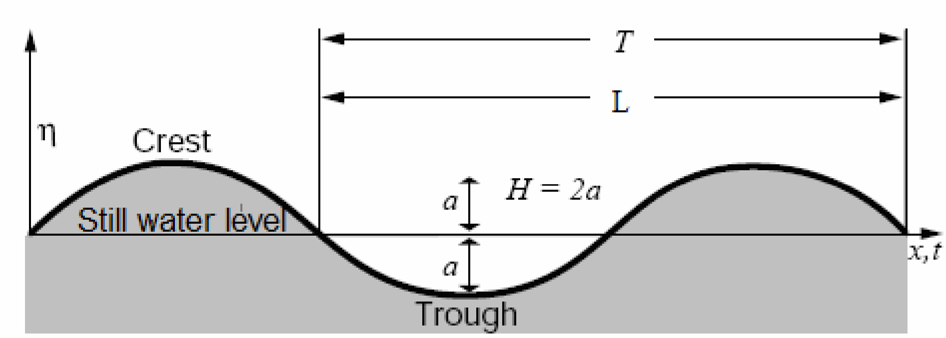


Figure 2-2: Sinusoidal Wave (Joubert, 2008)

The power contained in waves is often altered by friction as a wave approaches shore it begins to interact with the continental shelf and seabed eventually decreasing the wavelength and speed (period remaining constant) in turn decreasing wave power near shore. The decrease in power is dependent on seabed roughness and steepness (Segar, 2006; Boud, 2003). Wave height initially decreases slightly before increasing quickly as the wave travels into water that is shallower than, the wave's wavelength divide by 20 (L/20) (Segar, 2006).

Wave height is a factor of the wind speed, duration and fetch where the waves originate from, and maximum heights are reached when the fetch is long enough, but if the wind continues to blow at a certain speed wave heights do not continue to increase, resulting in “fully developed sea” (Segar, 2006). Wavelength is also a factor of fetch as longer wavelengths are formed by storms which cover larger areas, with strong wind storms that last for a relatively long period. Smaller weaker storms generally create waves that have a range of different, shorter wavelengths (Segar, 2006). The wavelength of these waves then determines the speed with which waves travel away from the storm, in the direction of the storm, with waves of longer wavelength travelling faster than waves of shorter wavelength (Segar, 2006). Thus storm waves organise themselves by wave length (wavelength dispersion) forming smooth swell, with the longest wavelengths reaching the shore first (Segar, 2006).

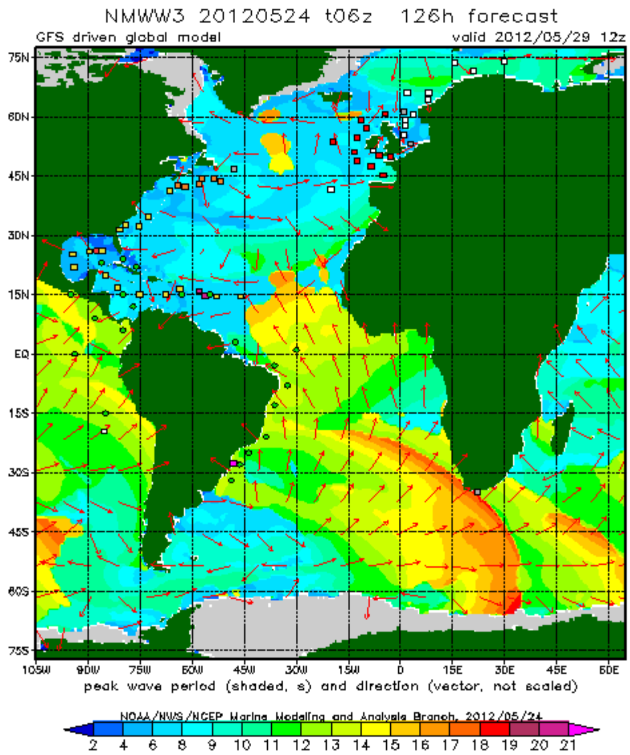


Figure 2-3: An example of Peak Wave Period and Direction of the South African Coast in Early Winter (NOAA, 2012)

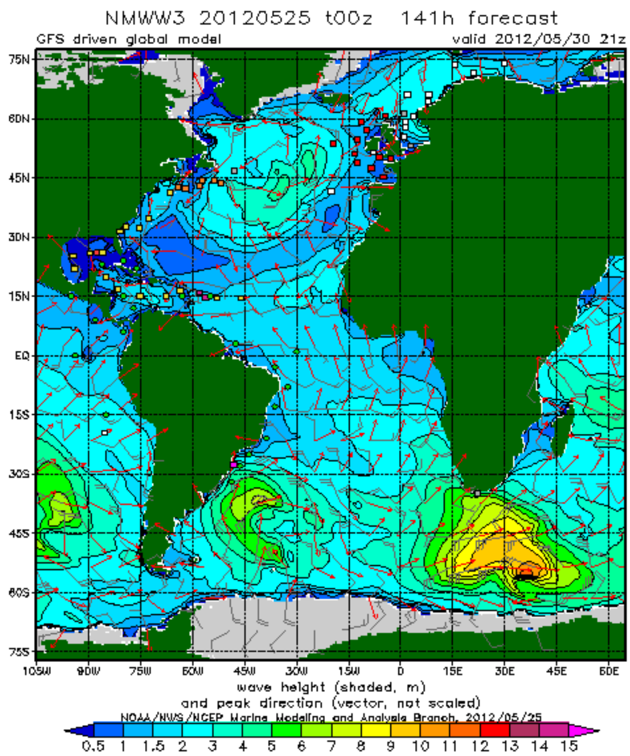


Figure 2-4: An Example of the Wave Height and Peak Direction experienced Along the Coast of South Africa in Early Winter (May-2012) (NOAA, 2012)

South Africa for instance experiences persistent wave activity as waves are generated by large strong anti-cyclone systems in the Westerly belt around Antarctica where fetch is not limited by landmasses. Longer fetches then translate into waves with longer wavelengths and longer periods particularly in the winter months (Segar, 2006). See Figure 2-3 and Figure 2-4. This is generally beneficial for electricity production from wave energy in South Africa, where; the highest electricity demand comes in the months when the most wave power is available (Boud, 2003). Boud, (2003) describes this:

> “There are great variations in power levels with the passage of each wave, from day to day and from month to month. However, the seasonal variation is generally

favourable in temperate zones, since wave energy, like wind power, is at its greatest in the winter months coinciding with the greatest energy demand." (Boud, 2003)

2.2 Harnessing Wave Energy

South Africa has the potential for harnessing wave energy along its coastline and a number of studies have been under taken to determine the areas of highest potential along the South African Coastline. Such studies include research by Van Wyk (1978), Dutkiewicz and Nurick (1978), Retief (1982), and more recently Fortuin, Moes and Rossouw (2008) and Joubert (2008). Originally the wave resources in South Africa were studied by Van Wyk (1978) and Dutkiewicz and Nurick (1978), who determined that relatively high wave energy levels were encountered on the south, west and south west coasts of South Africa. It was confirmed by Geustyn, (1983) that the Cape south west coast has the best documented wave energy resource (Van Niekerk, 2008; Retief, 1984). This is displayed in Figure 2-6. These energy levels vary seasonally and are prone to extreme weather events such as storm events on the east coast but the annual average pattern is that of the largest power levels being experienced on the south west coast of South Africa (CSIR, 2008; Joubert, 2008; Segar, 2006; Boud, 2003; Retief, 1982; Van Wyk, 1978). Thus it is logical that a site determined for power production from wave energy be located in a high wave energy area particularly since in shallower depths wave power is reduced (Segar, 2006; Boud, 2003; Retief, 1984).

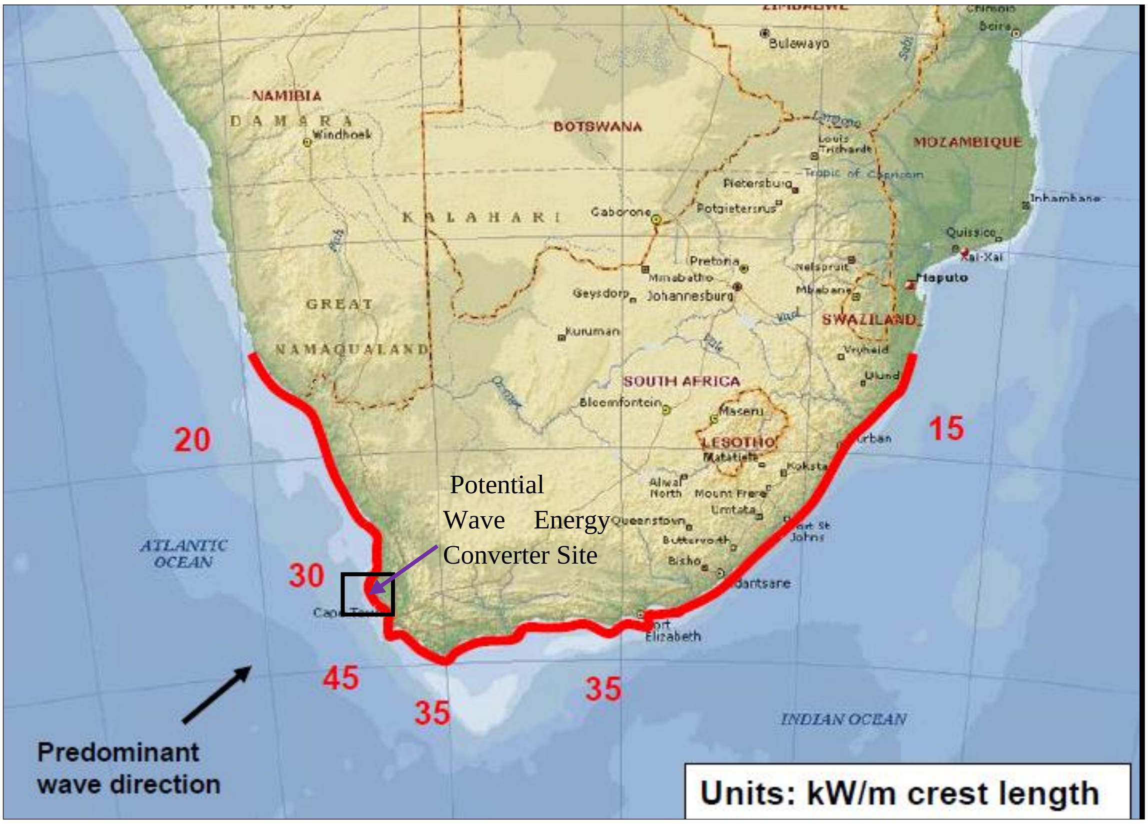


Figure 2-5: Adapted Map Displaying the Varying Off-shore Annual Average Wave Power Levels along the Southern African Coast (Retief, 2007).

Hence Retief et al, (1982) determined a 40km long stretch of coast line between Langebaan and Grotto Bay (South of Saldanha) with both north and south facing bays (see Figure 1-3), which receives almost entirely un-refracted south westerly swells, which are responsible for the peak power levels of wave energy which occur along this section of the Southern African coast (Retief et al, 1984; Geustyn, 1983). Mean annual wave power levels of roughly 30kW/m of wave crest length have been determined for these in-shore areas where the generation sites would be located during implementation (Retief et al, 1984). Higher mean annual wave power was discovered along Slangkop, a section of rocky, cliff coast line on Cape Point. However the practicality of the site would be an issue to the longer more complex transmission distances and a lack of smooth sandy seabed to deploy the devices (Joubert, 2008; Retief et al, 1984).

Although Slangkop has a higher mean annual wave power, the mean annual wave power experienced at Saldanha bay has a less variation, with relative power levels being higher in summer and lower in winter which smooth's the power peak, offering more consistent power generation over the entire year (Retief et al, 1982). The 40km stretch south of Saldanha was selected for its consistently high power levels occurring close to shore, resulting in mean annual 90% exceedance levels of 10 kW/m. These conditions tend to favour fixed, shallow water wave energy devices as they bypass complex mooring problems as well as reducing the electricity transmission distances to shore (Retief, 1982). This is beneficial as the United Kingdom tend to have to develop deep water devices as near shore wave resources in the UK are relatively poor unlike the south west coast of South Africa (Retief, 1982). High power levels for this site were reaffirmed in a study by CSIR in 2008 as seen in Figure 2-6.

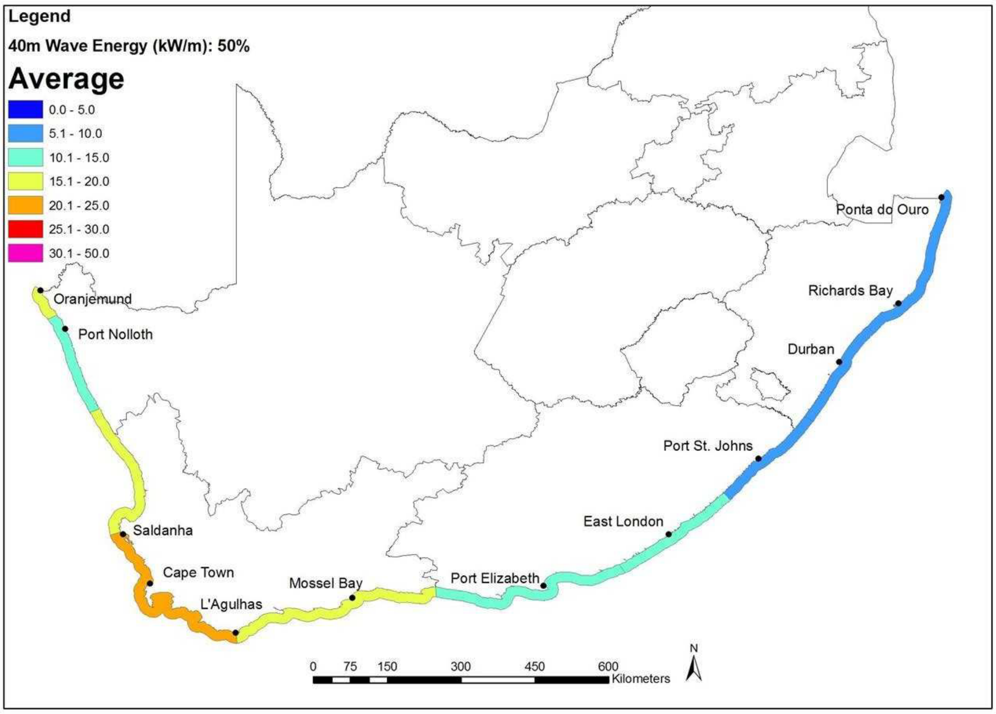


Figure 2-6: Near-Shore Annual Average Wave Power Chart at a Depth Contour of 40m and 50% Exceedance (CSIR, 2008)

2.2.1 Wave Energy Converter Technologies

There are a number of different designs and configurations for wave energy converters, ranging according to extraction method, proximity to shore, and the orientation of the device with respect to the prevailing wave direction (Joubert, 2008; Boud, 2003). The first major characterization of wave energy converters are their location in relation to the shore and seabed. They can be defined as shore-based, near-shore or off-shore and either floating or submerged as seen in Figure 2-7.

From here WEC's are categorised according to their interaction with the waves. Within this category there are three main types. A point absorber usually receives relatively little of the horizontal wave energy and is small compared to the wavelength. An attenuator device is orientated in the same direction as the prevailing waves, they are usually floating devices which are as long as the wavelength or longer (Joubert, 2008; Boud, 2003). A terminator device is orientated at right angles to the prevailing wave direction, which is similar to an attenuator device aligned in a perpendicular fashion allowing little to no energy to be transmitted through the device to shore (Joubert, 2008). WEC's are then classified by the basic design by which they convert wave energy into electricity. There is much variation in design but three main principles have been identified resulting in four dominant device designs. Categories include: oscillating water column type, oscillating wave surge converter type, reservoir storage type and relative motion type devices (Joubert, 2008).

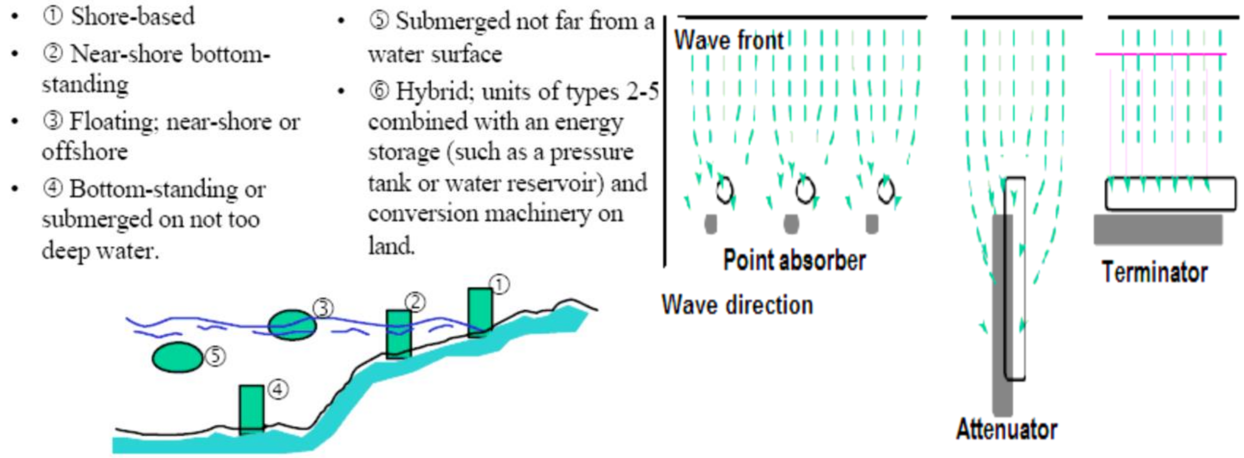


Figure 2-7: Classification of Wave Energy Converters by location and orientation in the waves (Joubert, 2008)

2.2.2 Wave Energy Converter Classification

Oscillating water column

Terminator devices (parallel to wave crest) are generally fixed near or onshore and comprise of a partially submerged, hollow structure with an opening below the water surface. This captures a column of air within the device, between the device and the column of water below. The opening receives incident waves which raise the water level, increasing the pressure in the air chamber forcing air through the turbine. Air is drawn into the device through the turbine as the water level drops during the trough period of the wave as seen in Figure 2-8 (Joubert, 2008). As the air pressure is compressed and decompressed air flows in and out of the device via the turbine, keeping it spinning regardless of directional flow (EMEC, 2012; Joubert, 2008). A bi-directional, axial-flow Wells turbine allows electricity to be generated from both the in and out flow of air from the device. The bi-directional Wells turbine is common in oscillating water column devices including in the Wavegen and Limpet developed by Queen's University in Belfast (Boud, 2003). Little of the wave energy that

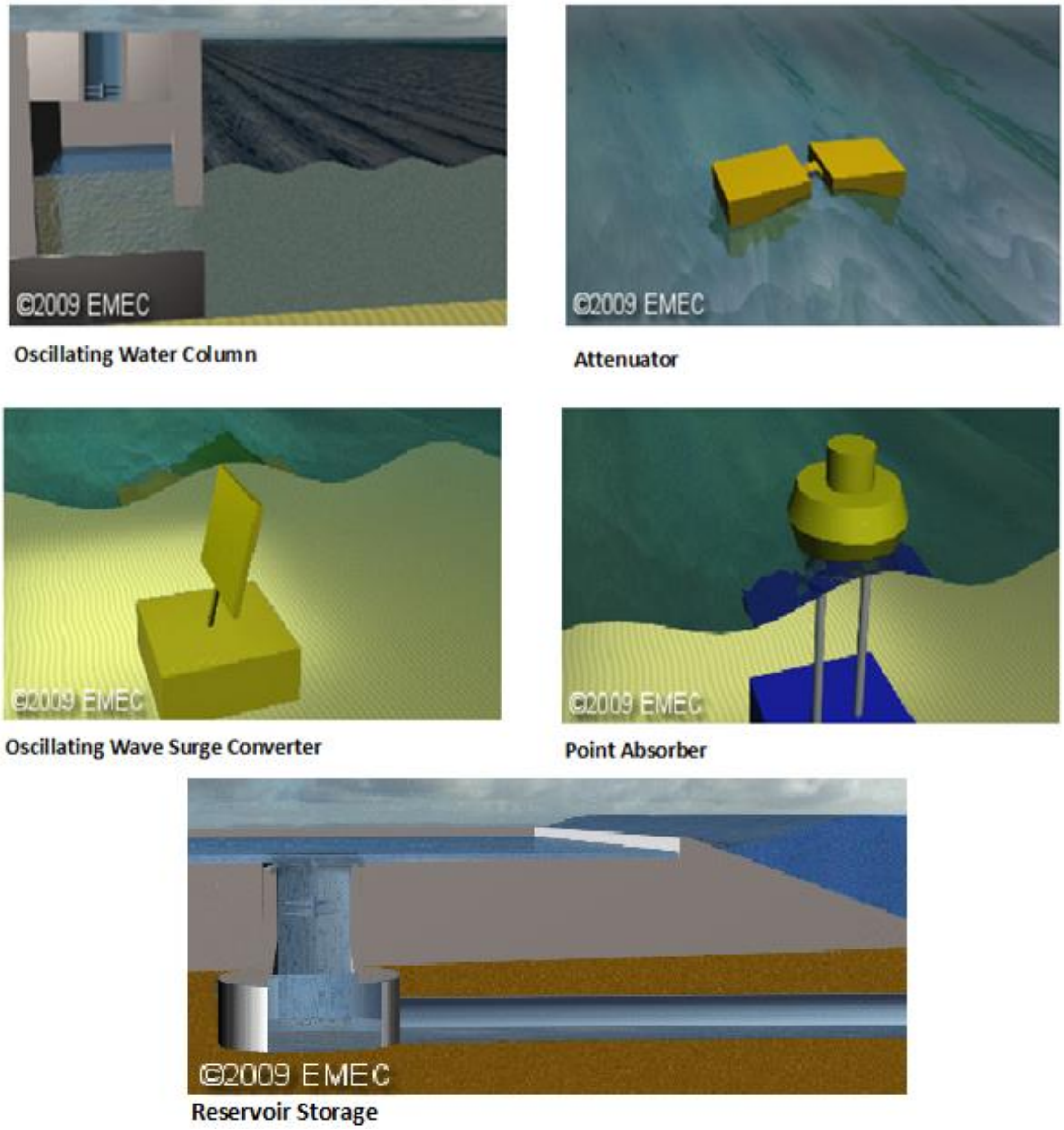


Figure 2-8: Operating Principles of Different Wave Energy Converter Designs (EMEC, 2012)

reaches the device is transmitted through the device to shore due to the terminating nature of these devices (Joubert, 2008). The Wavegen and Limpet machines are examples of commercialised oscillating water column devices however this study will focus on the Stellenbosch Wave Energy Converter (SWEC) due to it being a South African technology and the associated benefits (Joubert, 2008; CSIR, 2008).

Relative motion (Attenuators and Point Absorbers)

Relative motion type devices are generally point absorbers, linear converters or attenuators (aligned in the direction of the wave propagation), where the wave motion displaces an object (often vertically), which then shifts relative to another component of the same device (Joubert, 2008). The relative motion is used to power hydraulic pistons to pump fluid through a turbine to generate electricity, such as the Pelamis and Wave Star (Joubert, 2008; Pelamis, 2012). Both of the device designs are depicted in Figure 2-8.

Reservoir Storage

Reservoir storage type WEC's focus wave energy up a ramp, toward a raised storage reservoir. From the reservoir the water flows through low head turbines to generate electricity in a similar fashion to small scale hydro plants. Deployment can either be onshore where the system will be operated similarly to a pumped storage scheme or offshore where the focused wave energy is used to overtop the wall for the storage tank, topping up the storage. The Wave Dragon is an example of a commercialised offshore device.

Oscillating Wave Surge Converter

An oscillating wave surge converter is orientated perpendicular to the on-coming waves as it uses the direct wave action to displace a hinged deflector, which moves back and forth exploiting the horizontal particle motion of a wave. The back and forth motion drives hydraulic pistons which drive fluid through a hydraulic generator to produce power. An example of this is Aquamarine Power's, Oyster (Drew et al, 2009).

2.2.3 Wave Energy Converter Development

Hundreds of patents for wave energy converters exist and some patented ideas date back to 1799 with 340 patents between 1855 and 1973. However, progress has been relatively slow with few of these reaching operation (Espevik, 2010) There was a rapid increase in designs and development after 1973 during the oil crisis where prices were erratic, but once the oil price stabilised the development tapered off once again towards 1980 (Espevik, 2010). Only fairly recently with the concerns of climate change beginning in the 1990's and the drive for utilisation of renewable energy along with the increasing oil price, has there been a renewed interest in emerging technologies such as wave energy (Espevik, 2010; Joubert, 2008). A number of other factors have also begun playing part in the renewed interest in renewable energy and wave energy such as depleting supplies of fossil fuels, the need for energy security and diversifying of energy supplies, increased development and energy demand (Joubert, 2008). However the development of wave energy technologies tends to lag behind other more developed technologies such as wind and solar energy technologies. Until recently only a handful of patents had made it all the way to full scale testing and commercialization.

Espevik, (2010) noted that over 1000 patents existed for wave energy converters in 2010, with a number of companies beginning to progress from research and development toward commercialisation of Wave Energy Converters (WEC's) with many other systems entering the prototype stage of development. Cameron, (2007) suggests that the energy source and development in the industry is beginning to show major potential, consequently countries are perusing the development of the technology in a bid to corner the commercialization of a wave energy market. The large majority of WEC developers are located in or are testing in the United Kingdom and United States of America as such two markets are leading the race at all stages of development. The reason for this is the strong support for the industry shown by the government and a large local resource (CarbonTrust, 2011). Other factors attracting developers are the easily available site leases and completed strategic environmental assessments (CarbonTrust, 2011).

A number of devices have reached full grid connection and are ready for commercialisation. This started in 2000 when a Scottish company Wavegen produced the first commercial WEC called the Limpet. This onshore 500kW WEC produced electricity, however Wavegen has since been purchased by Voist Hydro who are developing a new converter (Cameron, 2007). The PowerBuoy designed by Ocean Power Technologies, utilises an up and down motion to drive a hydraulic cylinder located inside the buoy which pumps fluid to drive an hydraulic motor connected to a generator located on the sea bed. The PowerBouy received some of the first commercial contracts to for wave power generation systems in 2001 (Carter, 2005). These included a 1 MW power station for the Navy base in Hawaii as well as a contract for up to 10 MW of grid connected power in Australia (Carter, 2005). Currently the most popular WEC is the Pelamis, which is a 100m long, 750 kW offshore device also designed and tested in Scotland. The first commercial plant was a 2.25 MW plant deployed in Portuguese waters for the Portuguese power producer Eneris (Cameron, 2007). Pelamis Wave Power shipped the first device to Portugal in 2006 and the Pelamis P1 machines operated for 6 months before being towed to shore due to malfunctions (Cameron, 2007). In 2010 the 750 kW Pelamis P2 device was installed in European Marine Energy Centre (EMEC) in Orkney, with another P2 device planned for the same site (Carbon Trust, 2011). Aquamarine Power installed their prototype 315 kW Oyster 1 device in EMEC, with the first of three more connected 800kW devices planned for 2011 (Carbon Trust, 2011). A Danish outfit called Wave Dragon developed a grid connected, 7 MW offshore WEC for KP Renewables off Milford Haven in Wales in 2007 (CSIR, 2008; Cameron, 2007). It would be possible to extend this to a 77 MW plant (Cameron, 2007). The PowerBuoy was developed by a US firm Ocean Power Technologies. A 40 kW device has been installed in a US naval base and OPT have an agreement with Spanish power provider Iberdrola to install 1.4 MW off the coast of Spain (Cameron, 2007). A UK development Wavehub plans to provide a test site for producers to deliver electricity to offshore to be transported in bulk to shore. Both the Wave Buoy and the Pelamis are planned for the Wavehub development with Power Buoy expected to supply 5 MW and the Pelamis to supply 7 MW (Cameron, 2007) In South Africa plans were underway in 2006 to develop a 30MW wave power plant in Mossel Bay in the Western Cape but the project was eventually discontinued before a feasibility study could be completed (Cameron, 2007). Currently Abagold is undertaking a project in the development stage in Hermanus, Western Cape for 3 MW rated shore based reservoir storage type WEC. Initially there is a single retention pond with two 750 KW rated turbines planned. After five months of testing this would then be expanded and a second pond would be added to make up the 3 MW rating of the power plant with seven turbines (Clark, 2011).

2.2.4 Converters Selected for Local Comparison

A study by the University of Stellenbosch completes a review of the publicised wave energy converters throughout the world. It also determines which converters are in the latest stages of development. This study was used to select converters to be studied in this thesis that are known to be in the commercialisation stage and appropriate for implementation in South Africa (Van Niekerk et al, 2012). The Pelamis and Oceanlinx devices are commercialised examples which are useful comparisons to the SWEC due the advanced development of the Pelamis and the similarity in operating principle of the Oceanlinx.

Stellenbosch Wave Energy Converter (SWEC)

During the 1970's a Wave energy converter (WEC) was invented and developed by The University of Stellenbosch. Aptly named the Stellenbosch Wave Energy Converter or SWEC, the project never reached pilot phase. Consequently the project never reached full scale deployment due to the stabilization of the oil price which initiated the project in the beginning (Retief, 1982).

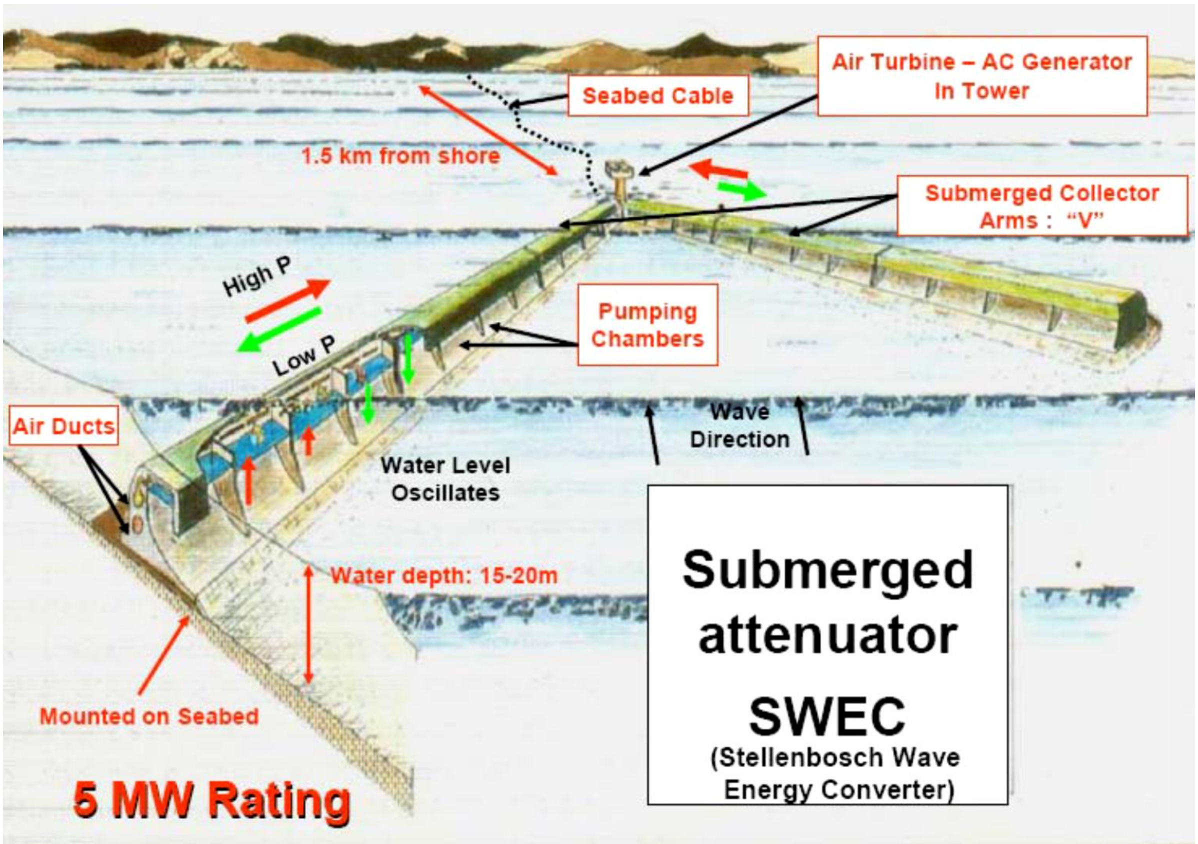


Figure 2-9: Design of the Stellenbosch Wave Energy Converter (SWEC) (Retief, 2007)

The SWEC consists of two collector arms arranged in a "V" shape with the mouth of the V orientated facing the prevailing wave direction. Then a single axial flow, variable pitch air turbine and generator are located at the apex of the V on an above surface tower (Joubert, 2008; Retief, 1984). See Figure 2-9. Air flow of up to 100 m/s will be experienced at the turbine. The collector arms are made of a number of individual units linked together in a series of OWC chambers so that the pressurised air travels along the arms and converge at the apex, then up to the power generator in the tower. The operating principle of the SWEC OWC can be seen in Figure 2-10. It is designed to be located off shore although, on shore designs do exist (Joubert, 2008). The device would be located approximately 1.5 km's off-shore with a 30° inclination toward the shore (van Niekerk, 2007). It is designed to be deployed in depths of 15 – 20 m. One collector arm is designed to contain 12 oscillating water column chambers (OWC) and be 160m long and the whole array of devices in the V formation will have an effective width of 226 m available for energy conversion (Joubert and van Niekerk, 2010). The arms would be constructed of prefabricated concrete, fixed to the ocean bed. Each V shaped array would have a 5 MW rating. The converter array was planned to incorporate 154 units located within a 40 km stretch of the south west coast of South Africa would have an overall power rating of 770 MW with the mean winter capacity being in the region of 450 MW (Joubert, 2008; Retief, 1984).

The electro-mechanical power conversion is estimated to have an efficiency of 75% (Retief et al, 1984). The variable pitch constant speed turbine of each unit will be coupled to a 5 MVA, 22 kV synchronous electric generator. Units will be interconnected in groups of six and a single collector seabed cable will be linked to shore via a 1.5 – 2 km long 22 kV, 35 MVA connecting the plant to the grid (Retief et al, 1984).

Two principles pointed out by Carter, (2005) which are being utilised by the SWEC are wave focussing and using smaller WEC's connected together to improve efficiency. The "V" shape arms of the SWEC focus waves toward the apex which concentrate the wave energy at the device and thus increase its efficiency. Secondly by using 12 units connected in unison the SWEC can be more efficient than one larger OWC device (Carter, 2005).

Costing of the SWEC (2006). For a 770 MW rated 40 km long power plant the cost per kilowatt hour at the prefeasibility stage was determined to be 60 c/kWh to 75 c/kWh. Wind energy in South Africa costs approximately 50 to 60 c/kWh with the electricity price being 25 c/kWh in 2006 (Retief, 2007).

Period comparison

The SWEC was designed for the relatively longer period of waves experienced in South Africa. Thus it reaches its full rated output (100%) at 12 second wave periods. Whereas only 75% of its rated output is achieved at wave periods of 8 seconds or 15 seconds as the efficiency declines in longer and shorter wave periods (Retief, 2007).

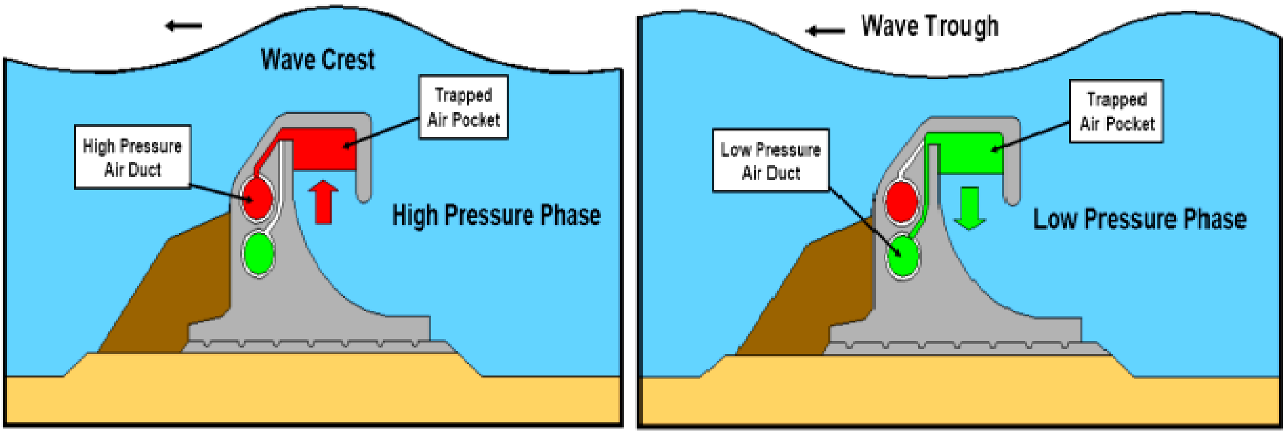


Figure 2-10: Compression and Decompression in the SWEC Oscillation Water Column Converter (Retief, 2007).

Pelamis

The Pelamis is a moored, floating device of the attenuator type. The device which consists of four tubular, hinged sections which use relative motion of wave crests rolling underneath the device to generate power through the compression and decompression of a digitally controlled hydraulic power system (Joubert, 2008). Pelamis reaches 100% capacity at wavelengths of 7.5 seconds. Longer wavelengths of 12 seconds tend to reduce power to 50% capacity at lengths of 12 seconds due to the length of the tubular sections being tuned to shorter wavelength climates (Retief, 2007). As such the Pelamis is more suited to generate electricity in European sea conditions where wave lengths are typically shorter.

The Pelamis, meaning sea snake, has a total length of 150m. The tubular sections of the device have a diameter of 4.6 meters in which the hydraulic pistons and power conversion systems are housed. At each hinge are hydraulic rams which convert relative motion into pressure. The hydraulic pressure is used to generate electricity through accumulators and two 125kW generators (Joubert, 2008). The maximum rated power translates into 750kW. Typically the device is deployed in water depths of greater than 50m as wave power is less dispersed.

Oceanlinx MK1

Oceanlinx (formerly Energetech OWC) developed an oscillating water column device called the MK1 which was deployed at full scale in 2005. The device utilises a parabolic focusing wall which focuses waves toward the oscillating water column, concentrating the wave energy (PIER, 2007). The device utilises “a two-way, variable pitch blade air turbine, which raises the average conversion efficiency from 30% to 60%.” It hosts a 100 square meter OWC chamber designed for a Dennis-Auld turbine (PIER, 2007). The device is able to be deployed in depths of up to 50m on fixed stand on legs with tensioned tethers to keep the device in place. The device rated at 1 MW – 2 MW was installed and operated between 2005 and 2009 (Oceanlinx, 2013; Previsic, 2004). See Figure 2-11.

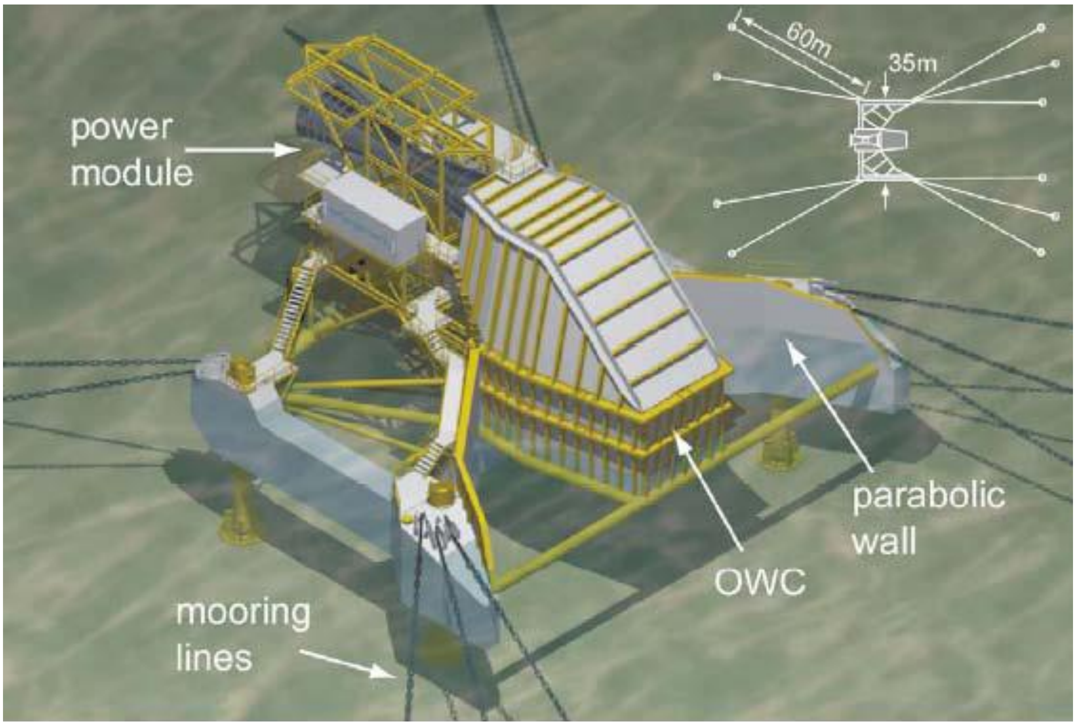


Figure 2-11: Diagram of the Oceanlinx MK1

152 units would be required to meet the 300,000 MWh/year designed installation capacity. A single Oceanlinx device is estimated to produce 1,973 MWh per year per each OWC unit. A single unit costing US$ 5.35 million to construct with a variance of between -27% and +35% (Price in 2004 US$) (Oceanlinx, 2013; Previsic, 2004).

2.3 Implementation

Implementation research covers a broad spectrum of industries and topics. People plan in everyday life, but the field of Strategic Planning emerged in the early sixties focussing largely on business strategy which is now common place in all varieties of businesses (Schmidt and Laycock, 2009). Essentially strategy planning is an organisational 'route map' to guide the organisation from the current period to a defined point (Schmidt and Laycock, 2009). Thus implementation planning covers a broad spectrum of industries and fields however "generalisations drawn from implementation research can offer guidance in formulating new implementation plans" (Kelman, 1984). According to conventional implementation research, "the program design should be simple and all the steps necessary to produce the desired result should be identified at the outset," (Kelman, 1984). Traditional implementation research advocates simple, straightforward principles to follow. In practice such simple rules can be difficult to apply when confronted with the dynamic issues that require creative problem solving. In such complexity new generalisations can be impractical.

The field has developed in the last four decades drawing heavily on the economic and social science fields, however much of the research is still fragmented by differing ideologies and diversity of fields of application and no clear methodological pathway (Elfring and Voelbreda, 2001). A comprehensive strategy may fail to succeed tor an entity based on the method of implementation or not having an adequate or clear implementation plan (Noble, 1999). Li et al, (2008) indicates that vague implementation strategies can hinder implementation plans significantly, just as a poor execution can stifle effective strategies.

Elfring and Voelbreda, (2001), discuss traditional schools of thought in contrast to the synthesizing schools which are aimed at synthesizing theory and practice. Development and importantly the classification of traditional schools was undertaken by Mintzberg, (1990) and Mintzberg et al, (1989) where nine traditional schools of thought are considered. Of the nine they are divided into descriptive (6) and prescriptive (3). The design school or the prescriptive theory resulted in the Strengths Weaknesses Opportunities Threats (SWOT) model which a very popular four step strategy is planning tool utilised by many businesses (Elfring and Voelbreda, 2001). The design school of thought and its SWOT model is described by Mintzberg as the model that underlies almost all of the prescriptive field (Mintzberg, 1990). The classified traditional theories were criticised for being fragmented and impractical concentrating on developing theoretical frameworks (Elfring and Voelbreda, 2001). This led to the synthesis of theory and practice with the focus on three schools namely; “boundary” “dynamic capability”, and “configurational” schools (Elfring and Voelbreda, 2001). The aim being to find a balance between theory and practice, and preventing the “splintering of the field into unconnected academic specialties” through over emphasis on theory.

Li et al, (2008) suggested there are five main organizational levels of implementation research in their review of 60 peer review articles across the Strategic Management Journal and 7 other management journals sourced from academic databases. The five levels are corporate level, strategic business unit (SBU) level, functional level, operational level and mixed levels (Li et al, 2008). A key finding is that “future strategy implementation research should pay attention to explicitly indicate the level of analysis” (Li et al, 2008). Within functional implementation, which is core theory for WEC devices, the majority of research is based on marketing strategies and neglects key areas that would be relevant to a WEC device, such as R&D implementation (Li et al, 2008).

In beginning to devise a plan the most common approach is to examine previous programs and their performance (Kelman, 1984). This sentiment maybe difficult to utilise as there is currently no example of an offshore wave energy device being implemented South Africa. Thus research will examine devices implemented or have had implementation plans formed abroad. Kelman, (1984) notes that compiling an implementation plan usually requires some critical judgement of policy and politics influencing the plan. Implementing a strategy or a plan is viewed as more of a “craft, rather than a science” (Li et al, 2008).

Of the 60 peer reviewed articles investigated by Li et al, (2008); the most common method used for developing implementation plans are questionnaires (23), with interviews and questionnaires accounting for more than half of the methods used. The least used methods are hypothetical scenarios, literature reviews, laboratory experiments and intervention methods (Li et al, 2008).

Schmidt and Laycock, (2009), layout the steps of formulating an implementation plan as first defining the need for a plan. This is done by questioning the core issues that the plan aims to address; assessing the timing of a plan; and determining the resources required for an implementation plan and their availability. Once the decision has been taken to implement a plan the next phase of the plan is to; identify key stakeholders that need to be part of the planning process. This includes departments, organisational representatives that can comment on behalf of the organisation, members of the public concerned and sources of information. Then work with key stakeholders to develop a formal work plan to support the planning process. Lastly, where appropriate, identify which stakeholders can address key issues involved in the plan to receive high value input and realise efficiencies (Schmidt and Laycock, 2009). The SWOT model; commonly used for the development of business strategy is the tool recommended by Schmidt and Laycock, (2009). The strengths, weaknesses, of an organisation, company or project are identified and the opportunities and threats are mapped in the market place. This aims to marry theory and internal resources and constraints with external factors in the business environment (Elfring and Voelbreda, 2001). Consequently this is the tool selected for stakeholder and permit identification and questionnaire development.

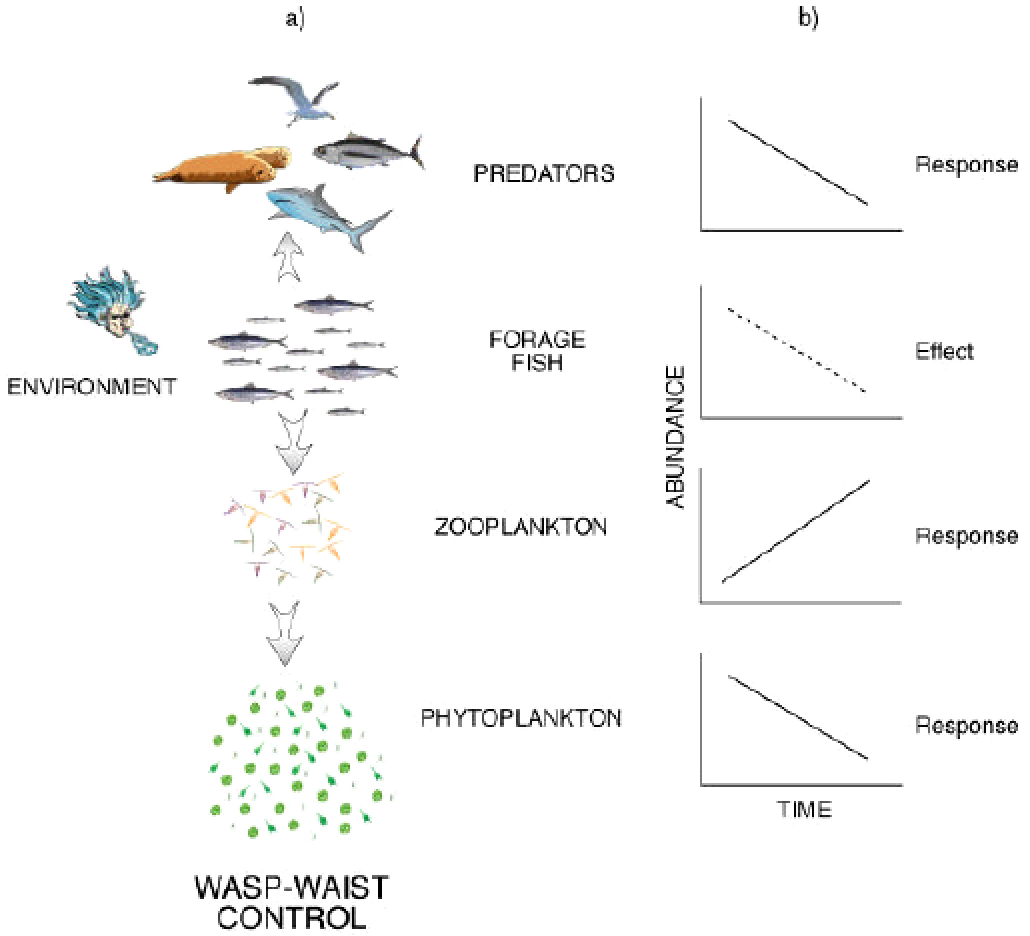
2.4 Environmental Impact of wave energy converters

South Africa is a rapidly developing nation with a unique history which has resulted in a complex energy mix. Due to national strategic targets of limiting climate change, improving energy security, and improving human development, a number of challenges have arisen. Renewable energy development is emerging as a major driver for national strategic targets such as socio-economic upliftment (Winkler and Marquad, 2009). Renewable energy is considered relatively benign when compared to traditional energy supply, however renewables are accompanied by a number of unique environmental impacts. Many of these impacts have been well documented in a short space of time. However the relative inexperience of the wave energy conversion industry, particularly in South Africa results in a gap in the literature. This chapter aims at providing an accessible investigation into the potential environmental factors and their complexities which may result in biasing environmental functioning or the secondary impacts which would be unique to the South African ecosystem. Given the specificity of impacts to individual ecosystems, it is important to understand the baseline conditions and stressors in the ecosystem present on the south west coast of South Africa.

2.4.1 Ecosystem Description

The desired site for the construction of the SWEC is the south west coast of South Africa (Retief et al, 1984). This site falls within the epipelagic zone of the Benguela Upwelling system. The wind driven Benguela Upwelling occurs near in shore on the west coast with a general equatorial flow, in the South Atlantic gyre (Lombard et al, 2004). Marine environments are usually characterised by high species diversity especially in tropical environments (Cury et al, 2001). However the Benguela being an upwelling system is a pelagic ecosystem, based on the high productivity of photosynthesizing phytophytoplankton. As such a number of characteristic traits are experienced along this section of coastline (Cury et al, 2001). Conversely to the species richness in tropical ecosystems, the upwelling system is dominated by a large number of species at the lower trophic level (feeding level of the food chain) (Cury et al, 2001). An especially productive population of phytoplankton exist due to the cool nutrient rich upwelling current resulting in dense plankton blooms. In turn the abundant phytoplankton supports a highly productive zooplankton population which provides for larger populations of foraging fish such as Anchovies and Sardines (Cury et al, 2001). Typical of the Benguela there is also an intermediate trophic level occupied by a limited number of species of plankton feeding pelagic fish, occurring in considerable abundance as seen in the Wasp-Waist Control diagram for a simplified upwelling ecosystem in Figure 2-12 (Cury et al, 2001). This large intermediate fish population is the reason for successful fisheries in the area. Species of fish include anchovies, sardines, horse mackerel and hake (Lombard et al, 2004).

The southern coast is closely linked with the western coast in that they are both “extremely important areas for pelagic fish spawning, as eggs and larvae are swept westwards and northwards onto the west coast shelf. The west coast, is utilised by young fish as a productive nursery area before returning to spawn on the Agulhas Bank” (Lombard et al, 2004). It is noted that a large amount of the control of the ecosystem lies with small pelagic fish in the Benguela upwelling (Cury et al, 2001). In other upwelling systems where over fishing has led to the collapse of the small pelagic fish species, a rapid decline of predatory fish and mammal populations was experienced which do not recover uniformly along with the recovery of pelagic species (Cury et al, 2001). However in South Africa it has been recorded that several species of seabirds were able to cope with large fluctuations in prey populations by prey switching successfully (Cury et al, 2001).



(a) Wasp-waist control within a simplified four-level food web in a marine ecosystem.

(b) The abundance of the prey fish (small pelagic fishes), which depends on the environment, controls both the abundance of the predators and of the primary production. A decrease in the prey fish abundance affects the abundance of the predators negatively. The same decrease in abundance of the prey fish reduces the predation on zooplankton, which increases in abundance. A more abundant zooplankton population increases grazing pressure and leads to a diminishing phytoplankton abundance (the control factor is solid line and the responses are dashed lines).

Figure 2-12: Wasp-Waist Control Diagram for a Simplified upwelling Ecosystem (Cury et al, 2001).

This theory may not hold true for longer term fluctuations in prey populations. Consequently in the Benguela upwelling system there is evidence of mid-trophic level, small pelagic fish exerting both top-down and bottom up control over plankton and near-apex (upper-level) predators (Cury et al, 2001). The result is that local fisheries place extreme pressure on both intermediate trophic populations and higher order predators through the decimation of prey populations. The Benguela also contains a notable number of predatory fish, seabirds and mammals at the upper and near apex, trophic level (Cury et al, 2001).

2.4.2 Impacts

All electricity generation technologies have an impact on the environment but wave power generation is often regarded as relatively environmentally benign, when compared with other generation technologies (Boud, 2003; Thorpe, 1999). This is the case especially when considering that in the operational phase, a WEC produces no atmospheric emissions, solid, or liquid waste. Thus wave energy is virtually a non-polluting source of energy (Thorpe, 1999). However, the deployment of a device can cause a varying array of both positive and negative environmental impacts. A variety of different impacts can occur during the seabed preparation, construction, operation and decommissioning of a WEC (Nelson et al, 2008; PIER, 2007; Boud, 2003). Both off-shore and shore based wave energy technologies have environmental impacts no matter how small (Boud, 2003). These impacts will vary depending on the size, design, operation and location of the WEC.

Internationally data on the specific environmental impacts of WEC's up to about 2007 is limited (PIER, 2007). However sources reporting on environmental impacts from the increasing number of demonstration WEC plants in Europe have been emerging since the industry entered the testing phase (PIER, 2007). Local experience is still insufficient, requiring an investigation on international experience. Problems may arise as the sites and designs of WEC's vary so greatly it is difficult to determine whether impacts will be similar in different localities. International experience detailed in a technical paper commissioned for the UK Department of Trade and Industry by Boud, (2003) recognises many generic impacts which arise when locating a converter in the ocean. The most common impacts of off-shore devices are on marine life via noise and interactions with fish and sea mammals. However even the generic impacts maybe site specific with substantial variety in occurrence (PIER, 2007; Boud, 2003; Thorpe, 1999).

Comparable Cases

Even though it is difficult to extrapolate specific impacts from international case studies it may be useful to consider a case which has a similar marine environment, cold upwelling and species dynamics (Blanchette et al, 2009). In fact the South African west coast and Californian coast have similar functional and trophic structures, both having high densities in herbivorous grazers, which far outnumber carnivore densities in both regions (Blanchette et al, 2009). The pelagic food webs have similar characteristics in both regions, containing high species densities at lower (planktonic) trophic levels, thus they both form highly productive fisheries. In addition they both contain a considerable number of predatory fish, seabirds and marine mammals. Finally both regions contain an "intermediate trophic level which contains small, plankton-feeding, pelagic fish dominated by one or at most a few species" (Blanchette et al, 2009). However it must be noted that there is an overall uniqueness of species community structures from region to region (Blanchette et al, 2009). Hence regions may be similar enough to consider some broad ecological impacts, but by no means should a study of a different region be used as a direct replacement for a detailed local ecological study.

Thus comprehensive studies will be examined for the broader environmental lessons they may provide. Nelson et al, (2008) completed a detailed investigation of the potential socio economic and environmental impacts involved in a WEC development off the coast of California. Although an investigation of the socio-economic impacts of WEC's is beyond the scope of this study a number of them may also be experienced off the west coast of South Africa if a WEC farm were to be developed. This paper along with PIER, (2007) delves deeper into site specific environmental impacts associated with WEC's. Nelson et al, (2008) and PIER, (2007) focus on coastal California and determine what the local environmental impacts will be of a wave farm on a stretch of coastline. Some impacts on marine life may be synonymous between California and the West coast of South Africa due to the cold, nutrient rich, upwelling currents which attracts some similar species of marine flora and fauna (Blanchette et al, 2009).

A number of impacts are investigated and these range from the near shore and shoreline environment, specifically relating to the change in wave patterns due to offshore WEC's. In turn the effects of the changing waves on wave-driven physical processes, offshore habitats and human activities (Nelson et al, 2008; PIER, 2007). The study also investigates the impacts on near shore biological communities during construction, operation and maintenance and decommissioning (Nelson et al, 2008). The impacts on marine anadromous fish habitats and marine anadromous fishes (fish which migrate from salt water to fresh water to breed). The effect of WEC's on marine birds and mammals and their interaction with WEC's (Nelson et al, 2008). A number of secondary impacts are noted on local communities and will need to be considered in a local study. The final chapter of Nelson et al, (2008) investigates the potential tools for monitoring ecological change. Some of the aforementioned studies may hold bearing in a local impact assessment, however caution must be used as some impacts that are over looked in international case studies may be more important locally.

2.4.3 Construction Phase

Nelson et al, (2008) considers the construction related impacts of WEC's. The paper states that the impacts of construction related activities such as "anchor set-down, directional drilling, and ocean floor cable burial have been evaluated and discussed by others (PIER, 2007), and their evaluations appear to agree that few and localised effects will occur" (Nelson et al, 2008). It does note that if the construction activities occur on a larger regional scale, installations may then require a more detailed investigation. Along with Boud, (2003) and Thorpe, (1999); PIER, (2007) lists noise as a major concern especially from activities such as pile driving, explosive decommissioning and engine noise from construction and maintenance vessels. Marine noise is noted to be able to kill or injure marine mammals, birds, and fish in addition to disrupting normal behavioural patterns (PIER, 2007).There is a gap in the knowledge surrounding the construction impacts of WEC's in South Africa but this will be investigated due to the importance of the local fisheries and diverse marine biodiversity (Retief, 1979). This will be considered in a local study as the construction methods and sites vary in different environments.

2.4.4 Operational Phase

The operational phase spans the life of the plant. Impacts experienced during this phase are of a direct impact of the device and cabling on its surroundings and vice versa. Impacts that may be experienced will be physical impacts on coastal processes, natural impacts on marine flora and fauna (both positive and negative), obstructive impacts for marine life and any pollutants from the device which affect the environment.

Physical Impacts

Coastal processes are reliant on wave energy to drive the processes and maintain certain habitats such as kelp forests and sediment transport cycles. WEC's may interfere with these processes by reducing wave energy. Zettler-Mann, (2010) numerically proved that WEC's reduce wave energy on the leeward side of a device. It was proved via a wave numerical model of the Wave Dragon, Pelamis and Aquabuoy (Zettler-Mann, 2010). Devices affect coastal processes by altering the wave patterns and the flow of water in the wake of the WEC's; most commonly altering the sediment transport and deposition systems (Nelson et al, 2008; PIER, 2007; Boud, 2003; Thorpe, 1999). These interactions are important to all of us because the energy of breaking waves erodes coastlines and moves sand along the coast to create and sustain beaches (Segar, 2006). Even small effects in these systems can have large ecological consequences (Segar, 2006; Boud, 2003). Noted impacts by Boud, (2003) are that devices can also act as obstacles to navigation and fishing (Boud, 2003). Shore based and near-shore devices mainly impact with visual intrusion and obstruction to coastal marine traffic, inhibiting natural corridors, and in large numbers may alter coastal dynamics (Boud, 2003, Thorpe, 1999). The Majority of these impacts can be minimised or even prevented with ample impact assessment such as a full environmental impact assessment (Boud, 2003). This will be discussed in the policy section to follow.

Natural impacts

PIER, (2007) considers many of the generic impacts mentioned by Boud and Nelson et al. Pier, (2007) goes further and describes the areas of sensitive habitat such as the hard bottom kelp forests. The effect on these forests from the reduction of wave energy may lead to the domination of kelp and algae species which thrive in marine forests of lower wave energy (PIER, 2007). It also describes sensitive species such as endangered or threatened marine mammals and species which inhabit off-shore and near shore environments. It states that they may be adversely affected by WEC development and should be protected. Interference with whale migratory routes, shading of highly productive micro-layers and upper reaches of the water column by blocking sunlight and incidental use of WEC structures as roosts or haul-out areas by bird and sea lions, are some of the potential impacts of the WEC's (Hofford, 2011; PIER, 2007). The electromagnetic field of submarine cables may also have orientation and feeding impacts on marine species (PIER, 2007).

There are a number of impacts that are not considered to be of significance by the paper from Nelson et al, (2008). The Toxicological impacts of antifouling agents used on WEC's are thought to be one of the fields adequately covered. The impacts are deemed to be appropriately researched by the authors with in the field of antifouling paints or agents and oil spills (Nelson et al, 2008). The effect of these oils or agents was reported to be of "minor importance" when compared with the toxicological effects in confined spaces such as ports and harbours (Nelson et al, 2008). This Impact will likely not be a very prevalent issue as non-toxic anti-fouling agents are available and will vary according to the WEC design. However this is a consideration that must still be made during the implementation of the device.

WEC's are assumed to have a negligible impact on plankton ecology by Nelson et al, (2008). It is not considered substantial as the plankton distribution and abundance of processes are deemed to be at such a large scale that even regional WEC developments would not have significant impacts on the plankton ecology (Nelson et al, 2008). The only notable impact is the increased surface area of settling site for the plankton which is a minimal benefit to planktivores (Nelson et al, 2008). It is not clear whether there may be a difference in the impacts between the coast of California and the West Coast of South Africa and whether the effect on plankton will also be negligible in South Africa. This will need to be investigated as there is limited literature on whether a wave energy converter would impact on plankton in Southern Africa.

Fish impingement and entrainment is expected not to be a major factor as Nelson et al, (2008) reports that it is likely that only over topping devices may impinge and entrain small fish due to the design of the device. Impacts on fish and fisheries will be highly variable and depend on the specific device being implemented. This factor in combination with the lack of deployment of any wave energy converters in South Africa means there is no source of reliable literature on fish impacts of WEC's locally.

Environmental Benefits

There may also be a number of environmental benefits associated with a WEC. Seabed mounted devices provide a hard, artificial structure which changes the dynamics of the seabed. Hard surfaces allow algae and invertebrates to attach themselves to the device (Thorpe, 1999). In addition the WEC creates sheltered areas for fish and marine life to rest and take refuge, fulfilling the same role as a marine reef. In this regard a WEC installation may benefit fish and some marine flora species. As a result the WEC may also attract some fowling organisms, thus threatening the device durability and operation (Thorpe, 1999).

Device Durability

The impacts of the device and construction should not be the only impacts considered. The impacts of the environment on the device need also be raised. Any device that is deployed in the ocean for the production of electricity enters a harsh environment of corrosive salt water, and rough swell as well as being exposed to interaction with marine life. The design of machinery operating in these conditions will be designed to resist corrosion and strong swell however biofouling is a factor that is site specific and difficult to cater for (Boud, 2003; Thorpe, 1999). Devices entering the open ocean become artificial reefs, providing a surface for a large number of marine organisms to settle (Thorpe, 1999). Such organisms can obstruct moving parts, and water flow dynamics ultimately reducing the performance of the device (Boud, 2003). There are methods for preventing fouling such as antifouling paints and sonic and ultra-sonic systems. Both methods have drawbacks, such as some of the paints are very toxic, but there remains no clear solution to prevent fouling of offshore devices (Boud, 2003; Thorpe, 1999).

Survivability of the device is also a key factor when considering the environment in which a device will operate. This is due to the wave energy experienced off the coast of South Africa being particularly high especially in winter storms (CSIR, 2008; Joubert, 2008). Leading to possible damage of any moorings, anchors and the susceptible components of a device (Retief et al, 1984). Thus in the waters of the south west coast survivability is a key aspect of any converter design (Retief et al, 1984). The importance of this factor with regard to the environment increases dramatically when devices which contain hydraulic fluids and oils are placed in such an environment. If the device has low survivability the risk of pollution from spills and the safety implications for other vessels greatly increases in high seas (Boud, 2003).

2.4.5 Decommissioning

The plan for the use of a device at the end of its usable life needs to be considered carefully. In decommissioning as with construction there will be an element of noise and marine traffic that will need to be considered in any activity (Thorpe, 1999). A floating device will likely be more safely and easily dealt with, being towed to shore and scrapped or recycled. However a seabed mounted device will be more difficult to deal with as the decision on whether to let the device erode, deconstruct it or remove it completely have considerably different cost and environmental implications. If they are turned into rubble or left they will act as artificial reefs and thus alter the seabed permanently (Thorpe, 1999). Globally this is a widely used technique to increase habitat diversity of a marine area but the effect on species diversity is by no means guaranteed. However the overall impact of artificial reefs is thought to be a positive impact, given a reef is not located in environmentally sensitive areas (Thorpe, 1999). If a reef is created there may be a number of legal criteria, and the long term impacts will need careful consideration as the structure will become a permanent feature on the seabed, as will associated effects on marine flora and fauna.

2.4.6 South Africa

There is a gap in the knowledge of environmental impacts of WEC's in South Africa (PIER, 2007). However there is some speculation from local project designers and industry experts. In Wave Power in South Africa: A Review by Retief, (1979) it is noted that there were no expected environmental impacts that could not be overcome. This report suggests that the only major environmental impacts would be those of the alteration of the wave climate and consequently what impact the alteration of wave energy has on the shoreline. This is due to the fact that during periods of high and medium wave heights the combination of high reflection and high conversion in the converters means significantly less wave energy is experienced on the shoreline (Retief, 1979). Wind can also only partly increase the wave energy between the device and the shoreline as the fetch distance is limited (Retief, 1979). However there were a number of recommended fields in which analysis of impacts was needed. These included: marine ecosystems, coastal ecology, geological and physiographic features, navigation of ships, fisheries, visual impacts and tourism, other local industries and other national agencies such as defence (Retief, 1979).

Coastal Processes

WEC's have been thought to affect coastal processes by altering the amount of energy embodied in a wavelength. The possibility of converters altering the summer and winter wave climate was suggested by Retief, (1979) with specific reference to the Stellenbosch wave energy converter. In addition the possibility of WEC's reducing the steepness of the waves if converters are located less than 30km off shore was also raised as a concern. This may cause beaches to accrete due to a reduction in the stable state beach erosion processes (Retief, 1979). Impacts may become more severe with seabed mounted devices near shore. This prompts an enquiry into the possible scenarios of WEC deployment in South Africa.

Risk of Wreckage

Surface wave energy converters will present hazards to the shipping industry. In particular devices with a low profile above the wave surface will make them difficult to see or to locate via radar in most sea states (Retief, 1979). Submerged converters with a close proximity to the surface may also present hazards to deeper floating ships. Due to the heavy oil tanker traffic around the Cape there are concerns of collision and the significant oil pollution threat this could pose (Retief, 1979 Thorpe, 1999). Thus the need arises to note the location of devices with navigation lights and radar reflectors (Retief, 1979; Thorpe, 1999). Additionally making the device location freely available via GPS co-ordinates to all vessels operating in the area would be practical. The mooring of the devices can be as much of a collision hazard as the devices themselves, as mooring systems can take up larger areas than the device. Consequently areas may need to be excluded from shipping activity altogether (Retief, 1979).

Fisheries

Retief, (1979) determines the size of South African fisheries a good reason to assess a devices impact on fishery ecology and associated marine species (Retief, 1979). It is uncertain whether an array of floating devices offshore, approximately parallel to the shoreline will alter the behaviour of fish living or migrating in that area. The ecology of such species would need to be examined individually to determine if there may be an impact (Coffey, 1992). Fish that spawn under the gravel of the seabed maybe disrupted by the moorings of the floating WEC devices or by devices fixed to the bed. Alternatively the shelter offered by devices whether floating or fixed may cause the device to act as a reef, attracting fish (Coffey, 1992).

Complexity

It is during construction and decommissioning that impacts are the most noticeable. Impacts on terrestrial environments are intensely studied, however ocean environments tend to hold more complexity while oceanic ecosystems research is more limited (Cury et al, 2001). Complexity in the ocean environment is inherent due to the array of species diversity and the large areas over which ocean currents flow (Cury et al, 2001). As such the subtle secondary impacts which occur may be overlooked or misunderstood. Due to the complexity of oceanic ecosystems it becomes important to understand what impacts they can withstand and how reversible impacts are (Cury et al, 2001). Thus key areas will require detailed specialist studies before an educated decision can be taken on WEC development.

As more experience has been gained in the WEC industry it has become clear that more potential impacts have been discovered. Although there is an existing body of knowledge on impacts of off-shore structures and activities, WEC’s do have unique impacts which will require consideration (PIER, 2007). Many generic environmental impacts can be identified from case studies internationally, where there is practical experience of implementing wave energy converters. However since there is no standardised design for wave energy converters it is difficult to accurately determine all the environmental impacts. Hence further study is required in order to determine what the environmental impacts may be with specific designs that would practically be of use in South Africa. In addition different localities provide unique habitat for a variety of different species of marine flora and fauna as well as having their own dynamic coastal processes. Hence the situational impacts for South Africa need to be investigated as there is currently no practical experience in WEC implementation locally.

2.5 Policy surrounding the implementation of a wave energy converter

Policy is largely meant to provide regulations to govern, standards to maintain a strategy of intent or instigate a shift in behaviour from the current norm (Brent, 2012). There are a number of different scales at which policy occurs. International; national; regional; provincial, and municipal policies can all affect the delivery of renewable energy technologies. However policies by themselves do not create an enabling environment for the implementation of renewable energy, but are still vital in providing direction in the development of the energy industry (Brent, 2012). The many different scales of policy are further complicated by the borders between countries and boundaries between terrestrial, maritime environments and international waters. The coastal zone in South Africa forms a complex legislative environment with overlapping policy boundaries and jurisdictions. As such clarity is required on the policies which would be applicable to the development of a wave energy converter. In conjunction with these policies the permitting requirements also need to be explored.

2.5.1 National Policy

Constitution of the Republic of South Africa

The supreme law of the country is the Constitution of the Republic of South Africa, 108 of 1996, which sets the scene for all other policy in the country. Any law or policy which is inconsistent with the Constitution is invalid (Van der Linde and Feris, 2010). Section 24 of the Constitution, is part of the "Bill of Rights and entrenches the right to an environment which is not harmful to health and well-being , and the right to have the environment protected, for the benefit of present and future generations through reasonable legislative and other measures which prevent pollution and ecological degradation; promote conservation and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development" (Brent et al, 2012, Van der Linde and Feris, 2010). Within the Constitution there are also a number of sections requiring government to provide services to communities in a sustainable way and promote a safe and healthy environment in sections 152(1) (b) and 152(1) (d) respectively (Brent et al, 2012). As such the constitution legislates the provision of services is achieved in an ecologically sustainable manner. Thus, in light of global climate change and the effect of greenhouse gas emissions, renewable energy provision falls into the South African governments' mandate. In fulfilment of this constitutional mandate to provide a healthy environment and services in a sustainable manner, government agencies have promulgated and amended a number of laws surrounding environmental protection all falling under the National Environmental Management Act and the Electricity Regulation Act (Van der Linde and Feris, 2010). The environmental right has led to the revision of environmental bodies, improved enforcement, and increases participation from private and public stakeholders (Van der Linde and Feris, 2010). All other laws in South Africa fall under the Constitution. The National Environmental Management Act and Electricity Regulation Act were promulgated in order to achieve the objectives of the constitution and meet the needs of the people without degradation of the environment for future generations.

2.5.2 Electricity Regulation

The regulation of energy and electricity through policy is the responsibility of the Department of Energy (DoE), previously known as the Department of Minerals and Energy (DME) (Newbery and Eberhard, 2008). They are responsible for creating and amending policy for the control of the energy sector.

Electricity generation, transmission and distribution are controlled by the Electricity Regulation Act, Act 4 of 2006. This piece of legislation is the overarching policy document for electricity generation, creating a regulatory framework for the electricity supply sector. It uses a licensing and registration style of framework to control the generation, transmission, distribution, and trading of electricity. It also controls the reticulation of electricity by municipalities. Under this act the "National Energy Regulator of South Africa (NERSA) is the custodian and enforcer" for the Act (Van der Linde and Feris, 2010). An objective of the act is to ensure sustainable supply of electricity which is empowering for renewable technologies in a market dominated by fossil fuels (Van der Linde and Feris, 2010).

National Energy Regulator of South Africa (NERSA)

National Energy Regulatory (NERSA) is delegated the responsibility as the regulatory authority by section 3 of the National Energy Regulator Act No. 40 of 2004. It installs NERSA as the authority with the mandate of regulating Electricity, Piped-gas and Petroleum Pipeline industries in terms of the Electricity Regulation Act, Act 4 of 2006. NERSA is the regulator for electricity supply in South Africa. Any institution which wants to generate electricity first has to register with NERSA as a generator and then has to apply for a generation licence from NERSA according to the Electricity Regulation Amendment Act 28 of 2007. A generation licence is required by an electricity generator if they are to produce more than 5 gigawatt hours per annum (DME, 2003a). NERSA's main objectives are to oversee registration and licensing of electricity generation and regulate electricity prices and tariffs, manage and monitor information systems, enforce performance and compliance and issue rules designed to implement national governments electricity policy framework, undertake integrated resource planning and make Electricity Regulation Act amendments among other aforementioned tasks

Although a licence is required for electricity generation, transmission and distribution; "any generation plant constructed and operated for demonstration purposes only and not connected to an interconnected power supply," is exempt from the obligation to apply for a generation licence (Electricity Regulation Act 4 of 2006). As such if a WEC is constructed purely for the purpose of demonstration and is not connected to the grid; no generation licence will have to be obtained. However if a project was privately funded and was reliant on producing and selling power in order to reach financial close and implementation then a generation licence is required. Despite the primary purpose of the plant being for demonstration, due to the fact that electricity will be sold, there needs to be regulation of that electricity according to the Electricity Regulation Act 4 of 2006 (DME, 2006).

- If a project is planned to be a commercial scale application of WEC devices a generation licence will also be required as per the Electricity Regulation Act.

- A WEC power plant would connect to the national grid in order to sell electricity to the grid. The process requires:
  - An application has to be submitted with Eskom to determine if the national grid has spare capacity at the substations in that region in order to be able to evacuate the produced power.
  - A cost estimate letter is then provided by Eskom for the grid connection. If the supplier is satisfied with the proposed connection cross they may accept the cost estimate.

- Before the plant can feed power into the grid, Grid code testing of the constructed plant with cold and hot testing is undertaken before power can be evacuated onto the Eskom National Grid.

- Once a power plant is operational annual reporting on the WEC plant's production and financial information is required by NERSA. This information is required by the end of the financial year reported on the annual reporting form or (G-Form).

Eskom

Eskom is a public utility which is regulated by NERSA and has the monopoly of electricity supply, transmission and distribution in South Africa. Unlike a pure monopoly Eskom cannot set prices and tariffs which are instead set by NERSA (Newbery and Eberhard, 2008). Eskom is governed by the Department of Public Enterprise (DPE) through a shareholder compact with 100% of its equity held by the state and is liable for the payment of dividends and taxes as outlined in The Eskom Conversion Act (2001) (Newbery and Eberhard, 2008). Eskom consists of Eskom generation, transmission and distribution all bundled into one company (Newbery and Eberhard, 2008). As such any renewable energy generation by an independent power producer (IPP) will have to meet the approval of Eskom and enter into a power purchase agreement (PPA) with Eskom in order to supply electricity to the grid (Newbery and Eberhard, 2008). The 1998 White paper on Energy Policy envisaged the unbundling of Eskom; however this never came to fruition.

The Energy White Paper (1998), National Energy Act and the White Paper on Renewable Energy

The Constitution (Act No.108 of 1996), states the need for a national energy policy to be established by the Government so that energy production can be reliable and production and distribution be carried out in such a manner that is sustainable and ultimately lead to an improvement in the standard of living (DME, 2003a). The White Paper on Energy Policy of the Republic of South Africa, (1998) is the energy policy that was created to achieve this goal. In addition to the overarching goal, major objectives of energy policy outlined in the White paper are too; “increasing access to affordable energy services, improving energy governance, stimulating economic development, managing energy-related environmental impacts and securing supply through diversity” (Winkler, 2005). A broader goal surrounding the previous goals was to achieve environmental sustainability in both the short and long term of natural resource use (Newbery and Eberhard, 2008). An aim of the White Paper was to allow consumers to choose between different electricity suppliers by unbundling Eskom and dividing generation, distribution and transmission as well as creating competition in the market. However this objective was eventually abandoned in 2004 ensuring Eskom would not be unbundled or privatised (Newbery and Eberhard, 2008). This objective of the White Paper no longer applies even though it has never officially been withdrawn (Newbery and Eberhard, 2008).

South Africa along with a number of other countries internationally is aiming to encourage the uptake of renewable energy technologies. This led to the other formal policy which is the White Paper on Renewable Energy, published by the DME in 2003 (DME, 2003a; Newbery and Eberhard, 2008). In fact in the White Paper on Renewable initially set a target of 10 000 GWh of renewable energy by 2013 which was extended to 2014 (Winkler, 2005; DME, 2003a). The renewable energy white paper supplements the 1998, White Paper on Energy Policy extending its goals and including renewable into the generation mix. Thus the key purpose of the White Paper on Renewable Energy is to ensure that national resources are allocated to renewable energy equitably compared to other energy supply options, given the potential of renewable energy technologies (DME, 2003a). In the renewable policy the objective of introducing competition into the electricity market is revisited (DME, 2003a) The 2003 White paper aims at achieving this through facilitating the introduction of Independent Power Producers (IPP’s). This has the dual benefit of increasing diversity of electricity supply and energy security while offering the benefits of competition. An outstanding objective of the policy is to manage the liberalisation of the electricity sector by transforming electricity distribution to a regional distribution system. A pre-existing goal of electrification is complimented by offering renewable energy to rural communities far from the national electricity grid (DME, 2003a). The White paper outlines the government’s vision, and methods for achieving the strategic goals which are also set with in the policy (DME, 2003a). It also mandates the use of the integrated resource planning resulting in the Integrated Resource Plan (IRP) published in 2010.

The National Energy Act No. 34 of 2008 aims at ensuring consistent supply of energy, while promoting a diverse sources of energy supply, and managing energy demand and conservation. In addition, under this act NERSA aims to promote research, appropriate standards, systems, processes and specifications for equipment used in electricity production and distribution (DME, 2003b). Ensure the collection of data and information, providing for certain safety, environmental and health matters relating to energy. Facilitate energy access in order to improve people’s quality of life (DME, 2003b). Commercialise energy related technologies while ensuring “effective planning of energy supply, transportation and consumption, helping to contribute to the sustainable development of the South African economy" (DOE, 2008). Thus, allowing NERSA to provide, "optimal supply, transformation, transportation, storage and demand of energy that is planned, organised and implemented in accordance with a balanced consideration of security of supply, economics, consumer protection and sustainable development" (DOE, 2008). This act provides the basis for energy data collection and planning. Under this act the Integrated Energy Plan (IEP) was created in 2003 by the Department of Minerals and Energy (DME, 2003b). The IEP realises the importance for the development of renewable energy, but does little to facilitate the uptake of renewable technologies (DME, 2003b). The IEP simply echoes the goals for renewables outlined by the 1998 Energy White Paper (Winkler, 2005). As such the act's impact on renewable technology and wave energy is limited.

Integrated Resource Plan (IRP)

The Integrated Resource Plan (IRP) 2010 was approved by the Inter-Ministerial Committee on Energy and enacted in May 2011 under the Electricity Regulation Act (No.4 of 2006) (DoE, 2011). The Integrated Resource Plan (IRP) is a subset of the Integrated Energy Plan (IEP). The IRP is not the energy plan for South Africa as it would be in other countries but rather fills the role of the National Electricity Plan (DoE, 2012). It is not designed as an operation plan but rather to provide direction for the expansion of the electricity supply over the period 2010 to 2030 (DoE, 2012). The 20 year blueprint of electricity expansion indicates that renewable energy will be responsible for 42% of all new generation, contributing 9% (17.8 GW) to the future energy generation mix. The remainder of new build electricity will be taken up by 23% nuclear energy, 15% base load coal power plants, 9% peaking gas plants, 6% peaking pump storage, and 6% non-peaking gas (DoE, 2012; DoE, 2011). The aim of the policy is to develop a sustainable investment plan for electricity generation and transmission for the next 20 years (DoE, 2012). Goals are: to improve the long term supply and reliability of electricity, determine South Africa's capacity needs in the medium term. Account for the environmental impacts and externalities from electricity generation and determine effects of renewable energy and provide a framework for ministers to decide on new generation capacity (DoE, 2012; DoE, 2011). This future plan ensures the uptake of renewable in South Africa, allowing penetration into the fossil fuel dominated market. However it does not directly allow for the uptake of wave energy which is not included in the analysis completed in the IRP (DoE, 2011).

IPP Procurement Programme and Renewable Energy Policy Instruments (REFIT & REBID)

10 000 GWh of renewable energy by 2013 set by the Renewable Energy White Paper, is a modest but none the less significant target being equivalent to approximately 5% of generation in SA. This is roughly equivalent to the production from two 660MW coal fired power plants (McGrath, 2010; Newbery and Eberhard, 2008). The Integrated resource plan for South Africa for the period 2010 to 2030 (IRP) proposes to secure 17800 MW of renewable energy capacity by 2030.

The IRP it legislates the implementation of a selection of technologies planning 42% of new build power plant to be sourced from renewable power (DoE, 2011). Wave energy is not included in this plan as a planned development option but an 'other renewables' category is included for the uptake of new renewable technologies in the Revised Balanced Scenario of the IRP 2010 (DoE 2011). This Revised Balanced Scenario was unfavourable in that it did not specify the amounts of renewable allowances allocated to each technology. This culminated in the Policy-Adjusted IRP after several round of public participation (DoE, 2011). The final scenario presented in the IRP 2010 specifies which portion of the planned renewable build is allocated to wind, solar PV and CSP technologies. Thus any future options for renewable build is being taken up by established technologies, resulting in fringe technologies such as wave energy remaining alienated by the final IRP 2010 – 2030 (DoE, 2011). The latest update is already past due and an iteration including wave energy does not exist. Such barriers inhibit the development of renewable energy developments through cost, technical, market, institutional, political, regulatory, social and environmental barriers. The purpose of policies is to introduce mechanisms and norms in order to overcome such barriers (Painuly, 2000).

Mechanisms for Implementing the IRP

Internationally renewable uptake is being facilitated through a number of different mechanisms such as quota settings and standardization but the most common method is through the utilisation of tariff restructuring for renewable energy. Feed in Tariffs or FITs are a form of policy instrument designed to encourage the uptake of renewable energy by setting a price higher than the market rate for non-renewable electricity (Winkler, 2005). The higher rate will then encourage the deployment of renewable technologies with the promise of more profitable power purchase agreements (Winkler, 2005). It is also legislated that the power suppliers are required to purchase all the renewable energy produced at this higher price.

South Africa implemented this tool in 2009 under the Independent Power Producers Procurement Programme is referred to as the Renewable Energy Feed-in Tariff (REFIT) (McGrath, 2010). This method is based on the levelised cost of electricity which determines the higher rate at which electricity should be purchased from different renewable technologies. The higher purchasing rate is necessary to ensure that renewable technologies are able to cover the costs of their development and operation. In South Africa REFIT phase one was implemented for only a limited number of established renewable technologies such as concentrated solar, landfill gas, small hydroelectricity and wind power plants (McGrath, 2010). The REFIT tariffs paid under phase 1 can be seen in the table.

Phase 2 encompassed a larger array of technologies including concentrated solar, large concentrating photovoltaic systems (CPV), biogas, solid biomass and concentrated solar central tower systems (CSP) (McGrath, 2010). A Renewable Energy Power Purchase Agency will be run by Eskom Holding Ltd as a single buyer office and this will be facilitated by National Energy Regulatory Authority of South Africa (NERSA) who award tenders to Independent Power Producers (IPP's) which allows an IPP to participate in the REFIT scheme (McGrath, 2010). The IPP is responsible for the design, engineering, construction, finance, maintenance, commissioning and operation of the REFIT power they produce (McGrath, 2010). The Renewable Energy Power Purchase Agency (REPA) will be obligated to buy renewable energy from the IPP in order to encourage market expansion. However an

IPP may also sell electricity directly to buyers but they will not reap the benefits of the REFIT scheme and are still required to obtain a generation licence under no. 4 of the Electricity Regulation Act 2006 (McGrath, 2010).

Table 2-1: Renewable Energy Feed-in Tariff for South Africa (McGrath, 2010)

Technology	REFIT	Size Constraint	Other
Parabolic Trough - storage (6hrs)	R 2.10/kWh		REFIT Phase 1
Wind	R 1.25/kWh		REFIT Phase 1
Hydro	R 0.94/kWh	1 – 10 MW range only	REFIT Phase 1
Landfill to gas	R 0.90/kWh		REFIT Phase 1
CSP trough - no storage	R 3.14/kWh		REFIT Phase 2
CSP tower - storage (6 hrs.)	R 2.31/kWh		REFIT Phase 2
Solid biomass	R 1.18/kWh		REFIT Phase 2
Biogas	R 0.96/kWh		REFIT Phase 2
Large grid connected PV	R 3.94/kWh	1 MW and larger	REFIT Phase 2
Concentrated PV	No Tariff		
Roof top PV below 1MW	No Tariff		
Wave energy	No Tariff		
Tidal energy	No Tariff		

However off grid power producers are not included in the REFIT tariff scheme as only grid connected technologies are eligible to receive these alternate power purchase rates (McGrath, 2010). A revision of this policy led to REFIT phase 2 where the newer programme still maintained the exclusion of other renewable technologies and off grid systems. The exclusion proved to be a considerable barrier to the implementation of wave energy technologies and other fringe renewable technologies. Wave energy was not part of REFIT phase 2 however it was stated that fringe renewable technologies may be considered at a later stage in other programmes when the technology has been further developed (McGrath, 2010).

The alternate policy instrument to FITs is Renewable Electricity Portfolio Standards (REPS) which sets the quantity of renewable electricity to be taken up. Government sets a quota of renewable electricity to be taken up and tenders out the supply of that electricity to Independent Power Producers (IPP's) (Winkler, 2005). This is similar to the Renewable Obligation instrument but differs fundamentally in that a renewable obligation could be met by importing electricity whereas portfolio standards has to be met through domestic sources

(Winkler, 2005). REPS could be sub-divided into different quotas for different sources of energy according to their viability, allocating more of the quota to the higher resource (Winkler, 2005). This system is beneficial in that there is no upfront cost for the government but the burden is likely to be passed onto the consumer through higher electricity prices or taxes (Winkler, 2005). A comparison of the benefits and drawbacks can be seen in Table 2-2. Winkler, (2005) suggests that REPS would be a more beneficial strategy for South Africa to follow than a FITs programme. REPS have the benefit of setting a quantity to be achieved but allow prices to be determined via competitive bidding (Winkler, 2005). This strategy has now been realised with the implementation of the Renewable Energy Bids (REBID) process being launched in 2011 (Kernan, 2012). In august 2011 the department of energy (DoE) launched the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) and invited potential IPP's to submit proposals.

Table 2-2: Benefits and Drawbacks of Renewable Energy Policy Instruments (Winkler, 2005).

Comparison of Policy Options to Promote Renewable Electricity			
	Renewable Electricity Portfolio Standard	Feed-in Tariffs	Renewable Obligation
Ensures quantity of renewable energy and diversity of supply?	Yes	No	Yes
Promotes investment by guaranteeing prices?	No	Yes	Yes
Does not require government to pick a winner?	Depends whether target is differentiated	If price is differentiated by technology	Yes
Requires government investment	No	Yes	Yes

Under the new REBID system for the financing, construction, operation and maintenance of the first 3725MW of onshore wind, solar thermal, solar PV, biomass, biogas, landfill gas or small hydro projects (CSIR, 2012). The first procurement phase of the DoE's REIPPPP includes five bidding windows. Initially: 1) 4 November 2011. 2) 5 march 2012 3) 20 August 2012 4) 4 March 2013 and 5) 13 August 2013, however delays have been experienced. In these bids the two main evaluation criteria are price and economic development 70/30 respectively. Other criteria are technical feasibility, grid connectivity, environmental acceptability, Black Economic Empowerment status, community development and local economic and manufacturing propositions. Bidders whose responses rank the highest gain the preferred bidder status which allows them to process permits and move toward the final bidding phase and financial close (CSIR, 2012).

This process has already been hailed as a success as power purchase agreements (PPA's) for 1415MW of renewable energy were allocated in the first round of REBID (Kernan, 2012). Substantial competition was experienced in every available technology included in the process. The REBID process was facilitated by the National Treasury instead of NERSA and required an initial fee for members to receive bidding documentation to ensure genuine interest (Kernan, 2012). The REBID allocated tenders according to a weighted score sheet where cost effectiveness is given 70% and socio-economic development was give 30% of the weighting. Both of these factors have a direct influence of the renewable energy project (Brent, 2012; Kernan, 2012).

Wave energy was not included in the list of technologies accepted to be part of the REBID system. Thus The REBID programme in effect acts as a barrier to wave energy development as it focuses development on established technologies and excludes wave energy from the bidding process. Thus it would not even be considered by Eskom as a possibly form of renewable energy to fulfil the quota under REBID. In the following rounds of the programme it remains to be seen whether wave energy and other fringe technologies will be included in the bidding process. Although REBID is thought to be a more effective programme it proves to be a highly exclusive programme for fringe technologies which tend to be more expensive such as wave energy conversion.

The ISMO Bill

Independent Systems and Market Operator Bill (ISMO) was tabled in May of 2011 in Gazette No. 34289, where it was proposed as legislation to establish a national public entity responsible for:

- Generation resource planning
- Transmission service and implementation
- Buyer
- System operations and expansion planning
  (RSA, 2011)

The Bill aims to remove conflict of interest between the buyer and seller of electricity; roles which are almost entirely held by Eskom. The goal is to help incorporate Independent Power Producers (IPPs) into electricity generation while relinquishing the financial burden of constructing new generation from the state. If the existence of an entirely state owned ISMO was realised and a level playing field was created for new generation entrants, the market would be open to the development of wave energy converter technologies. A key determinant to the success of wave energy would then be the selection criteria with which new generation technologies are selected. Much of the potential benefit lies with the political will to relinquish control of the generation market and expose consumers to more variability in the electricity price.

2.5.3 Environmental Regulation

The National Environmental Management Act (NEMA)

The National Environmental Management Act No. 107 of 1998 (NEMA), makes up the fundamental environmental regulation which “gives effect to the environmental right guaranteed in Section 24 of the Constitution, 108 OF 1996. This act repeals a large portion of the previous Environmental Conservation Act 73 of 1989 (Van der Linde and Feris, 2010). NEMA creates a framework of fundamental principles which apply to environmental decision making, combined from international environmental law as well as the Constitution.

At the core of these principles is ecologically sustainable development (Van der Linde and Feris, 2010). All the legislated environmental management principles are legally binding to organs of state and organisations regarding the activities they undertake (Brent et al, 2012). It makes significant pollution or environmental degradation a criminal offence. This gives policy much more power than the previous act. To match the power a large amount of responsibility is delegated to the state as sole trustees of the environment on behalf of the countries inhabitants (Van der Linde and Feris, 2010). This means that environmental and lease permissions for all environments (including marine) will be controlled by the state.

NEMA was created with a number of aims in mind. The act aims to establish the necessary governmental institutions which will ensure effective environmental protection. It also ensures "fair environmental decision-making and for the conciliation and arbitration of conflicts" (Van der Linde and Feris, 2010). In addition to creating a framework for the environmental impact assessment process, with qualities of strict liability and a broader duty to "prevent, control and rehabilitate the effects of environmental degradation and pollution" (Van der Linde and Feris, 2010).

NEMA acts as an umbrella for the environmental regulation of South Africa covering terrestrial, atmospheric and marine environments. NEMA as the primary environmental legislation is complemented by a number of sectoral laws which have been promulgated to address specific areas of concern. These laws are "environmental management, environmental impact assessment, air quality, biodiversity, marine and living resources, integrated coastal management, protected areas waste management, pollution, mining, forestry and water management" (Van der Linde and Feris, 2010). The specificity of these acts will be discussed with regard to the development of a Wave Energy Converter in section 5.5.

In June of 2010 the latest set of Environmental Impact Assessment Regulations 2010 were promulgated in terms of NEMA (Act No. 107 of 1998) by Buyelwa Sonjica, the Minister of Water and Environmental Affairs (DEADP, 2012). The legislation under this act is as follows:

Procedures:	EIA procedures {Government Notice No. (GN) R.543}
List of Activities:	**Listing Notice 1** {listing activities for which a Basic Assessment process must be conducted) Government Notice No. (GN) R.544}
	Listing Notice 2 {listing activities for which a Scoping /Environmental Impact Report (EIR) process must be conducted) Government Notice No. (GN) R.545}
	Listing Notice 3 {listing activities and sensitive areas per province, for which a Basic Assessment process must be conducted) Government Notice No. (GN) R.546}
Framework:	Environmental Management Framework Regulation {Government Notice No. (GN) R.547}

(DEADP, 2012)

It is expected that only some of the number of afore mentioned policies will have bearing on the development of a Wave energy converter, and those are likely to be the environmental management, environmental impact assessment, biodiversity, and integrated coastal management acts under NEMA. The Sea-shore Act, Marine living Resources Act, and the Mineral Resources Act may also have bearing in the development of a wave energy converter.

2.5.4 Regulation in the Coastal Zone

The White Paper on Sustainable Coastal Development 2000 was produced by the Department of Environmental Affairs and Tourism (DEAT) and it was created in order to recognise the uniqueness of the coastline and its value to the nation. This principle along with sustainable coastal development and promoting a new style of coordinated and integrated coastal management, underpin the policy objective (DEAT, 2000). The paper sets out broad goals and objectives as well as a Plan of Action to achieve such goals (DEAT, 2000). Policy goals of public participation, promotion of public access to the sea shore, preservation, sustainable development to eradicate coastal poverty, control of pollution and natural resource management are key goals to the conservation and prosperity of the coast line in all regards (DEAT, 2000). The Sustainable coastal management paper delegates the responsibilities of lead agent for a province to a body in each province while local authorities are given responsibility for managing daily operations above the high water mark (DEAT, 2000). The paper entrusts the ownership and management of the coastal waters and sea shore to the state. These national assets are to be managed in the interest of the public and ensure they remain inalienable by the parastatal organization as stated in the Sea Shore Act (21 of 1935) (DEAT, 2000). This act also delineates different coastal zones seaward of the high water mark. It defines the sea shore as the area between the low and high water mark, and the rest of the coastal ocean boundaries (DEAT, 2000).

The coastal zone of South Africa is split up into a number of boundaries. Boundaries are defined by the white paper on sustainable coastal development and the Maritime Zones Act no. 15 of 1994. The low and high water marks are the highest and lowest tidal points on shore. From the low water mark to 12 nm (12 nm =22.2 km) seaward are the territorial waters. In territorial waters the full extent of South African law applies. Between the low water mark and 24nm seaward are the contiguous zone and maritime cultural zones. The maritime cultural zone allows SA to lay claim over any archaeological or cultural discoveries. The prohibited zone extends 50nm seaward from the coast while the Exclusive Economic Zone (EEZ) is up to 200nm out to sea. The EEZ is the boundary in which South Africa is entitled to all economic activity form mineral and fishing rights funder the Maritime Zones Act. Boundaries are depicted in Figure 2-13 (DEA, 2009a). In these zones South African law applies to all persons in the sea and air space above (DEA, 2009a). The sea bed within these zones up until the continental shelf is controlled and managed by the state in trust for the public. As such the land and permissions to develop on the sea bed would require lease agreements from the government. Beyond 200nm are international waters which fall under the international law of the sea (DEA, 2009a; DEAT, 2000; RSA, 1994).

The Maritime Zones Act is responsible for the call for a new Coastal Management Act to update and add to the Sea-Shore Act (SSA) which focussed on the ownership and use of the sea and sea shore (DEAT, 2000). The sustainable development white paper ultimately led to the promulgation of Integrated Coastal Management Act 24 of (2008) due to NEMA and the SSA inadequately providing sound management of the coastal zone and access to coastal public property (DEAT, 2000).

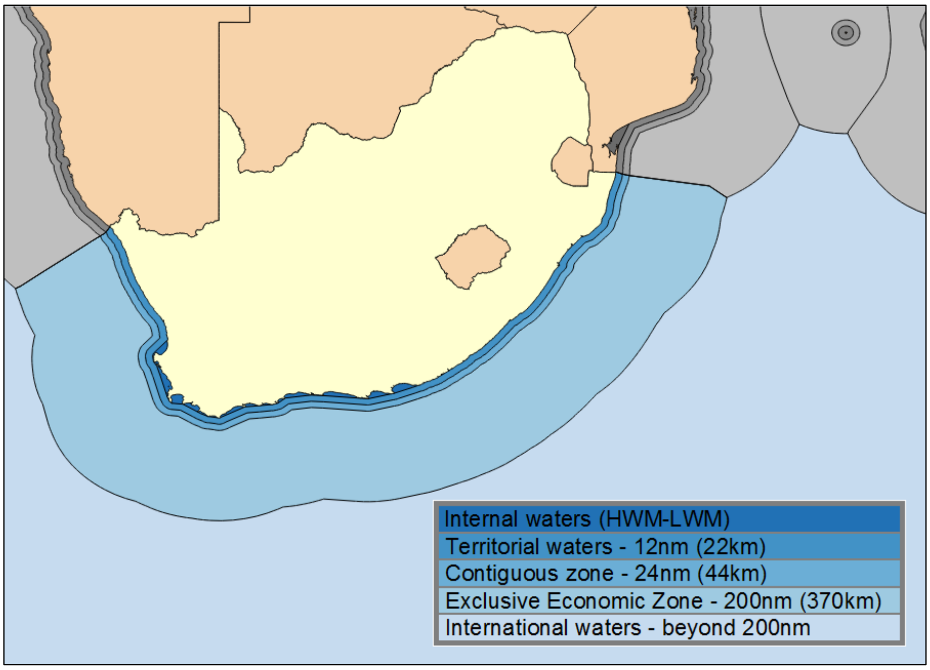


Figure 2-13: Ocean Regulation Boundaries, Adapted from; A User-friendly Guide to the Integrated Coastal Management Act of South Africa (DEA, 2009b).

2.5.5 Integrated Coastal Management Act

The, National Environmental Management Integrated Coastal Management Act (ICMA) (No.24 of 2008) is currently the replacement for the repealed Sea Shore Act. It forms an organization of integrated coastal and estuarine management in South Africa, stating norms, standards and policies so that the conservation of the coastal environment may be promoted. It was created to protect and enhance the state of coastal public property (DEA, 2009a). Improve and prolong the conservation of "the natural attributes of coastal landscapes and seascapes" (Van der Linde and Feris, 2010). All the while aiming to ensure that "development and the use of natural resources in the coastal zone is socially and economically justifiable, as well as being ecologically sustainable" (DEA, 2009b). The Act forbids "incineration at sea, controls dumping at sea, pollution in the coastal zone, inappropriate development of the coastal environment and other adverse effects on the coastal environment" (Van der Linde and Feris, 2010). This act is applicable to the outer extent of the Exclusive Economic Zone boundary of the maritime zones act therefore covering any proposed offshore development (DEA, 2009a).

The ICMA was enacted on the 1[ST] of December 2009, however a number of sections have not entered into force, as the Act will be implemented in a phased approach. The sections scheduled to enter into force at a later stage are:

- Section 11: ownership of coastal public property
- Section 65: award of leases and concessions on coastal public property
- Section 66: terms of coastal leases and coastal concessions
- Section 95: existing leases on, or rights to, coastal public property
- Section 96: unlawful structures on coastal public property
- Section 98: repeal of legislation

(DEA, 2012)

Due to the need for further consultation between government departments the listed sections have not entered into force. This act impacts on any oceanic development in terms of a lease agreement for a piece of subsea land or coastal planning scheme. A proposed development may only occur once the application has been approved by the relevant Minister, MEC, or municipality with the appropriate authority as stated by the ICMA (DEA, 2009a). Where the minister is the Minister of the Department of Environmental Affairs and the MEC is the "member of the Executive Council of a coastal province who is responsible for the designated provincial lead agency in terms of this act" (DEA, 2009a). If the development were to pose a threat to navigation of vessels, then the relevant Minister would also include the Minister of Transport (DEA, 2009a). Authority to approve a lease may be delegated from the Minister to the MEC and from the MEC to the municipality with permission from the Minister (DEA, 2009a) Lease provisions are accounted for in this act and will be fully unbundled in Chapter 5. The ICMA is the first permit which would be required in order to gain permission to generate electricity.

Provincial Policy

The Western Cape Government tends to be one of the most proactive provinces in encouraging renewable energy uptake. As such the Western Cape Provincial Government developed the Western Cape Renewable Energy Action Plan. The Western Cape Renewable Energy Action Plan may have the effect of encouraging renewable energy as the Action Plan sets targets of "12% of the electricity consumed in the Western Cape will be from certified renewable energy resources by 2014, 18% by 2020, 30% by 2030" (DEADP, 2007). This policy acts as a guiding principle for local government rather than for specific energy planning. As such the policy outcome on wave energy technologies is not known.

Applicability to Wave Energy Conversion

As wave energy conversion is a relatively new form of electricity generation many of the implications of policy on the technology are unclear. This is due to a number of factors adding complexity to the permitting process. Firstly the development occurs offshore in the ocean. This is a policy environment which has previously not been married with electricity regulation and thus one which has become incongruent. The land on which the development would take place is defined as coastal public property and is entrusted to the state. As such use of which must be in the benefit of the entire community. In the majority of electricity generation applications land can be purchased or is already state owned. Finally since this type of development is not common, the full extent of the legal environmental provisions have not been realised. Environmental policy should be able to adequately designate the mitigation action required do to NEMA's inherent flexibility. The complexity around permitting and policy will be discussed in reference to the SWEC device in chapter 5.

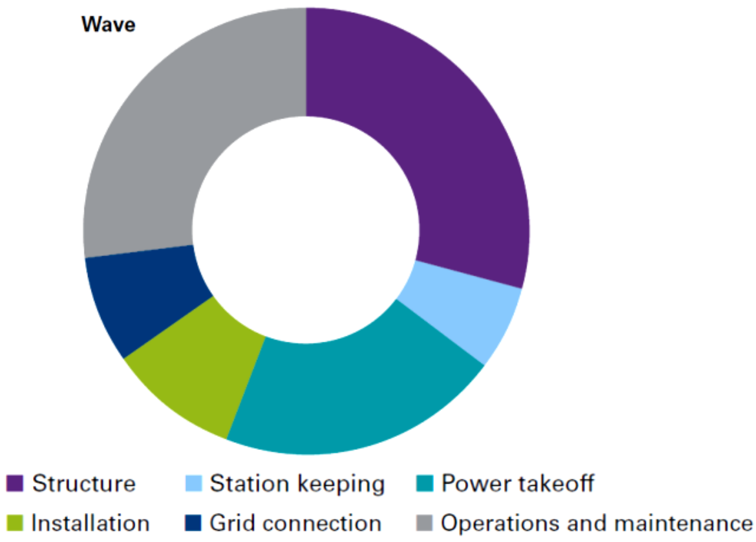
2.6 Levelised Cost of Electricity

There are a multitude of options when selecting a renewable energy power plant and the diversity in the number of designs of wave energy converters is just as significant. There are differences in design, operating principle, location and construction material. As such the considerable variety makes comparison very difficult, even though a number have been attempted (Van Niekerk et al 2012; Cameron, 2007; Thorpe, 1999). With the variability in power output, capacity factors and operating conditions of devices it is difficult to quantify how much weight has to be given to the capital cost of a device against units of electricity being produced. Hence the levelised cost of electricity has emerged as a common measure of comparison for both renewable and non-renewable electricity sources and this does not exclude wave energy (PIER, 2007).

The levelised cost of electricity (LCOE) is defined as the price of electricity that equalises the discounted revenues and costs such that the investor breaks even (IAEA, 1984). It thus allows an individual to compare the unit cost of different technologies with different investment costs, fuels costs, maintenance costs, life-spans, efficiencies and availabilities on a per kWh basis (IAEA, 1984). However levelised costing of WEC's can be problematic. There are less than ten well researched devices entering into initial commercial applications internationally and they tend to be the most advanced WEC's technologies with projects typically being 2-3 MW in size (EMEC, 2012; CSIR, 2008; PIER, 2007). A considerable proportion of devices are still in the prototype and conception phases. Due to wave energy being an immature technology there is no commercial track record to help to estimate project economics (PIER, 2007). However literature has attempted to account for costs of wave energy conversion and a significant amount of work has been done on the costing of WEC's although much of it is theoretical with little practical grounding. A number of generalised conclusions have been drawn.

2.6.1 Costs

Carter, (2005) concludes that the design of wave energy converters can have implications for the cost according to generation method, materials and location. The more complicated the design of a wave energy converter, the higher the component costs become. This needs to be considered in relation to the efficiency and power output of the converter. For example air turbines are more expensive than hydraulic generators. Floating devices also have the benefit of making use of established ship building techniques which reduces the cost (Carter, 2005). The proximity of the device to a grid connection impacts on the costs as electricity transmission costs are high, particularly in the ocean. Therefore on-shore devices have a cost advantage as they do not require sub-marine cables (Carter, 2005). Maintenance costs can be high due to access needing to be via boat for off shore devices. Thus they need to be kept to a minimum. Oscillating water columns are at a disadvantage as they function in a highly corrosive air-water environment, whereas submerged devices operate only in water. Therefore OWC's require corrosion resistant materials which utilise non-toxic, anticorrosives which raise costs (Carter, 2005).



*Colours represent the capital costs while grey indicates O&M, including leases and insurance.

Figure 2-14: LCOE of components for wave energy converters in an early commercial farm (Carbon Trust, 2011).

Figure 2-14 displays the different costs involved in a wave energy generator. All these different costs are common to all electricity generators but the proportions of the costs and overall cost vary depending on technology used and site location (Carbon Trust, 2011). Discount rates tend to be a reflection of the confidence in a certain technology. Lower discount rates would indicate more confidence in a technology and its performance. As performance and confidence improve, the discount rate will decrease, thereby increasing the relative importance of operations and maintenance spending to the overall cost of electricity (Carbon Trust, 2011). Figure 2-14 represents the proportions for a floating wave device such as the Pelamis and the installation costs maybe higher for a bottom mounted wave device (Carbon Trust, 2011).

Research from the Carbon Trust (2011) and the Marine Energy Accelerator (MEA) tried to estimate a levelised cost of electricity (LCOE) for energy from WEC's, however they discovered that there was large variation in the costs of different devices and noteworthy uncertainty surrounding the performance of devices. This occurs partly due to the extremely different designs and basic concepts for wave energy converters, which makes the analysis of wave energy costs more troublesome as two completely different principles have to be compared. Thus modelling energy performance of new concepts with certainty is a challenge (Carbon Trust, 2011). In addition only a few firms in the wave energy industry have an accurate idea as to what their costs for a full-scale device are in practise. Therefore only the firms which have solid grounding and operating experience for their cost estimations carry significant value when used in comparisons. The MEA creates estimates based real costs rather than estimates as they only use established developers with accurate ideas of their costs. Thus the estimated baseline cost ranges for wave energy are 38p/kWh to 48p/kWh for medium to high energy sites respectively (Carbon Trust, 2011). In South African Rand terms R4.80/kWh to R6.06/kWh for medium to high energy sites (using the 2012 average exchange rate of 1 GBP = 12.62 ZAR) (Currency, 2012). These estimates are considerably higher than the first round of estimates in the 2006 Carbon trust study as the understanding of device performance and post installation costs for the first devices have improved, as well as fluctuating market for deployment vessels and material prices (Carbon Trust, 2011).

2.6.2 Capacity Factor

A trait of wave energy is that it is not consistently delivered, as with wind and solar energy for electricity generation there is a degree of variation over a period. Capacity factor is a ratio of the amount of energy actually produced to the rated output of a device, running for 100% of the time. Thus wave energy will not be available for electricity production 100% of the operating life. This then needs to be factored into the LCOE calculations and long term data is required to make a conservative estimate on the proportion of time wave energy will be available. Ioulia Papaioann, (2011) estimates that in the United Kingdom wave energy may provide capacity factors in the region of 30 – 45% as well as being predictable, making wave energy suitable for hybrid systems and balancing with pumped storage. This may not seem high when compared with capacity factors of 80 to 90% for coal fired power stations. Conversely when compared with the wind power capacity factors at optimistic levels of 25 – 30% for South Africa (Hageman, 2011), wave energy becomes attractive especially when you note that South Africa has a higher wave energy regime than the Unite Kingdom (Hageman, 2011).

2.6.3 Costs Estimates

A number of studies have attempted to estimate the costs for wave energy converters to be used as comparisons with conventional technologies and other WEC's. Such as Joubert, (2008) as seen in Table 2-3.

Table 2-3: Capital Cost Comparison of the Most Developed WEC's versus Traditional Technologies (Joubert, 2008)

Energy Source	Capital Cost (R/kW)
Limpet	20 000
Oceanlinx (Energetech)	9 750
SWEC	3 283
Wavedragon	19 500
Pelamis	26 000
Aquabuoy	19 600
Achemededs Wave Swing	9 750
Wind Energy	6 500
Nuclear Power	13 000
Coal Fired Power Station	11 538

This capital cost comparison was carried out based on estimates provided by the device developers themselves. Costing such as this is carried out due to the lack of data on operation and maintenance costs (Joubert, 2008). A more realistic comparison can be made with O&M costs included and that will be attempted in this thesis. However as data may still be limited as an annual percentage was extrapolated from literature and practical experience and used as a proxy for the O&M costs in a LCOE calculation.

2.6.4 Operation and Maintenance

One of the major variable costs in wave energy conversion is the operation and maintenance costs (O&M). Costs for renewable energy technologies are characterised by relatively high capital costs and low operating costs due to the fuel for the majority of devices being free (Boud, 2003). The most significant factor affecting the O&M is the down-time experienced by a device, due to component failure, which requires unplanned maintenance (Boud, 2003). The energy output is then lowered thus raising generation costs. This means that a large degree of component reliability is highly beneficial (Boud, 2003). Running cost is the next major factor in O&M as operating in difficult environments, such as the ocean with access required by marine vehicles, quickly raises costs and affects the economics of a plant and energy generated (Boud, 2003). Fouling of devices by marine life is suggested as a possible negative impact on the maintenance costs of the device (Retief, 1979). Operating in difficult environments with fouling and so on will mean the need for scheduled maintenance. The harsher the environment and less resistant the device the greater maintenance will be required reducing the plants availability thus raising costs (Boud, 2003). Therefore minimizing these costs are paramount, leading to off-shore WEC’s designed to need minimal off-shore maintenance, vital components located above the water level, ensuring that extra components are available, undertaking scheduled maintenance and condition monitoring (Boud, 2003). Future innovations thought to be of paramount importance to reducing O&M costs are highly reliable seals, motors, valves and bearings as well as improving availability, reliability and maintainability (ARM) techniques (Boud, 2003).

2.6.5 Assumptions

Not all data is readily available and sometimes data does not exist due to insufficient experience in the industry and uncertainty in the future. As such assumptions are made in LCOE. Assumptions used need to be explained and motivated as they extensively impact on the outcome of the LCOE and the accuracy of the result (PIER, 2009). PIER, (2009) notes a number of major assumptions used in the LCOE calculations for power plants. They range from general assumptions on escalating O&M, labour and insurance to the plant characteristics such as efficiency, variable and fixed costs, financial assumptions and tax information (PIER, 2009). Therefore each individual LCOE calculation is determined by the underlying assumptions. In chapter 3 a LCOE calculation will be undertaken for the SWEC wave energy converter and all assumptions and methods will be clearly stated.

2.7 Messages

Although there are many broad issues being raised in the relatively immature industry of electricity production from wave energy three main themes arise as significant barriers to implementation. The wide variety in device designs and localities for generation create uncertainty and make marked solutions difficult to achieve.

- Significant uncertainty shrouds the potential environmental impacts with answers difficult to achieve due to the variation in device design, location and operating principle.
- Policy in South Africa is complex, with a number of key stakeholders holding influence over the outcome of a potential project. Policies are also not geared to manage wave energy development and may act as a barrier instead of encouraging wave energy.
- Cost at this early stage in the industry development is extremely high when the output is compared to traditional generation technologies.

Uncertainty and inexperience are the key drivers in the difficulty facing the industry, intensifying the listed core areas above. The following chapters assess a number of topics surrounding the key issues outlined.

3 Levelised Cost of Electricity

Levelised cost of electricity (LCOE) is calculated by summing the discounted lifetime costs of a device or farm and dividing the total by the expected lifetime output. LCOE allows the comparison of different technologies by calculating the price of electricity over the life time of the plant. This costing method allows renewable technologies to be compared with traditional fossil fuel technologies accounting for their differing cost centres, intermittency, variability and efficiencies. This makes this costing tool valuable in producing a comparable, high-level estimate of the cost of electricity generated by the SWEC device.

Reliable cost estimates are difficult to uncover. This is due largely to the lack of measurable data to conduct such modelling exercises. The lack of reliable data is due to limited availability as well as a factor of the difficulty in quantifying the large selection of device designs, operating principles and wave climates resulting in large variations in data and measuring methods (Harris and Pederson, 2012; Previsic, 2004; Boud, 2003). Thus, the quality of the study's outcomes is dependent on the input data and as well as the assumptions made to compensate for incomplete data. The assumptions used in this cost estimate define the results. Any estimates used must be interpreted in the context of the model parameters and assumptions listed in Table 1-1.

3.1 Assumptions

Assumptions form the backbone of any costing exercise. As experience in the industry is so scarce a wider plethora of assumptions are required to determine a cost estimate for the SWEC device. The greater the use of assumptions and estimates the greater uncertainty that exists within a model.

Uncertainty in the cost estimate is represented in the categories of:

- *Technical*—Uncertainty in physical climatic conditions, measurements or scaling.
- *Estimation*—Uncertainty resulting from estimates based on incomplete or untested designs.
- *Economic*—Uncertainty resulting from variation in costs of materials, labour, or capital.
- *Other*—Uncertainties in permitting, licensing, and other regulatory actions; or labour disruption.

(Booras, 2010)

Typically, wave energy converter's highest costs are reflected in the foundations, structure, mechanical-electric plant and operation and maintenance cost centres (Whittaker and Folley, 2007). Foundations, structure and mechanical-electrical plant costs are all highly device dependent, hinging on materials and design (Whittaker and Folley, 2007). Device selection tends to be a trade-off between maintenance and capital costs (Whittaker and Folley, 2007). Maintenance includes upkeep, insurance, unscheduled repairs and replacements. The final influential factors are the conversion efficiency from wave to wire and plant availability which is attributable to reliability and maintenance plan (Whittaker and Folley, 2007). Data from a wide number of meaningful sources was utilised where feasible. However assumptions have been made for practicality. The following cost estimates aim to serve as a guide for the potential costs of a SWEC array in relation to existing technologies.

3.1.1 Component Costs

Pederson, (2006) undertook a basic costing exercise which aimed to bring forward the estimated component and construction costs of the SWEC from 1984 until 2003 when the exercise was completed. It used inflation as the driving force to present costs estimates from 1984 in 2003 money. This is not the most accurate method for estimating component costs, but with limited resources and scope, it served as a crude estimate with easily adjustable factors. Due to resource constraints this method was further utilised to derive costs up until the year 2013. The merits and demerits of this method are discussed in section 1.7 and 3.4.

It was initially assumed that the SWEC could begin feeding power into the grid from the construction of the first unit and begin to pay itself back lowering the LCOE (Harris and Pederson, 2012). However, as with other renewable plants the SWEC would be arranged in an array. The array would then have a number of collector cables feeding power from the turbines into one centralised substation. This is where the SWEC plant would be metered by Eskom, and based on the REIPPPP programme it is unlikely that Eskom would commit to a power purchase agreement piece meal. Consequently the developer would have to take on the lost opportunity cost of the operational devices while the remainder of the array is developed. However this cost is not accounted for in the estimate.

3.1.2 Capital Investment

The capital investment which is required for the SWEC was initially determined by Retief et al in 1984. These cost estimates were determined based on industry costing at the time. The current calculation utilises the LCOE method to obtain the most accurate industry estimates for wave energy. However, according to Harris and Pederson, (2012) such cost estimates in current market climate would take a team of people a number of months to produce. The difficulty arises as there are a number of highly specialised components that have not been produced before that and would need to be designed, quoted and produced by specialists in industry (Harris and Pederson, 2012). Estimates from specialist would be required for the concrete structure, casting, and the turbine design which hasn't been tested locally. Specialised vehicles which haven't been used in South Africa would need to be ordered from abroad and potentially re-engineered for the SWEC specific projects (Pederson, 2012). Such work is beyond the scope of thesis. As such the estimated capital costs are extrapolated to current day based on inflation rates. This method creates large uncertainty in the capital cost of the device but is the only way to formulate a SWEC specific estimate within the scope of the thesis. The cost estimates were originally updated up until 2003 prices by Kenneth Pederson of Prestedge, Retief, Dresner and Wijnberg (PRDW) (PTY) Ltd in Pederson, (2006). An Inflation rate of 6.15%, based on the average producer price index between 2003 and 2012 was used to produce a conservative estimate of cost (StatsSA, 2013). The producer price index was utilised as it captures the real growth in output and not just the cost of living. Thus the growths in the cost of components are captured rather than being skewed by the prices of consumer goods.

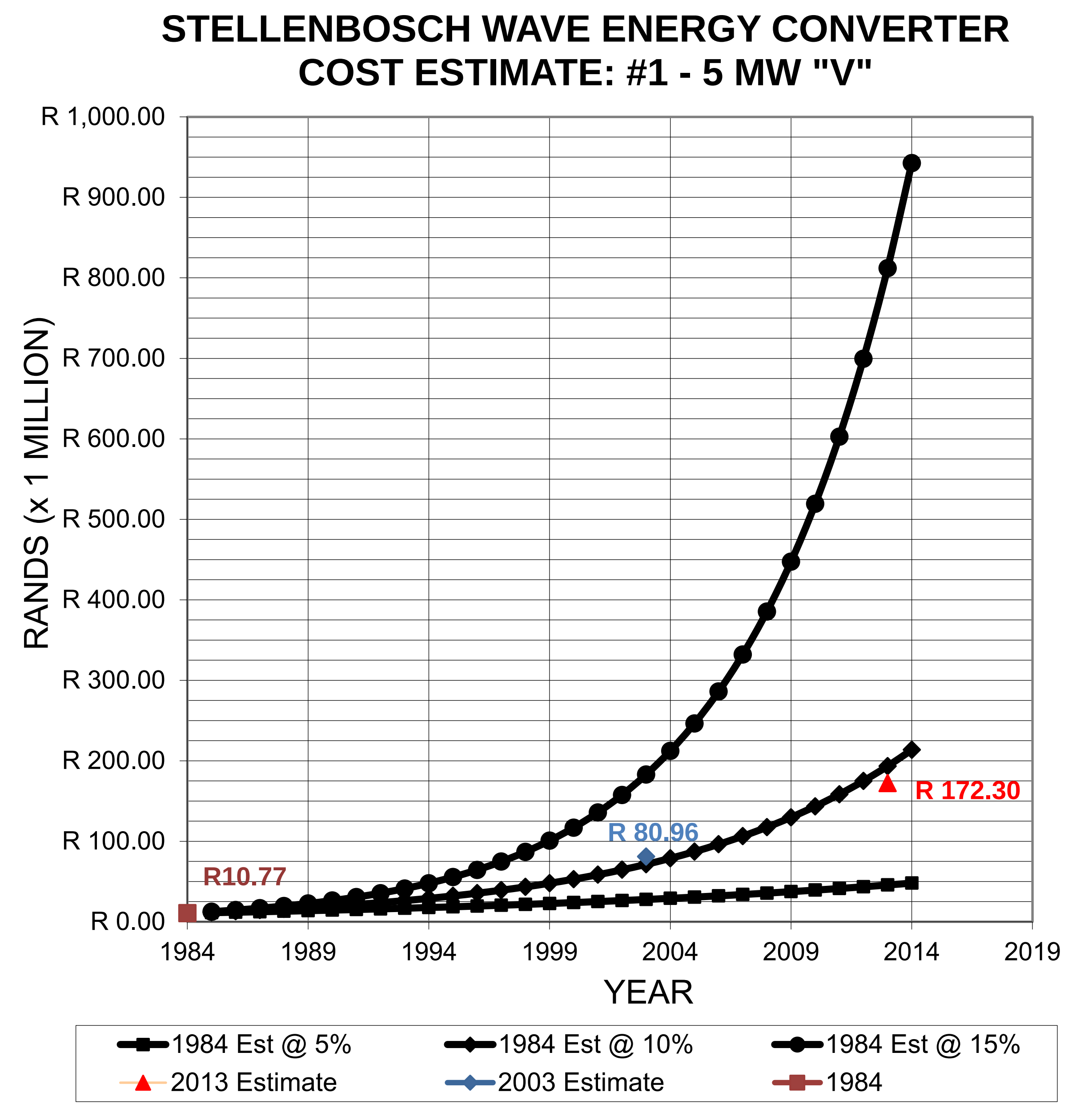


Figure 3-1: Stellenbosch Wave Energy Converter Capital Cost Estimate of the First 5 MW "V" Unit in 2013

Seen in Figure 3-1; based on an inflation rate of 10.5% assumed by Pederson, (2006) between 1984 and 2003 the estimated cost of producing the first 5MW SWEC unit rose from R10.77 million to R 80.96 million by 2003. Based on the 6.15% average inflation rate between 2003 and 2013, (StatsSA, 2013) the cost of producing the same unit in 2013 rose to R 172.30 million. These costs based on the 2003 component estimate indicate an increase of almost R 100 million/ 5MW unit based on assumed inflation rates.

Figure 3-1 indicates the dramatic increase in the costs of the SWEC device growing at a rate of close to 10% annually since the 1984 cost estimate. This shows that the capital cost of the device in today's period would cost more than in 1984 if inflation is discounted. The cost per megawatt installed being close on R35 million/MW is a significant stumbling block for any energy technology.

3.1.3 Capacity Factor

As South Africa tends to have a relatively high wave energy climate (Figure 2-1; Figure 2-5) compared to the United Kingdom (30-45%), the upper value of the capacity factor would likely be more representative (Retief, 2007; Papaioann, 2011). Based on the research of Retief et al, (1984) over a 22 month testing period a winter average output of 2.9 MW and a summer average output of 2.2 MW was estimated per "V" unit (rated at 5 MW). Based on the equation:

$$Capacity\ Factor = \frac{(MW\ Ouput)}{(Name\ Plae\ Capacity)}$$

Equation 5: Capacity Factor Formula

$$Capacity\ Factor = \frac{(4380hrs * 2.2\ MW) +\ (4380hrs * 2.9MW)}{(365\ days) * (24\ hrs) * (5MW)}$$

Equation 6: Capacity Factor Calculation for the SWEC

Where:

- Winter/Summer period is assumed = 4380 hours (6 months)
- Name plate Capacity of one SWEC "V" unit = 5 MW

Thus: Capacity factor is equal to 51% for the SWEC on the south west coast.

According to literature a 30 – 45% capacity factor is expected for wave energy converters in general (ARUP, 2011; Papaioann, 2011). According to the estimates of Retief et al, (1984) the south west coast would experience capacity factors in the region of 51%. As there is uncertainty in either estimate until device testing is completed 51% capacity factor will be used as the base scenario for calculations. However the effect on LCOE of a range of capacity factors has been tested in the cost estimate and the results are displayed in Figure 3-3.

3.1.4 Efficiency

The electro-mechanical power conversion efficiency was determined in the detailed designs for a SWEC plant by Retief et al, (1984). It was determined to be 75% (Retief et al, 1984). It is likely that the device efficiency will be lower than the efficiency used as near shore devices have extraction inefficiencies imposed on them by the environment (Retief et al, 1984). Further study and tests may cause efficiencies to decrease as hydraulic efficiency, electrical losses of the seabed cables, wave directions and wave period are accounted for in the efficiency estimate. Such additions will only become available through further study and tests. Conversely technological developments since 1984 may be able to increase efficiencies but would also require further study. The cost estimate consequently assumed a system efficiency of 75%.

3.1.5 Operation and Maintenance

Previsic, (2004) also noted that the O&M costs have a considerable effect on the estimated LCOE. O&M costs for wave energy are currently very high and there is much room for improvement. In addition the author notes that a lack of experience in operating wave farms leaves O&M as the aspect of costing with the most uncertainty and more experience is required to validate the quoted estimates (Previsic, 2004). In the study: System Level Design, Performance and Costs; Previsic, (2004) uses the standard O&M costs from the oil and gas industry which have experience in operating off shore. This approach was noted when preparing assuming the O&M cost estimate. Previsic, (2004) determines a LCOE estimate for an offshore OWC WEC. It is called the Oceanlinx MK1 (Previously the Energetech OWC) and uses a similar operating principal to the SWEC. The costing was done for a commercial scale plant of 152 devices located in deeper water receiving higher wave energy. Individually an OWC device would produce 1973MWh while the entire array would produce 300 000 MWh/yr. The LCOE prices determined for the device are 9.2 c/kWh (real) and 11.1 c/kWh (nominal) in 2004 dollars (Previsic, 2004). Using a rand - dollar exchange of $1 = R8 (Average rate 2008:2013) (Standard Bank, 2013). In rand terms the economic factors were:

- LCOE was 0.74 R/kWh (real) and 0.89 R/kWh (nominal) in 2004 ZAR
- The total capital cost was R 1904 million.
- Annual O&M of R 84.4 million
- 10 year Refit cost of R 117.6 million

Assumptions for the O&M costs for the SWEC are drawn from the study by Previsic, (2004); the only discoverable cost estimate to have been attempted for a similar device type. Additionally the costing was also completed for a commercial size array of 152 devices, similar to that of the SWEC at 154. The O&M cost for the Oceanlinx MK1 (formerly the Energetech OWC) is R68 million (Previsic, 2004). This represents 4.45% of the total capital cost of the Oceanlinx device. PIER, (2007) in cost estimates of the Oceanlinx MK1 and the Pelamis device determined O&M rates of 6.22% and 4.66% of the total capital costs respectively. Although crude, for want of a better substitute a flat rate of 4.5% of the total capital cost will be used as the O&M cost for the SWEC as a value in a 2% range of 5% tends to be representative for a WEC device in current research (Renewable United Kingdom, 2010; PIER, 2007; Previsic, 2004; Boud, 2003). This cost will be divided into 2.5% of capital cost as the fixed O&M and 2% toward variable O&M cost. Replacement costs of components were noted in Retief et al, (1984) where the turbines are estimated to need replacement after 25 years (Retief et al, 1984). For sake of simplicity and the assumption that modern turbines would likely have longer lifetimes, the cost of replacement was excluded from the cost of the SWEC's 30 year lifetime.

3.1.6 Learning Rates

The SWEC as with the majority of wave energy technology is new and untested. Estimates on the rates of learning have not been tested; therefore expectations are incorporated into the model from literature. This study uses the learning rates estimated by Black and Veatch which were adopted by ARUP, (2011). A pessimistic learning rate of 13.8% is assumed for wave energy industry which drops to 11.6% by 2030. Optimistic learning rates are suggested as 16.9% by Ernst and Young and slightly lower rates of 15% are suggested by Renewable United Kingdom (2010).

3.2 Estimate Results

Using the method and parameters stated in section 1.7 a simple Levelised Cost of Electricity (LCOE) was calculated. This was used to draw a comparison to obtaining the cost of the SWEC relative to the existing electricity market. Data from Retief et al, (1984) and Pederson, (2006); was drawn on for the costing of the SWEC while costing for a new, large (750 MW) Supercritical coal plant was drawn from South Africa's Integrated Resource Plan 2010 Tables: Technology Cost Input and Import Options (DOE, 2011). Note economies of scale are not included in the simple cost estimate as there is no experience in savings of scaling up manufacturing either for the SWEC or any other wave energy converter in South Africa. The basic results of the cost estimate are displayed in Table 3-1.

Table 3-1: Results for the simple LCOE estimate

Levelised Cost of Electricity Results (c/kWh)				
Factor	**COAL**	**SWEC** (*i* =8%)	**SWEC** (*i* =15%)	**SWEC** (*i = 8%* +Cabling)
LCOE	451.76	1567.17	2056.76	1614.43
CRF (ratio)	0.08	0.09	0.15	0.09
O&M Cost	105.51	882.03	882.03	908.62
Fuel Cost	145.95	0.00	0.00	0.00
Cost of Capital	261.41	877.98	1367.56	904.45

It is clear that at a wave energy capacity factor of 51%, a higher discount rate significantly raises the cost of capital while the intermittency of the natural resource makes electricity generation more costly due to the shorter periods of amount of time the device is able to produce power. The cost estimates are not meant to represent mature technology costs and as a result are significantly higher due to risk induced, high capital cost and inflated O&M requirements based on the lack of experience in the industry. High O&M costs of 4.5% of the capital cost per annum for both the SWEC and the Oceanlinx devices translate into an equally high share of the LCOE for both the SWEC and Oceanlinx devices at roughly 50% of the total LCOE (PIER, 2007; Previsic, 2004). Compared to traditional technologies such as coal it is clear that the cost centres of the SWEC revolve around capital and O&M costs while traditional plants costs have a considerable reliance on fuel inputs with O&M being less significant.

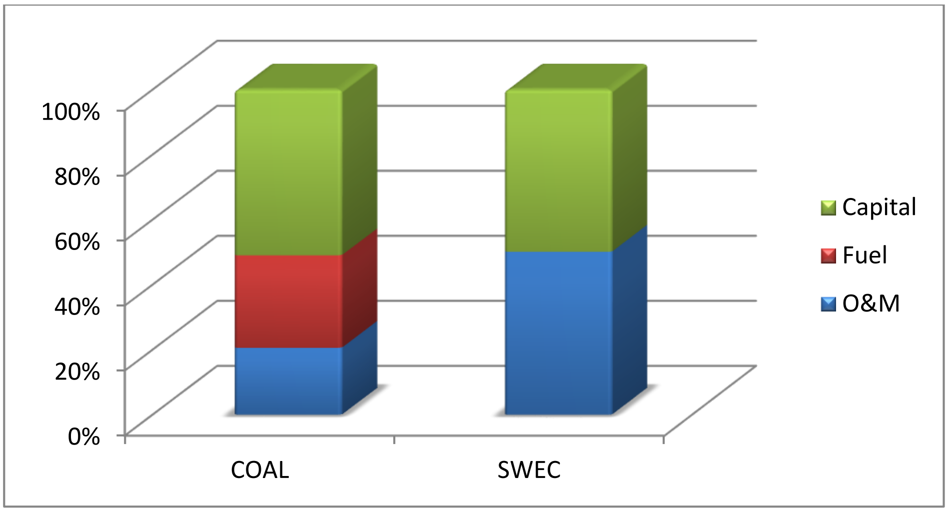


Figure 3-2: Relative Weight of Cost Centres Between Coal Power and Wave Power

Figure 3-2 represents the two major existing cost generating factors. First there is the large risk associated with the SWEC device due to uncertainty and lack of experience in operating the device in an untested environment. Such inexperience leads to inflated capital, operation and maintenance costs. Secondly the SWEC does not require any fuel thus fuel costs are absent, while they play a considerable role in the costing of traditional technologies.

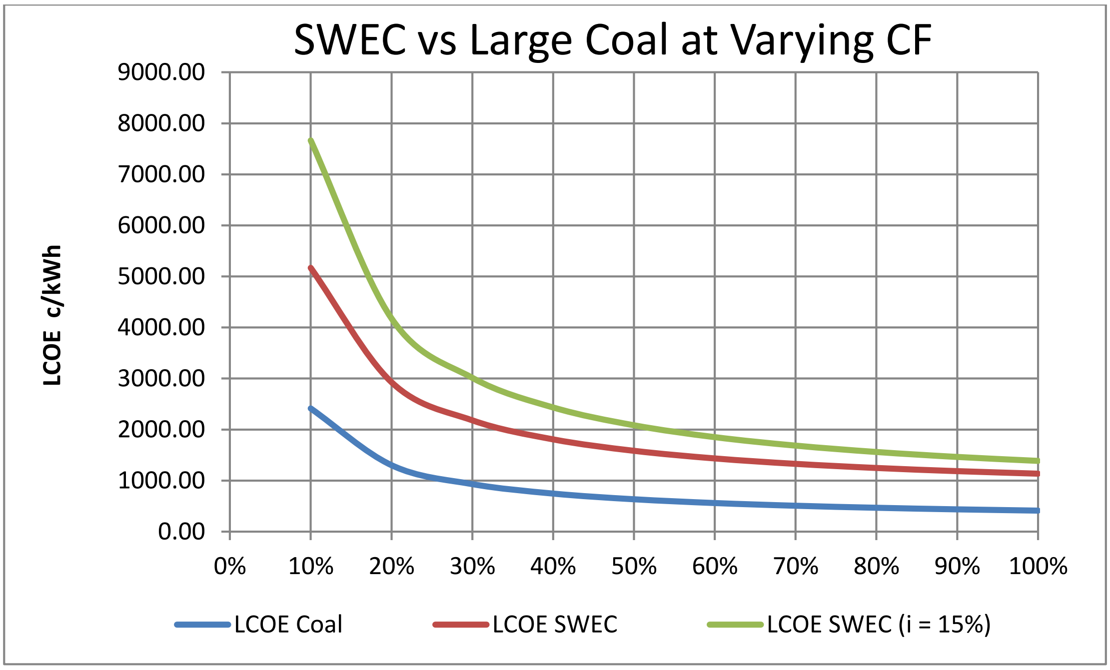


Figure 3-3: The LCOE at Comparative Capacity Factors where (i = 8%)

Since the SWEC is ultimately reliant on the ocean to provide 'fuel' the availability of the resource is the driving factor in the long term cost and generation. The a relatively higher capacity factor reduces the LCOE of the SWEC while a low capacity factor can cause a device to be completely unviable as seen in Figure 3-3. Consequently if capacity factors were as low as 20% or 30% the case for investment in the SWEC would be unjustified. At high capacity factors the SWEC is an expensive option but it is more competitive where the resource is available in abundance. There is a considerable cost reduction where the SWEC cost is (> 2000c/kWh) in the LCOE at capacity factors below 30% as oppose to coal costing in the region of (~ 1000c/kW) at capacity factors lower than 30%. At a standard discount rate of 8%, Coal power is relatively cheaper at low capacity factors as it is able to achieve cost reductions through less fuel usage at lower capacity factors.

It is important to note how much more expensive the SWEC device would be than large scale new coal build despite the fuel effectively being free. These are due to the high capital and O&M cost centres which can be markedly reduced through R&D and scalability (Harris and Pederson, 2012; Previsic, 2004; Boud, 2003). Due to the large risk involved when investing in immature technologies, significantly higher discount rates can be experienced. A discount rate of 15% is used by the Carbon Trust in calculating the LCOE of wave farms in order to take account of the risk involved in a wave energy project (Carbon Trust, 2011). When this rate is applied to the SWEC the relatively higher cost of capital due to risk is represented by the green line in Figure 3-3.

What is important to note in the cost estimates is that the cost of subsea cabling is excluded, which is quoted in the region of € 1 million per kilometre (Sinclair, 2012). The LCOE may rise dramatically if the burden of the cost fell on the producer as seen in Table 3-1. Given the minimum of 40 km worth of subsea cabling required for an array the LCOE would be increased by 500c/kWh and if that distance was required to be 80 km either for environmental or contingency the capital cost rises by 1000c/kWh (ERC, 2013).

3.3 SWEC in the context of other Energy Technologies

A wider cost comparison was also conducted utilizing the open source SNAPP V3 (Sustainable National Accessible Power Planning) electricity supply planning model developed in 2009 by the Energy Research Centre (ERC), University of Cape Town with financial support from WWF-SA (ERC, 2013). The model utilises Eskom's adequacy report online facility and is calibrated up to 2014. Beyond 2014 the model bases new capacity growth on the Department of Energy's, Integrated Resource Plan 2010(ERC, 2013; DOE, 2011). In the IRP 2010 the reference case investment plan is utilised as the base case for the technology assumptions in the SNAPP model (ERC, 2013). SWEC data computed into the SNAPP V3 model was obtained from Retief et al, (1984) and Pederson, (2006). Component costs were inputted into the SNAPP tool in order to allow a comparison of the present and future costs of the SWEC device to other energy technologies in the mix. This also allows for us to see the effect of discount rates over an energy mix of peaking and base load plants. It is important to note that SNAPP does not account for the financing costs.

As expected at a capacity factor of 51% and a discount rate of 8% the SWEC is significantly more costly than existing renewable, and base load power plants (see Figure 3-4). Only centralised, solar PV would be cost comparative to the SWEC in the current period and that is due to the high price of the technology with the relatively low efficiencies (17%) and capacity factors (ERC, 2013). What is clear are the cost savings into the future attributed to the learning rates. The more optimistic learning rates of 16.9% rendered larger cost reduction in the future with the pessimistic rates limiting the reduction of the LCOE.

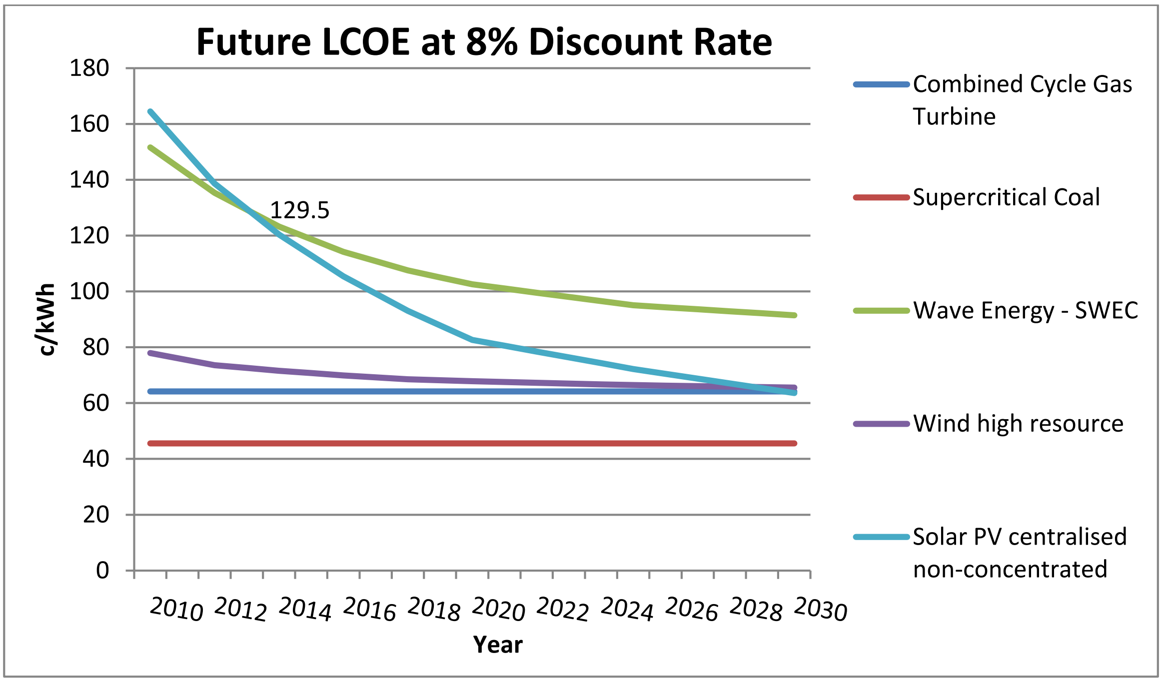


Figure 3-4: Influence of Learning Rates on the LCOE Comparing the SWEC to existing Technologies at an 8% Discount Rate

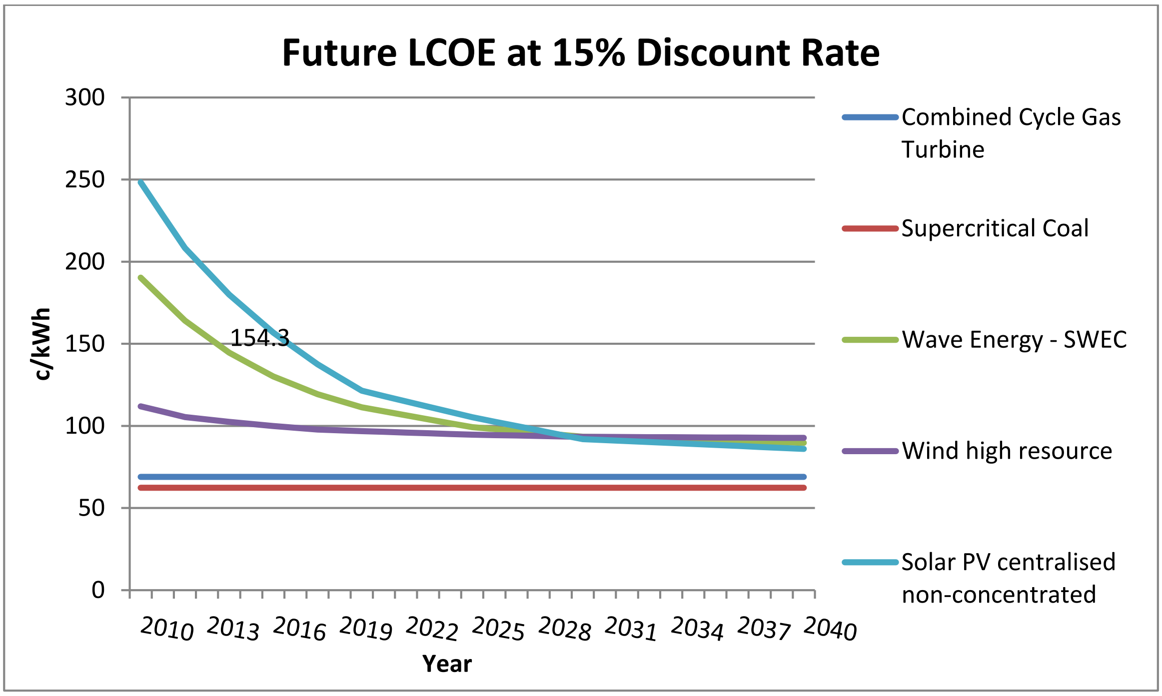


Figure 3-5: Influence of Learning Rates on the LCOE Comparing the SWEC to existing Technologies at a 15% Discount Rate

As the learning rates assumed in the IRP 2010 are significant a rapid decline in the cost of PV is projected. As the learning rates are considerably higher than for wave energy, PV is expected to become cost competitive more quickly. It is likely that the cost of centralised PV in 2013 is already lower than what is forecasted by the data in the IRP 2010. Although varying learning are quoted from different sources, literature surrounding wave energy seems to indicate trends of above 10% beyond 2020 (ARUP, 2011; RUK, 2010). However this will vary widely between device types and is purely speculative until practical experience is gained with the SWEC or any specific device.

When discount rates are raised to 15%, inherently indicating a more risk prone investment climate, and assuming a 51% capacity factor for the SWEC (see Figure 3-5), the device becomes more cost effective than centralised solar PV at capacity factors of 19% (ERC, 2013). In the short to medium term the SWEC has a lower life time cost than PV due to the relatively high assumed capacity factor and the optimistic efficiency of 75% compared to solar PV's 17% combined with the higher cost of capital (*i*=15%). However the SWEC is still significantly more expensive than wind and traditional technologies and has extensive cost reductions to achieve before being a viable competitor. As solar PV's steep learning rates are realised, PV regains cost competitiveness in the long run. What is noticeable is how much more cost competitive the SWEC is at a higher discount rate when learning rates are realised. In an optimistic scenario, it may even become cost competitive with high resource wind if significant learning is experienced. Note it is unlikely that a PV plant or high resource wind farm would be subjected to discount rates similar to those of the SWEC plant (15%) due to more experience in those technologies translating into lower discount rates and costs. Traditional technologies are likely to experience even lower discount rates than renewables.

3.3.1 Comparison to Wave Energy Technologies.

The Oceanlinx is the most similar developing wave energy technology to the SWEC device due to the OWC operating principle, the focussing parabolic wall and the terminating nature of the device. The LCOE for the Oceanlinx MK1 is 0.74 R/kWh (real) and 0.89 R/kWh (nominal) in 2004 ZAR, with a total capital cost of R 1904 million for a 152 units. Estimated annual O&M cost is R 84.4 million (Presivic, 2004). Escalated to the current period at an average inflation rate of 5% per annum the cost estimate of the Oceanlinx MK1 at the early commercialisation phase having gone through R&D, demonstration, testing and deployment is far less costly than the SWEC device which is at the early stage of design. This is largely due to the fact that per kW output for a lighter, smaller more easily deployed device in the Oceanlinx, with risk reduced through other prototypes. Whereas the SWEC would require deep water deployment, large volumes of materials, foundations and site works and far more risk with no prototypes to de-risk and reduce costs. Comparative cost estimates can be seen between the Oceanlinx and the SWEC with an optimistic and conservative cost of capital estimate in Table 3-2.

Table 3-2: Comparative LCOE for Wave Energy Technologies

Levelised Cost of Electricity Wave Energy Technologies (ERC, 2013)		
Scenario	**Device**	**LCOE (R/kWh)**
Base	Oceanlinx	1.38
Optimistic	SWEC (*i* =8%)	1.29
Conservative	SWEC (*i* =15%)	1.54

*Assuming optimistic learning rates of 16.9% per annum as seen in Figure 3-4 and Figure 3-5

3.4 Discussing Costing in Reality

Costing of marine engineering is extremely difficult. Obtaining prices for materials such as concrete and steel will take in depth investigations (Harris and Pederson, 2012). Costing of the turbines, civil works, ducting and helipads required by the SWEC is a highly specialised task (Harris and Pederson, 2012). Accurately comparing costs of the SWEC to other devices would require the integration of the specialised component costs into cost comparisons. Additionally devices to be used for comparison such as the Oceanlinx also requires updating of their cost estimates since the study in 2006 and adjustments for the local market (Harris and Pederson, 2012). This is due to the variation in wave climate internationally. The Pelamis for instance was designed for shorter period European wave climates (~8s). In order to realistically estimate the cost to deploy the Pelamis in South African waters, Pelamis Wave Power would be required to integrate the cost of redesigning the Pelamis for longer wave periods (~12s) (Harris and Pederson, 2012). The largest barrier to comparative costing is the lack of experience and access to detailed device cost information. In light of these factors producing a comparative costs for the SWEC, Oceanlinx, and Pelamis is very complex (Harris, 2012). The SWEC costing was consequently explored within the bounds of the limited data. Comparisons to the SWEC will be drawn from literature.

The development costs for a wave energy converter would be significant. Although South Africa experiences relatively conservative permitting costs in the region of R10 million per renewable project. On the other hand the sitting cost of a WEC array would be much larger and comparable to the cost of siting offshore wind turbines. A sub-sea geotechnical study of the seabed can cost in the region of €15 million (R220 million) per study and is a vital piece of due diligence as it can represent a fatal flaw of a project. In addition to geotechnical studies and permitting the cost of raising capital, especially when through debt finance can also carry very large premiums. Although these details are too detailed for this study. They are costs that would need to be considered during development and in any detailed costing exercises.

Transmission costs can represent one of the major cost centres which alter the pricing of a device depending on which entity accepts the burden of the transmission. A significant capital cost is added to a wave farm if the development requires self-build transmission cables and substation. In the case of a full scale SWEC array; the costs will be minimised by the plant being able to connect to the 400 kV transmission lines at Koeberg Nuclear power station approximately 17 km south of the Southern portion of the wave farm (Retief, 2007). Assuming Eskom (the national utility) will own and operate the substation and high voltage grid cables (as is standard in the REIPPP), transmission costs will depend on the costs of transporting electricity from the plant location to the sea shore. Costs of transporting energy to shore are dependent on the technologies used. According to Sinclair, (2012) the likely option would be submarine high voltage cables. For large scale offshore wind farms the cost of transporting electricity to shore can represent 20 - 25% of the overall capital outlay. Submarine cables are largely the cause for this high cost and it is likely that they will represent a similar cost in wave farms with Sharkey et al, (2011) estimating cabling accounting for 10% of the overall cost. A crude cost estimate for the SWEC array would suggest that at an exchange of R10 to the € 1; a kilometre of cabling would cost R 10 million. Given the minimum of 40 km worth of cabling required a minimum estimate of R 400 million would be expected. If double circuit cables are to be used allowing for (N-1) contingency as is suggested by Sinclair, (2012); the cost would double. Additionally, if the array were spread out over 80km to reduce environmental impacts, the costs would again double to fall in the region of R800 million. The cost impact would then be based on which entity would take ownership of the cabling, Eskom or a private developer. Cost may be minimised by routing a single hub from the substation via a high voltage cable (275 KV or higher) to a central point out at sea to be owned by Eskom. The developer would be responsible for the costs of the internal 22 kV collector cables. This design is implemented in the Wavehub concept in the United Kingdom, effectively acting as a central adapter to which projects may connect (Wavehub, 2012).

Offshore wave energy may experience further cost reductions as the technology matures. This is represented by the technology learning rates which are estimated at between 10 and 15%. These are reflected in the economies of scale which are expected in construction, installation, operation and maintenance, but are heavily dependent on learning in plant design and O&M plans (Callaghan, 2006). Learning rates are both untested and uncertain with only a handful of WEC's having been operational for a limited number of years.

Many external factors exist which impact on cost estimates. Many of the device designs including the SWEC require onshore fabrication facilities. If these facilities are not available at the ports the costs will rise rapidly as they have to be installed. In the case of the SWEC manufacturing facilities will be required at either the Cape Town or Saldanha harbour. Given the close proximity of the Saldanha Bay harbour, it would be the favoured location for a manufacturing plant. However any device production requires the services of jack up rigs and specialised maintenance vessels. If the harbours cannot accommodate these vessels harbour expansions may be required adding to the expense (Harris and Pederson, 2012). The availability of these vessels also plays a very large part in the cost of such a project. Vessels have to be pre-booked for specific construction periods. Given that these periods require specific weather conditions or windows, bad weather may lead to long delays and amount to significant expense on the basis that vessels are paid for whether in use or not (Harris and Pederson, 2012; Retief, 2012).

Cost estimates for the SWEC contain a considerable number of assumptions and outdated cost estimates. The combined uncertainty makes an updated cost estimate unreliable and the estimate should not be utilised beyond a high level comparison. Although not a costing tool, the estimate does shed light on the relative costs of the SWEC compared to traditional and renewable technologies. Cost comparisons of the SWEC to the Oceanlinx reveal that the SWEC would need to realise large learning rates in development as well as achieve favourable cost of capital to be competitive with the Oceanlinx. Although a high-level estimate the exercise indicates that the SWEC is at a similar cost to that of internationally developing wave energy technologies which are also relatively expensive due to the immaturity of the industry. If large learning rates that are expected in the industry can be realised locally the SWEC device may become cost competitive by 2025. However, lack of data makes a detailed comparison difficult, with large degrees of variability due to exchange rate fluctuations, as estimates were calculated across currencies and extrapolated at average annual inflation to the current period. Additionally assumptions used in the model further add to the uncertainty of the estimates.

4 Environmental Impacts

The deployment of a device can cause a varying array of both positive and negative environmental impacts. A variety of different impacts can occur during the seabed preparation, manufacturing, construction, operation and decommissioning of a WEC (Nelson et al, 2008; PIER, 2007; Boud, 2003). These impacts will vary depending on the size, design, operation and location of the WEC. Both off-shore and shored based wave energy technologies have environmental impacts no matter how small (Boud, 2003). Impacts specifically associated with the SWEC would not be uniform across all sites, thus cannot be quantified across all possible site localities (Retief, 2012). Therefore the study draws on comparative impacts, literature and local expert opinion to formulate potential local impacts specific to the SWEC and South Africa. This thesis focuses largely on potential negative impacts. As a first of its kind investigation into wave energy in South Africa; full detail of negative impacts is necessary for transparency and as a starting point for further research.

A number of direct impacts come about from placing a 226 m wide foreign object on the bed of the sea. A SWEC device creates hardened, angular surfaces in an environment where previously there were only soft surfaces. As such the device will create an obstruction to sediment transport, animal navigation and mobility, as well as habitat alteration. An entire array of 154 angular devices compounds these local scale impacts and increases the severity and complexity of impacts at a regional scale (Finlay, 2012; Retief, 2012). Although a full EIA and specialist study is beyond the scope of this chapter, a number of the outstanding issues are identified and suggestions from expert commentary is utilised to begin to suggest the potential scale and severity of environmental impacts of a SWEC array. Impacts during the operational, construction and decommissioning phases of the SWEC plant are suggested to have impacts on certain aspects of species and ecosystem dynamics.

4.1 Impacts of Activities

The SWEC converter is a large device with each of its two “V” shaped arms measuring 160 m long with an effective width of 226 m and the widest point. The full spec of the device is listed in chapter 2.2.4. The construction, operation and decommissioning of such a device will require a number of activities. The required activities are listed in the Table 4-1: (Retief, 2012).

The nature of the environment in which the activities described in Table 4-1: occur; result in considerable environmental impacts. Consequently the environmental impacts will be unbundled to provide a clear indication of the extent and significance of such potential impacts. Further specialist study is recommended in specific sensitive areas in which deployment may occur.

Table 4-1: List of Activities Involved in the SWEC implementation

Activities involved in the SWEC Implementation (Retief, 2012)		
Phase:	**Activity: (temporary) / (long term)**	**Type:**
Construction ***(temporary)***	1.a Dredging, bottom levelling and preparation of construction site	Preparation
	2.a Driving of piles into the seabed by specialised marine pile driver	Construction
	3.a Transportation of pre-cast concrete sections via specialised vessel	Transport and works
	4.a Attachment and draw down of concrete sections to piles	Construction
	5.a Assembly of turbine, generator, electrical infrastructure and directional drilling for buried cabling.	Construction
Operation ***(long term)***	6.a Generation and transportation of electricity	Transport and works
	7.a Maintenance vessels and crew under taking works at the device location	
	8.a Repair vessels and repair works	Transport and works
	9.a Emergency Vessels and vehicles	Transport and works
Decommissioning Option A ***(temporary)***	10.a Full deconstruction of the WEC device	Deconstruction
	11.a Floating and transport of entire device and materials back to shore.	Transport and works
Option B ***(temporary)***	10.b Or semi dismantling and transport of components	Semi De - construction
	11.b Non harmful materials and sections remain intact. Abandoned and converted into artificial reef	Rehabilitation
	12.b Or Explosive deconstruction and construction of artificial reef	Explosion and Rehabilitation

4.2 Ecosystem Dynamics

The desired site for the construction of the SWEC is the south west coast of South Africa (Retief et al, 1984). This site falls within the epipelagic zone of the Benguela Upwelling system. In the Benguela upwelling system there is evidence of mid-trophic level, small pelagic fish (Anchovies and Sardines) exerting both top-down and bottom up control over plankton and near-apex (upper-level) predators (Cury et al, 2001). Consequently local fisheries place extreme pressure on both intermediate trophic populations and higher order predators through the decimation of prey populations. Given the ecosystem dependence on the dominant mid-trophic, foraging fish and the balance with lower trophic species and near apex predatory species noted in section 2.4.1, the concern is that any change in the ecosystem dynamics brought about due to the development of the SWEC may create an added pressure for the intermediate trophic level species. This would render large impacts on upper apex predators such as whales, seals, dolphins, sharks, rays and large fish many of which are high value endemic species (Lombard et al, 2004). A number of unique discoveries have come to light with regard to apex predators in the upwelling system. Baleen whale species in particular exhibit unique behaviour within the proposed construction area and these issues will be discussed in section 4.4.2 (Finlay, 2012).

4.3 Construction

The construction phase requires site preparation, transportation of materials and installation activities. All such activities carry impacts on marine life, with differing severity and intensity. A seabed mounted wave energy converter such as the SWEC requires significantly more site preparation before construction can be undertaken. Activities include vegetation clearing, seabed levelling, lay down areas, pile driving, component assembly and increased vessel traffic. Therefore concerted consideration for marine life disturbance during construction should be given (PIER, 2007). Efforts can be focussed to certain windows as construction would be limited to short periods of time when weather windows permit. As no undersea construction has occurred at the site to date; data on seabed habitats is limited and no site specific studies encompassing the specific value of the site have been undertaken.

4.3.1 Biodiversity of the Proposed Location

When the proposed construction site is considered in terms of the biodiversity assessment a number of key conclusions were drawn. The conclusions are discussed based on the different coastal zones; the intertidal (near shore), sub tidal or shelf (shallow, deep and sub photic zones) and the regional areas. As the SWEC would be placed within the deep to sub photic area (10 – 30 m depth) off the coast, direct construction impacts will likely occur within the deep photic area. The spatial relationship of depth to distance out to sea can be seen in Appendix A: Figure A - 1: Bathymetry of the west coast of South Africa (CSIR, 2008). The descriptions of the photic, tidal, and subtidal zones can be seen in Figure A - 2. From Figure 4-1: Representation of the Extent of the Depth Strata off the south west coast of South Africa (Lombard et al, 2004), indicates that the SWEC would be placed in deep to sub-photic habitats with shallow photic and tidal habitats remaining between the SWEC development location and the sea shore. The area in which construction is to take place contains endangered biozones according to Lombard et al, (2004).

SWEC in the Context of the NSBA

Although research is limited; the South African National Biodiversity Institute (SANBI) in partnership with the Department of Environmental Affairs and Tourism undertook the South African National Spatial Biodiversity Assessment (NSBA) 2004 which completes a "spatial assessment of the conservation status of selected marine biodiversity patterns at a national scale" (Lombard et al, 2004). Although it does not give an indicative answer as to the exact species which may be under threat on site; due to the lack of research it is a useful tool to assess the broader scale value of the marine habitats which could be under threat from a development. The study draws on research and expert input from 47 experts from a plethora of marine biodiversity fields as well as 30 other participants from the research field. The National Spatial Biodiversity Assessment although appropriate to use as a point of reference to highlight major issues that may arise in the event of such a development does not substitute any SWEC specific on site locality study.

The Irreplaceable Habitat Map is a spatial biodiversity study undertaken to determine the irreplaceability of biodiversity and its geographic location nationally. The Study considers inter-tidal habitats near shore, subtidal habitat comprising of the shallow photic area (~10 m to the abyssal plain) as well as habitat analysis for seaweed, intertidal invertebrates and fish (Lombard et al, 2004). The intertidal habitats which lie directly behind the SWEC development site are likely to be impacted by the laying of subsea cables for electricity evacuation as well as feeling the effects of reduced wave energy. Small impacts on the near shore environment carry significant threats as the spatial biodiversity assessment ranks the intertidal habitat along the proposed SWEC site as “totally irreplaceable” see Appendix B: Figure B - 1: Irreplaceability analyses of intertidal habitats (50km) (CSIR, 2008). Thus implementation of the SWEC or any other converter carries the threat of habitat destruction and environmental impact in the near shore environment which may prevent environmental authorisation being awarded or impose stringent conditions.

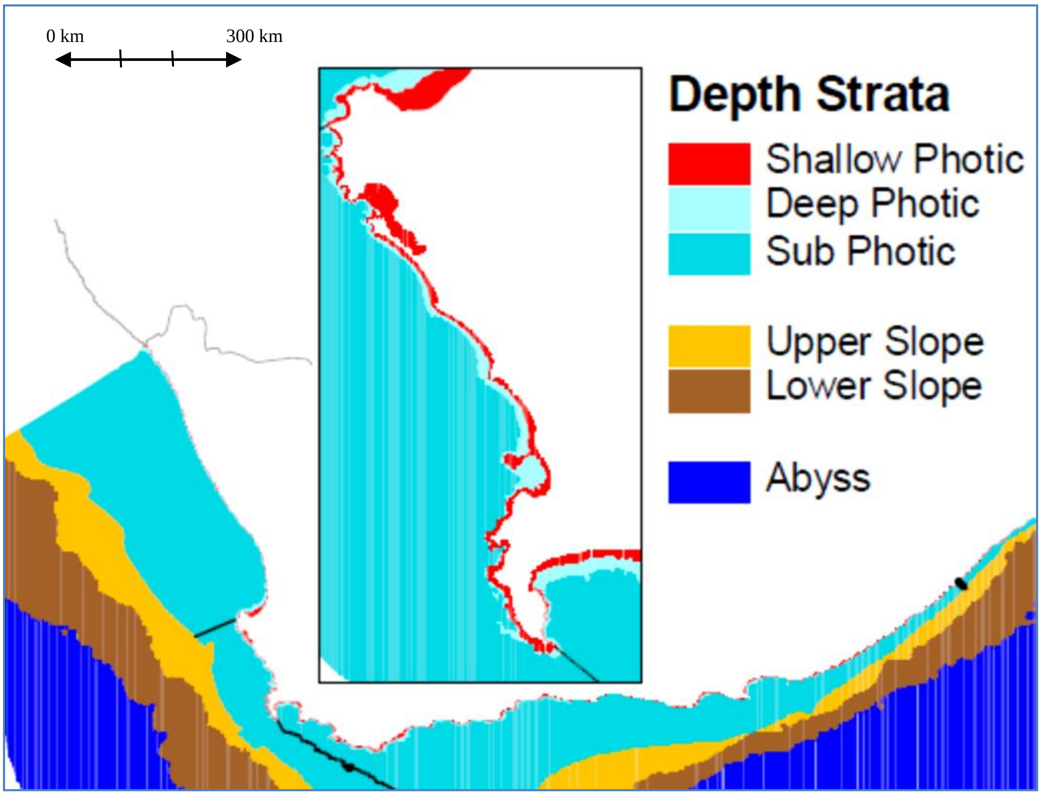


Figure 4-1: Representation of the Extent of the Depth Strata off the south west coast of South Africa (Lombard et al, 2004)

The reason for the high priority habitat near shore is due to the spatial assessment being carried out on the pretext of the distribution and number of species within three categories which were used to rate the irreplaceability of different habitats. The study was based on three datasets and their ability to reach a target where each species is required to occur at least once in any MPA or 50 km stretch. These datasets included:

(i) "The seaweed distribution data supplied by J. Bolton (Bolton and Stegenga 2002; Bolton *et al.* 2004). This dataset is a presence matrix of 803 species, in 59 x 50km coastal strips around South Africa."

(ii) "The intertidal invertebrate data supplied by C. Griffiths (Emanuel *et al.* 1992; Awad *et al.* 2002). This dataset is a presence matrix of 2524 species, in 27.5 x 100km coastal strips around South Africa."

(iii) "The fish data supplied by J. Turpie (Turpie *et al.* 1999). This dataset is a presence matrix of 1239 species, in 52 x 50km coastal strips around South Africa"

(Lombard et al, 2004)

Intertidal invertebrates occur in the inter-tidal zone, while seaweeds, kelp and smaller reef fish occur largely in the shallow and deep photic areas in kelp reefs and coral reefs along the coast. Although the SWEC device would be located in the deep to sub photic area it is likely that there will still be direct construction impacts on seaweeds, kelp, intertidal invertebrates and fish. In addition the reduced wave energy due to the SWEC's terminating characteristics and the associated subsea cabling for the SWEC may impact on the habitats between the SWEC and coast line. The results for the irreplaceability analysis for seaweeds, intertidal invertebrates and fish for the South African coast line were completed by Lombard et al, (2004) are provided in Figure 4-2.

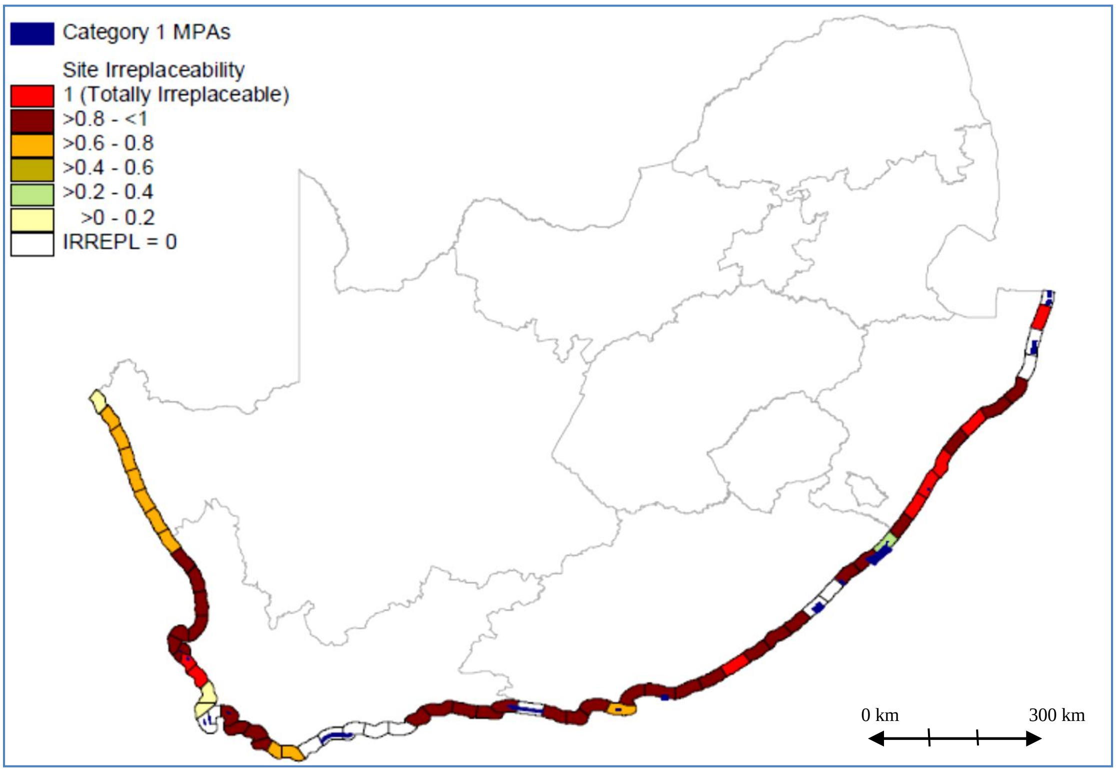


Figure 4-2: Irreplaceable Habitats Scale for seaweeds, intertidal invertebrates and fish. SWEC site=1 (100% irreplaceable) (Lombard et al, 2004).

According to the study of the three key datasets the near shore coastal habitat at the location of the SWEC development is completely (100%) irreplaceable (Lombard et al, 2004). This would mark it as highly valuable habitat and destruction of it would not be able to be compensated or restored elsewhere (hence the totally irreplaceable rating). That makes any development which threatens the habitat in the area unfavourable. In addition subsea cabling infrastructure for the SWEC would need to be addressed methodically as it would run directly through the inter-tidal environment. Cabling activities may have high impact, reducing the functioning of irreplaceable habitat. Since the ecosystem dynamics may be fundamentally altered by the reduction of wave energy, placing the SWEC in a manner which reduces wave energy may pose a greater threat to the functioning of the irreplaceable inter-tidal habitat and coastal processes (PIER, 2007; Lombard, et al, 2004). The typically high energy favouring kelp and algae species may be threatened as reduced wave energy may give seaweed species which thrive in lower energy environments a competitive advantage (PIER, 2007). Thus any development in the deeper waters obstructing wave energy from reaching the near shore may fundamentally threaten irreplaceable habitat.

Beyond the intertidal habitat, subtidal habitat occurs within the shallow, deep and sub photic areas. It is specifically in the deep photic area where kelp reef and coral reef habitat can be found, which overlaps with the desired site for the development of the SWEC (Lombard et al, 2004). This suggests that the construction of the SWEC development may offer direct impacts to kelp forests and coral reefs (Lombard et al, 2004). In "subtidal environments reefs are regarded as one of the most threatened habitats" (Lombard et al, 2004). Despite this there is a significant lack in spatial data documenting the reefs distribution, type, density and size. The spatial biodiversity assessment used a measure of bottom complexity by utilizing measurements from species and intertidal analyses in 10 km sections of coastline. According to the complexity analysis for the deep photic zone the length of the SWEC site proposed for development is ranked as having low complexity (Lombard et al, 2004). This would indicate that the deep photic areas are sand-bottom dominant and there are likely few reefs; therefore the threat to reef systems is low. However the analysis is only abroad scale assessment without any reef specific information relying on proxy measures to produce results. An onsite investigation into coral and kelp reef systems would be required to replace the assessment completed by Lombard et al, (2004) as it is only sufficient to serve as a regional study. The deep photic complexity map indicating low complexity for the south west coast can be seen in Appendix B: Figure B - 2 (Lombard et al, 2004).

The threat of habitat destruction due to construction activities is adjudged to be less significant than they would be in an intertidal habitat. This is due to the irreplaceability value of subtidal habitats being lower than they are for near shore environments according to the study by Lombard et al, (2004). The irreplaceability was ranked to be moderate at between 0.4 to 0.6 (40% - 60%) irreplaceable as seen in Figure 4-3 where the subtidal habitats are assessed on a 20 minute by 20 minute grid reference scale. Due to the lack of data on marine biodiversity patterns in the subtidal habitats, surrogate dataset were utilised. The datasets were based on abiotic data, which are the non-living chemical and physical features of the environment such as sediment type and bathymetry of the seabed. Features such as these act as a proxies for biodiversity based on the sediment type, bathymetric conditions that certain habitats portray (Lombard et al, 2004). The abiotic features which were selected as proxies are as follows:

(i) "The deep-sea sedimentary environment map of Dingle *et al.* (1987) (provided by L. Drapeau, MCM, and updated in this report).
(ii) Texture of surficial sediments of the continental margin (Marine Geoscience, Series 3, Department of Mineral and Energy Affairs, 1986).
(iii) Submarine canyons from P. Ramsay (Marine GeoSolutions)
(iv) Untrawlable grounds on the Agulhas Bank (R. Leslie, MCM). These were treated as a separate habitat, because it is assumed that they differ in complexity from surrounding areas (they are untrawlable because of hard outcrops).
(v) Seamounts (marine chart SAN 4, Hydrographic Office, SA Navy)"

(Lombard et al, 2004)

The proposed SWEC site would be located in a 0.4 – 0.6 rated area however the site borders 0.6 -0.8 and 0.8 - <1 rated areas in the sub tidal zone (Figure 4-3) (Lombard et al, 2004). Therefore construction in the proposed site would be conceivable although the surrounding habitat is high value habitat which would be unfavourable to disturb. In addition it should be noted that the analysis is only a proxy for expected conditions and would not be sufficient to conclusively state the biodiversity richness of the proposed site. Consequently a detailed biodiversity study would need to be conducted for the site with a degree of monitoring in order to prevent excluding migrating species from the study.

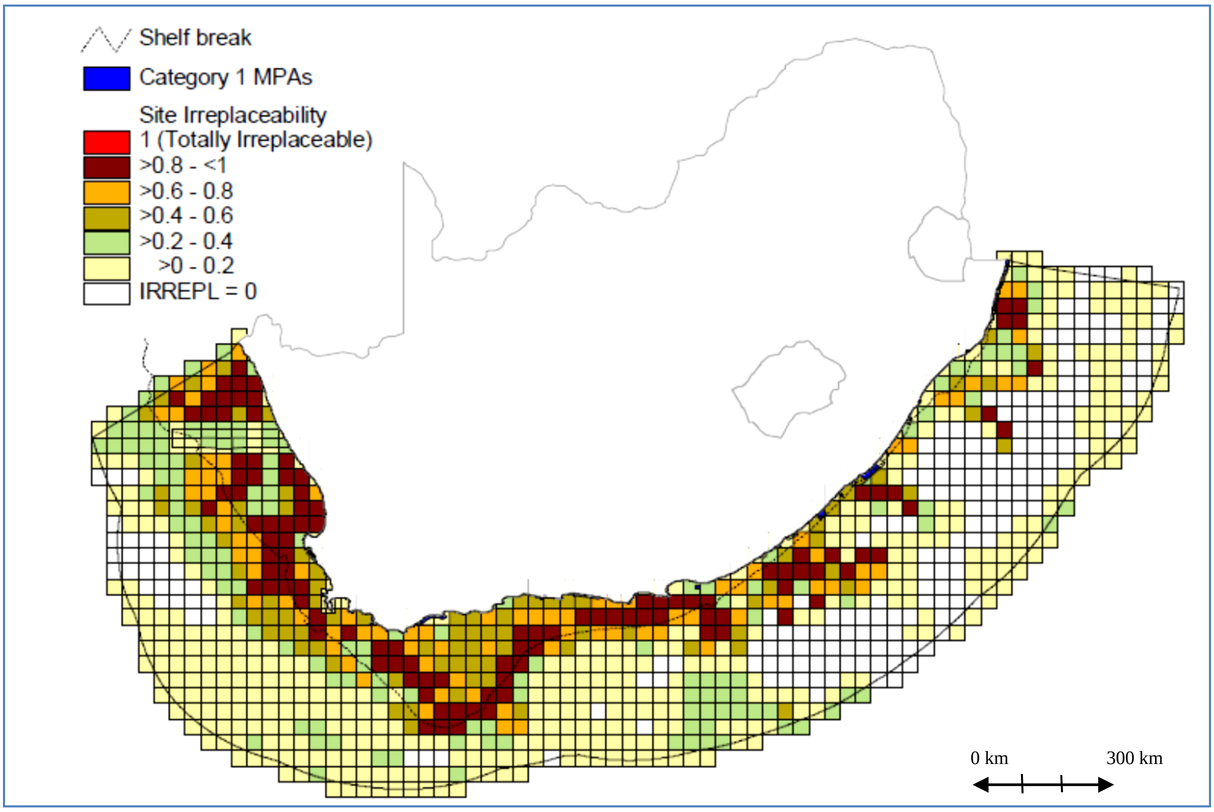


Figure 4-3: Irreplaceable Sub-tidal Habitats Scale. SWEC site 0.4 – 0.6 (40-60% irreplaceable) (Lombard et al, 2004)

Due to the biodiversity value of the areas surrounding the SWEC site, a nine factor analysis was used to complete a Biozone Threat Status map by the 47 experts. Expert workshops were used to generate this assessment where the experts rated nine threats on a scale of 0 -10 for each of the biozones. Ratings of the threats were provided for current conditions in the biozones as well as for future scenarios (Lombard et al, 2004). The nine threats considered in the survey are displayed in Table 4-2.

Table 4-2: Nine Threats to Coastal Biozones in SA, Ranked by Experts (Lombard et al, 2004)

Threat	Current total rating	Future total rating
1. Extractive marine living resource use (EMLRU)	158	179
2. Pollution	79	100
3. Mining	55	73
4. Coastal development	49	73
5. Climate change	41	72
6. Catchment issues	39	43
7. Non-extractive recreational activities (NERA)	38	48
8. Alien invasive species	22	40
9. Mariculture	18	32

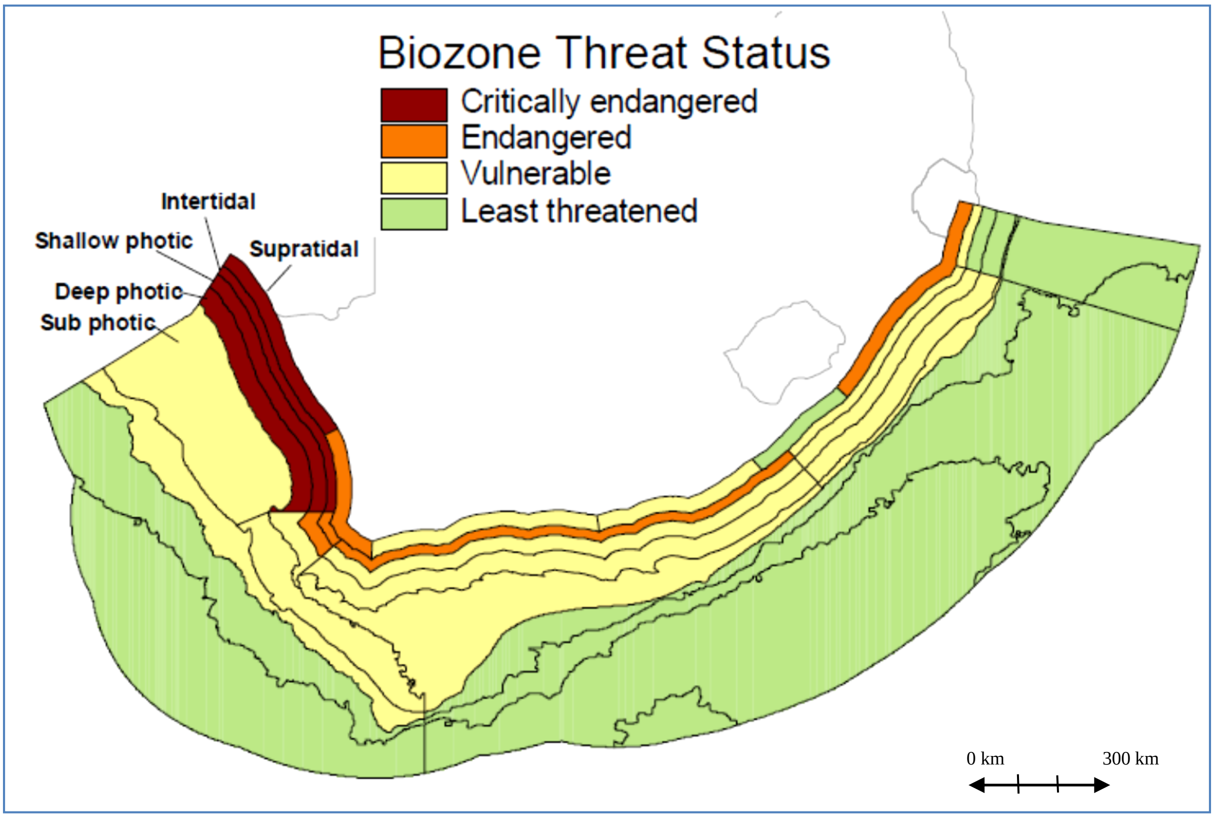


Figure 4-4: Summed expert rating for nine threat factors, per biozone, ranked from Least threatened to Critically endangered (Lombard et al, 2004).

Based on the rankings of the severity of the threats for each biozone a map was constructed to portray the threat status of South Africa's marine environment (Figure 4-4). The south west coast is regarded as either endangered or critically endangered depending on the depth strata which are being operated in. The threat status for this section of the coast is only reduced to vulnerable in the sub photic areas. As the SWEC will predominantly be operated in the deep photic and shallow photic area, large scale construction and thus the foot print of an array poses a major threat to the critically endangered habitat. The findings by Lombard et al, (2004) make a large scale development in the area unattractive and the potential to have wide spread environmental drawbacks for species reliant on the critical habitat. Currently the largest threat to the biozone contained in the proposed SWEC site is extractive marine living resource use (EMLRU) (Lombard et al, 2004). EMLRU may be exacerbated by habitat destruction associate with device and cable construction. However the EMLRU threat may also decline if the entire SWEC site were ruled as an exclusion zone, preventing fishing entirely (PIER, 2008). Additionally this could pave the way for an extended MPA which is proposed for the coastline surrounding Dassen Island and Sixteen Mile Beach (see Figure 5-2) which would almost remove the threat of EMLRU on the south west coast (Du Plessis, 2012).

4.3.2 Wave Energy Site Selection

Little literature surrounding the issue of site selection for a wave energy converter in South Africa exists. The key deciding factor in locating a wave energy converter is the wave energy and prevailing direction of the wave climate. This directly affects your energy output and is naturally the first factor influencing the location of a WEC (Geustyn, 1983). The studies which do exist are based on wave climate however a high wave energy climate is only one factor in many that play a part in site selection for a WEC site. Some of the earliest work on this was compiled by Retief et al, (1982) where a site on the south west coast was selected based on the high wave energy climate, wave direction, soft sandy seabed, close to a demand center and in close proximity to the electrical grid (Retief, 2007; Retief et al, 1982). Shipping routes and marine safety were also considerations discussed by (Retief et al, 1982).

More recently a wave energy site selection process was initiated. In 2008 the Council for Scientific and Industrial Research (CSIR), (2008) was commissioned to undertake a site selection study for Eskom; South Africa's in the "*Selection of Sites for Deployment of Wave Energy Conversion Technologies*," completed for Eskom (public utility power provider) as a prospective site selection tool for a wave energy device location on the South African coastline. The study is effectively a mapping exercise which uses constraint mapping to eliminate areas where wave energy development would interfere with human or natural activities. The exercises utilised factors such as wave energy climate, environmental sensitivities, marine protected areas, and shipping routes. The results of the study by CSIR, (2008) align with the conclusion of the SWEC developers that the proposed SWEC site along the south west Coast of South Africa detailed in Figure 1-3, as the preferred site for the deployment of a WEC. A diagram with the overplayed selection criteria of the CSIR can be seen in Figure 4-5.

Figure 4-5 indicates the sections of prefer coastline listed in green. This layer is a base layer identifying preferred areas depending on high wave energy environment and distance from shore, creating the solid green band hugging the coast line. Areas not preferred or excluded from wave energy deployment are displayed in solid red. Over this layer the marine protected areas and national parks have been identified in orange horizontal lines and solid yellow respectively. Shipping routes are overlaid in diagonal red lines seen in Figure 4-5. The final layer is areas of biodiversity sensitivity displayed in red crosshatch. When all these layers are brought together in Figure 4-5 it allows you to quickly identify which areas would be appropriate for WEC development and these areas would be those appearing in solid green with no overlay (CSIR, 2008). The result is the off shore stretch of coast line between Cape Town and Saldanha Bay being identified for a potential WEC development. This suggested stretch encapsulates the area between Grotto Bay and Langebaan suggested by Retief et al, (1982) for the location of the SWEC device.

The CSIR study identified the same section of coast line between Grotto Bay and Langebaan (Figure 1-3) as the preferred site for a WEC, despite the considerable value of the biozones located on the south west coast suggest by Lombard et al, (2004). The outcome of the NSBA detailed in Figure 4-4 is contradictory to the area suggested by the CSIR, (2008) detailed in Figure 4-5. The study by CSIR, (2008) determined Grotto Bay to Langebaan approximately 15km seawards as the preferred site mainly due to its favourable near shore wave conditions. The site selection included criteria beyond wave energy such as “fishing routes, shipping routes, marine biodiversity, major features, geology and seafloor conditions, adverse weather conditions, unsuitable topography, current and wave interactions and coastal mountains” (CSIR, 2008). Although marine diversity is a consideration, the selection process includes only marine protected areas as an indicator for sensitive species and ecosystems. CSIR, (2008) note that use of national marine protected areas as an ecosystem sensitivity measure as a limiting factor. This assumption assumes that all high value areas of the coastline are protected. Considering only 11% of the South African coastline is protected a significant portion of biodiversity is difficult to account for. The study by CSIR does utilize the national spatial biodiversity assessment in the site selection process, but the degree to which this factor influences the constraint mapping in selecting a WEC site is unclear. CSIR, (2008) recognise this fact and state that “thresholds can be critical in determining the areas available for deployment of WEC farms, and these will need specialist investigation when decisions are made on specific locations” (CSIR, 2008). Also the relative importance of each criterion such as environmental versus the technical perspective will need to be agreed upon on a site specific basis (CSIR, 2008).

Even if large tracts of the proposed SWEC site remains unprotected the south west coast still contains extents of limited habitat which are vital to the functioning of species and ecosystem dynamics. Any development may interrupt the system functioning, therefore potential impacts on species and their interactions with the device need to be assessed meticulously. Impacts on specific species will be discussed in order to unbundle potential threats to sensitive marine life.

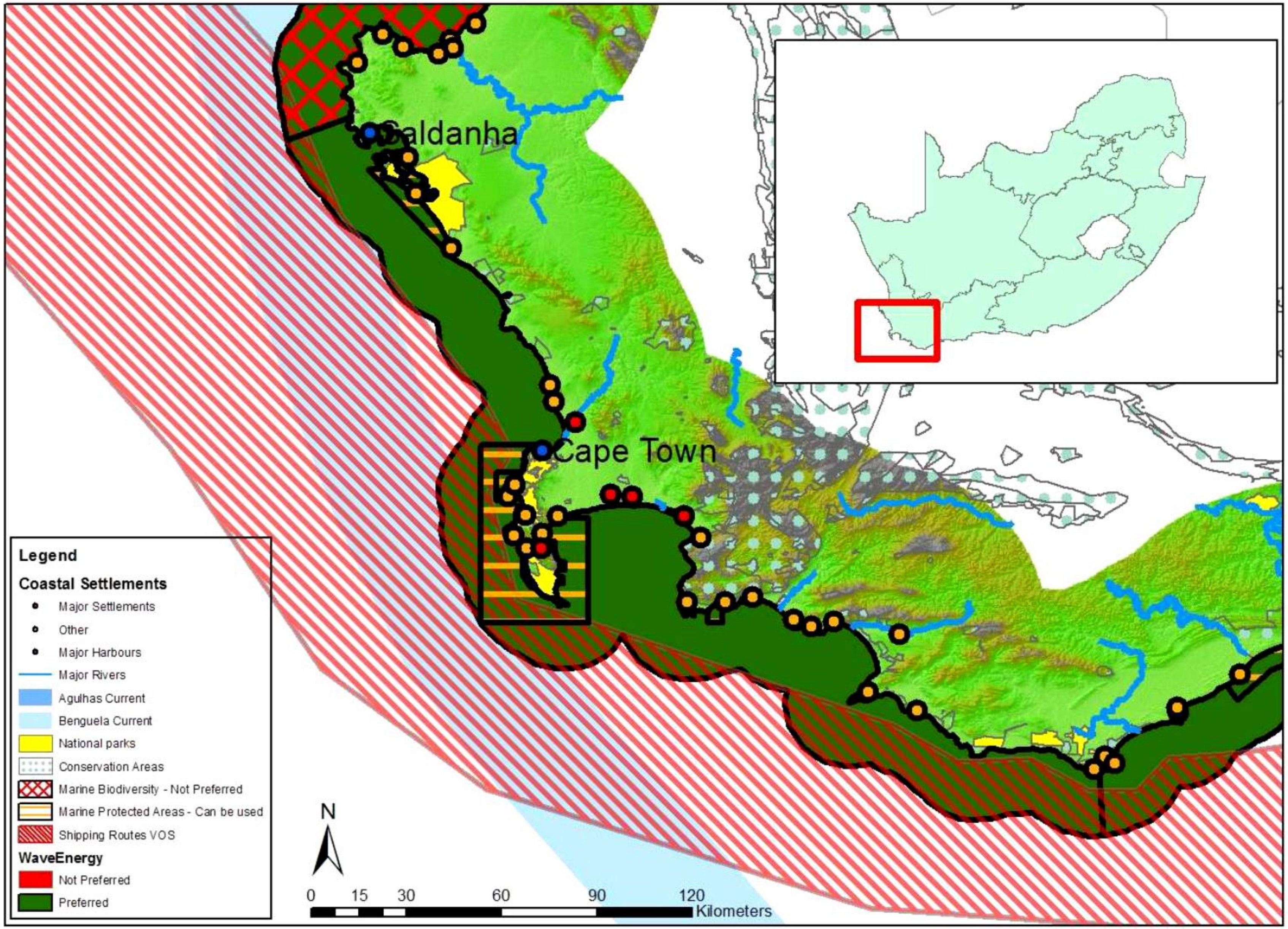


Figure 4-5: Site Selection Criteria for the South Western Coast of South Africa (CSIR, 2008)

4.3.3 Site Preparation

Site preparation offers one of the biggest threats to endangered and threatened habitat. A number of activities will be required before the segments of the SWEC can be drawn down and fixed into the seabed. Activities which are documented to cause environmental impacts is the dropping of anchors or supports for the WEC which would crush benthic organisms, increase turbidity as well as altering the accessibility to certain habitats (PIER, 2008). A change in the turbidity of the environment would reduce photosynthesis due to increase suspended solids resulting in lower productivity of photosynthesizing organisms which may have up the chain impacts within the ecosystem (PIER, 2008). The major concern in the case of the SWEC would be vegetation clearing due to the sheer size of the SWEC.

The SWEC device consists of two 160 m long concrete arms that are approximately 4m wide which gives the development a foot print of 1280 m^2 (0.128ha) for the concrete cast sections of the SWEC. However if the area between the arms of the SWEC is also subject to vegetation clearing then the effective area translates into 12800 m^2 which is equivalent to 1.28 hectares in size. It is possible that the seabed between the devices converter arms would need to be cleared and levelled to benefit the functioning of the device and to be utilised as a lay down and anchor set down area during construction. The combination of these activities would result in the destruction of significant tracts of habitat which is rated as critically endangered in the expert summation in National Spatial Biodiversity Assessment (Figure 4-4) (Lombard et al, 2004). If the project were to be scaled up to a commercial array of 154 SWEC devices the footprint of vegetation destruction from the devices is at a minimum 20 hectares habitat. If the worst case is expected and the effective area is used in the same calculation the maximum habitat destruction could potentially be 197 hectares excluding the area of seabed required for cabling routes. The placement of such structures on hard surfaces would result in the crushing of corals and organisms preferring hardened habitat. On softer sandy surfaces increased turbidity and changes in sediment deposition may affect particular benthic organisms and certain species spawning patterns (PIER, 2008). The development of a full array would represent large scale destruction of sensitive habitats presenting a large challenge requiring far more extensive and fine scale studies in order to derive a conclusive answer.

4.3.4 Noise

Noise is the other of the major concerns when constructing within the marine environment. The construction of the SWEC has a number of noise generating activities throughout construction ranging from boat traffic to directional drilling (cabling) and pile driving (Finlay, 2012; Retief, 2012). Noise impacts can be particularly damaging under water as the sound carries much larger distances in submarine environments. The impacts become more severe when the noise is percussive and repetitive (piling) as this has the potential to drive species away, ultimately altering normal behaviour (Finlay, 2012). As such the construction methods of the SWEC need to be considered in terms of noise production.

Noise Generation

The SWEC locality would be a number of kilometres from port where vessels and equipment would be launched. Consequently vessels would have to travel to and from the proposed site in order to conduct further studies, site investigations, transport equipment and device components as well as the required mobile construction vessels. The transportation requirements result in a considerable increase in marine traffic in the area which increases noise levels. The route to and from the site would become busy with vessels thus increasing the level of disturbance experienced by fish, birds and mammals. It remains to be determined if animals in the area are used to high levels of marine traffic or whether the noise impact would alter normal behavioural patterns; as such further investigation is required (Retief, 2012; PIER, 2007).

Depending on the precise method chosen to construct the SWEC device there would be an element of noise in the site preparation and draw down of the device segments into predetermined positions. This marine noise would likely be a combination of boat noise, potential dredging, vegetation clearing or any sediment removal equipment (Finlay 2012, Retief 2012 and PIER, 2007). Although noise creation would occur the severe impact from noise would be as a result of seismic surveys, directional drilling and pile driving (Nowacek et al, 2013). Seismic surveys use “loud, primarily low frequency sound to penetrate the sea-floor, and are known to disturb and could harm marine life” (Nowacek et al, 2013). The aim of a survey is to determine solid seabed to locate bottom mounted WEC’s on a stable surface. Uncertainties around seismic surveys and the increasing frequency of their use there is a growing need for the development establishing “operational standards and systematic planning” (Nowacek et al, 2013). Directional drilling would be required in the case of wanting to submerge subsea cables below the seabed. This would have a hammering noise effect as well as vibration with possible disturbance on intertidal invertebrates and fish. It is most likely that this activity would be required in the intertidal zone in order to cross the turbid surf zone (PIER, 2007).

The SWEC is a bottom mounted device which will most likely be lowered via a jack up rig and driven into the seabed via marine pile driving equipment rather than the traditional gravitational base foundations (Retief, 2012). The activity of pile driving generates a high decibel, repetitive, percussive noise which carries great distances in a marine environment (Finlay, 2012). Vibration and the noise may frighten off a number of mobile species in the surrounding area. It is documented that underwater noise if of sufficient level and frequency can injure or kill marine mammals, birds and fish (PIER, 2007).

Noise Impacts on Marine Animals

The most severe noise impact would be due to the extreme percussive hammering from pile driving or loud low frequency noise from seismic surveys (Nowacek et al, 2013; Finlay, 2012). The other major concern would be the boat noise from increased marine traffic with other noise factors being short term or more localised and of lower decibel levels. Boat traffic would act as a potential disturbance to the marine animals where pile driving may even injure or kill marine life at certain levels. Marine mammals rely on vocalizations to communicate under water between group members with this interaction being particularly important amongst whale species (Finlay, 2012). Therefore constructing a device such as the SWEC, with the noise impacts from seismic surveys, pile driving activities and boat activity can potentially be very damaging. The negative effects of pile driving activities on mammals are well documented and have to the potential to cause avoidance or mortality in extreme cases (PIER, 2008). Frid et al, (2011) reports that in off-shore wind farm construction noise impacts were reported to be influential on whale species up to a distance of 15km away. Whales and dolphins are thought to be the most severely affected animals due to their communication requirements but fish and birds may also experience injury or mortality due to certain levels and frequency of noise pollution (Finlay, 2012; PIER, 2007) Impacts may include deterring the animals from feeding or using the area as a migratory corridor (Finlay, 2012). Impacts on specific species will be discussed individually.

4.4 Operation Phase

The ocean consists of a number of complex interactions between marine flora and fauna, currents, temperatures, and salinity. All the factors combine to form the unique pelagic ecosystem located on the south west coast. The operation of a WEC such as the SWEC may alter the dynamics of the natural environment. However the placement of an entire array of devices will have a much more considerable impact (Retief, 2012). When considering the minimum 20 year period for which the devices will be deployed, it is vital to consider the environmental impacts of the development in the long term. This point is compounded when the potential impacts of the device are unclear. There has been limited study of the impacts of wave energy converters and the completed studies are largely theoretical and based on a wide array of devices for different localities (Boud, 2003). Hammar, (2014) suggests that “stressors across marine renewables (offshore wind, wave power and tidal turbines) are all similar,” but there are still uncertainties regarding specific stressors such as collisions in submerged devices. Consequently a synthesis of potential operational phase impacts for the SWEC device in South Africa would offer a starting point for any study aimed at developing a wave energy converter locally.

4.4.1 Up the Chain impacts

A single WEC unit capturing roughly 30% of the wave energy over a hectare of sea bed 2km’s off-shore is unlikely to have any significant impacts on ecosystem population dynamics or regional sediment transport patterns (Retief, 2012). Thus the significance of any impacts would be low. Therefore the likelihood of secondary prey impacts of a single WEC unit on up the chain (apex) predators would be minor. This is not to say that there may not be direct impacts on larger predators (Sharks, seals, dolphins and whales) due to direct interactions with the SWEC unit.

The deployment of a single SWEC unit would introduce a large reef size, hardened surface into a soft, sandy environment with relatively few topographic features. This is likely not to be an isolated event as many WEC’s will be located in sandy bottom environments hence utilizing piled structures as foundations (PIER, 2008). Along with the hard surface structures, would be the colonization by reef type species, introducing diversity into a relatively less complex environment. The reef would be an attraction to species offering new feeding and sheltering habitat, resulting in a different and more diverse biological community than a typical sandy habitat. Impacts will result due to the interaction of species not typical to the environment. In the worst case the altering of the environment may provide habitat for invasive species (PIER, 2008). The degree of the impact would depend on the scale of the development. A full SWEC array of 154 devices will have impacts with considerably higher magnitude than a single unit. The density and placement of the devices in the array would act as important factors in the significance of the impact (Retief, 2012; PIER, 2008).

An array of 154 SWEC units would have much larger scale impact parameters. The implication of an entire SWEC array on trophic organisms, pelagic fish and predators extends beyond the direct habitat and population impacts (Finlay, 2012). The long term negative disturbance of pelagic fish species due to the operational outputs of the device are expected to be insignificant (Finlay, 2012; Retief, 2012). With increased sheltering and habitat for pelagic fish species in combination with a no catch zone the population size would be expected to increase (Finlay, 2012). The factors contributing to these conditions of population growth are discussed further.

The SWEC may require the operational area to remain a vessel free zone to reduce collision risk creating the no catch zone. As such fishing vessels and trawlers will have no access to approximately 80 km^2 of marine environment with a full WEC array. The concrete wall and lower energy climate behind the SWEC will likely encourage the settling of marine organisms and the seeding of an artificial reef (Finlay, 2012). This reef will increase productivity by creating a breeding and feeding haven for pelagic fish in which they are not threatened by fishing activities. This has the potential to boost intermediate trophic level fish populations. This will allow the smaller fish habitat to recover from fishing and trawling events to a large enough degree that a WEC array would increase fish populations and possibly the numbers of higher order predators contributing to species recovery (Finlay, 2012; Cury et al, 2001). Therefore an entire SWEC array may have the potential benefit of creating a protection zone by excluding fishing activities and creating breeding habitat (Finlay, 2012). In combination with incorporating mitigation measures into the SWEC design such as holes for crayfish could enhance the ability of the SWE to form protective habitat. High order predators may then experience up the chain (marine food chain) impacts through the alteration of prey resources at the intermediate trophic level. Seals, seabirds and porpoises would all be affected by the operation of the SWEC in the pelagic zone (Cury et al, 2001).

4.4.2 Direct impacts

Energy Extraction - Coastal Processes

WEC devices reduce the wave energy behind the device in what is known as the wave shadow. As noted in section 2.4 Zettler-Mann, (2010) numerically proved that WEC's reduce wave energy on the leeward side of a device, proved for the Pelamis and the Wave Dragon. The reduction in wave height and energy was proven down wave on a site specific basis for the Portuguese continental near shore using the Wave Watch 3 and SWAN Models for the entire year of 2009 by Bento et al, (2014). The amount by which this occurs may potentially have impacts on near shore marine life and coastal processes (Gonzalez-Santamaria, 2013). One category of device known as terminator devices lie perpendicular to the wave direction converting large proportions of energy (device dependant but >30%) into mechanical energy.

Gonzalez-Santamaria, (2013); PIER, (2007) notes this reduction of wave energy available to coastal processes may result in up to forty eight changes to:

- sediment transport patterns;
- beach nourishment;
- coastal erosion and;
- Among other coastal processes.

Depending on the design of the project, the structure of the SWEC would act as a breakwater or jetty. WEC's have been thought to affect coastal processes by altering the amount of energy embodied in a wavelength. The possibility of converters altering the summer and winter wave climate was suggested by Retief, (1979) with specific reference to the Stellenbosch Wave Energy Converter. In addition the possibility of WEC's reducing the slope of waves if converters are located less the 30 km offshore was also raised as a concern. This is of importance as waves are responsible for shaping beaches and recycling sediment.

Waves begin to interact with the seabed when the wavelength equals the depth of the water. Typically, depths of approximately 50 m and less is where waves start to have an appreciable impact on bottom current (Segar, 2006; Boud, 2003). The placement of the SWEC device in depths of up to 50 m would reduce wave energy and create a wave shadow on the leeward side of the device. The reduction in energy would reduce the near bottom orbital currents resulting in sedimentation in areas that would usually not experience sedimentation (PIER, 2008). Consequently the delivery of dissolved and particulate material (food) to benthic (bottom dwelling) organisms would be reduced in the wave shadow but also beyond due to the lower wave energy (PIER, 2008). This carries the threat of altering wave driven benthic (bottom) systems resulting in less productive benthic systems but further detailed study is required. Additionally the vertical mixing of stratified layers of water would be hindered due to the reduced wave energy behind the SWEC (PIER, 2008). The result of less mixing is that the deeper, cooler waters are not mixed with the warmer, surface waters resulting in warmer sea surface temperatures. The alteration of sea surface temperature could fundamentally alter species composition of near shore communities in the south west coast, cool current system (PIER, 2008). Although the extent to which reduced wave energy could alter vertical mixing is uncertain the overall impact on the near shore community from both reduced nutrient transport and increased sea surface temperature needs to be addressed in a further fine scale study.

On the shoreline waves arrive at many varying angles. This generates currents that move along the shoreline carrying suspended sediment. Waves which occur at a perpendicular angle to the shoreline will either deposit sediment or recover sediment and suspend it in the retreating water body (PIER, 2008). The angular long shore currents transport sediment in what is known as long shore drift where sediment is recycled and moved along the coast in a dominant direction (PIER, 2008). There are many methods for calculating the long shore drift. Using wave power evaluations, PIER, (2008) "correlates the energy flux of waves in the direction parallel to the shore with sediment transport measured in sediment traps" (PIER, 2008, pg. 71). It is empirically proven that the reduction in wave height due to an offshore WEC results in an amplified reduction in long shore currents and hence long shore sediment transport (PIER, 2008; pg. 71). This method can only provide estimates of long shore current due to variation in shoreline angles and irregularity of the seabed (PIER, 2008). However, a discernible reduction in wave energy would alter sediment recycling and transport (Retief, 2012; PIER, 2008; Boud, 2003).

A reduction in wave energy would also alter the patterns by which sediment transport occurs. Beaches tend to follow accretion cycles which mimic wave cycles (PIER, 2008). The results of the numerical model of Abanades et al, (2014) shows the reduction in wave energy leads beaches to accrete and the evolution of the beach profile (Abanades et al, 2014). This concern of a reduction in the erosion of the beach face was raised for the SWEC device by Retief, (1979). The increased deposition rates may also begin to alter rocky, hard-bottom environments such as kelp forests and allow them to become sand dominated environments (PIER, 2008). Unlike rocky environments, organisms inhabiting soft, sandy habitats survive by living within the sediment where as they would attach themselves to rock in the harder habitat. Although organisms survive insulated from hydrodynamic forces within the sediment layer, the layer is inherently dynamic (PIER, 2008). Sediment deposition varies with wave energy, impacting on particle size and shape, resulting in shallower horizontal slopes, and finer sediment in higher energy environments (dissipative beaches) than low energy beaches (reflective beaches) (PIER, 2008).

As the site selected for the SWEC development is based on a sandy seabed surface (shown in Figure 4-6) the possibility of altering sediment transport and consequently shifting the profile of beach habitats is an appreciable concern (Wilkinson and Japp, 2005; Lombard et al, 2004). Sediment transport impacts are more severe with seabed mounted devices particularly when placed near shore, as the larger interactions between a bottom-mounted, terminator device and the waves driving sediment transport process, yield more of the waves energy (Joubert, 2008; PIER, 2008). The reduced wave energy results in decreased sediment transport volumes. This could have a number of knock on effects ranging from beach accretion, shallower slopes, and the accumulation of smaller particle sizes on dissipative beaches (PIER, 2008). An interesting nuance of dissipative beaches is that the higher energy waves associated with these beaches break further off shore, resulting in calmer environments very close to shore. Resultantly PIER, (2008), indicates that studies show the species richness and biomass abundance tends to be higher in the near shore environment of high energy (dissipative) beaches. This leaves organisms of sandy habitat exposed to changes in wave energy as the deposition rates would be increased. Increased deposition rates would alter the shape of the beach consequently changing the structure of the community and reducing habitat of beach spawning fish (PIER, 2008). Since knowledge on sandy beach habitats is limited, projecting the expected impacts of reduced wave energy would require further research on a beach specific scale. This prompts an enquiry into the possible sedimentary effects of WEC deployment in South Africa.

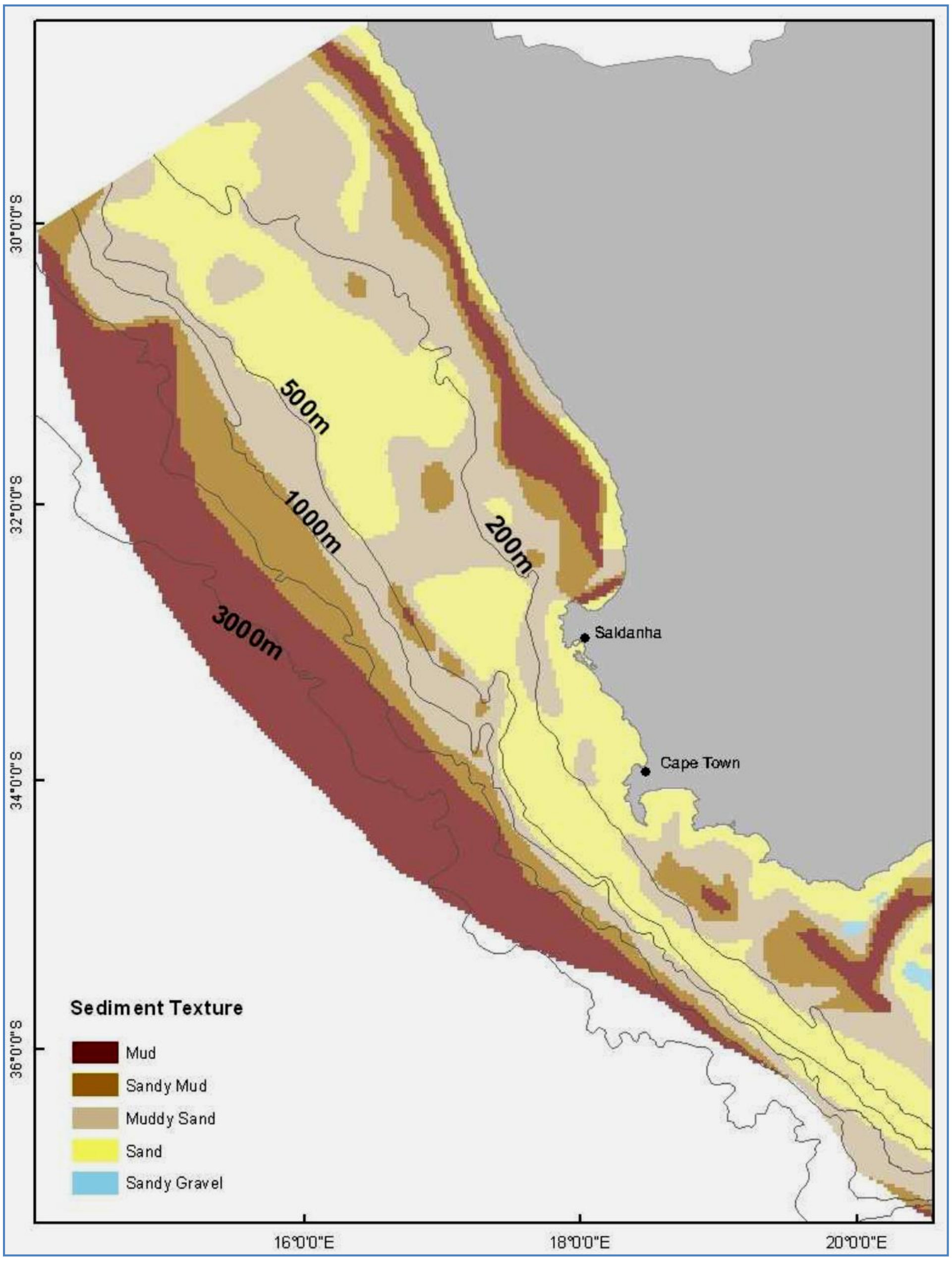


Figure 4-6: Sediment Texture for the South African Coastline (Wilkinson and Japp, 2005).

The reduction of wave energy via conversion also carries ecosystem dynamics implications as a relatively small decrease in wave energy levels could "lead to a pronounced increase the competitive advantage of faster growing algae and kelp species over wave- resistant species (e.g. giant kelp over bull kelp, fleshy algae over coralline algae)" (PIER, 2008; pg. 90). The estimated wave energy thresholds at which lower energy kelps will become dominant are displayed in Appendix C: Figure C - 1. High wave energy environments such as the surf zone have non-linear relationships with the population dynamics of kelp, intertidal invertebrates and other organisms; making an assessment of the impacts of a reduction in wave energy particularly difficult if not unachievable (PIER, 2008). Amongst the stated impacts the reduction of wave energy may also include the reduction of growth rates in plant organisms among some drift feeders and species reproducing via dispersal. The cause is the reduced wave energy limiting food transport, as well as reducing fertilization rates due to weakened dispersal and settlement of larvae (PIER, 2008). The reduction of wave energy has a highly complex impact or influence on the environment during the operation of a wave energy converter. The multitudes of interconnected relationships between marine organisms in the photic and intertidal habitats are not simply linear relationships which can be easily deduced. Therefore both linear and non-linear impacts need to be considered in their full complexity.

Marine Birds

The south western coast of South Africa is host to a number of marine birds. Coastal habitat as well as coastal islands form important habitat for many bird species. The SWEC development is proposed to be in part located between an important island habitat and the coastal habitat from many marine birds (Ralston 2012). Dassen Island in particular is a significant refuge for marine birds, providing an important conservation area and is in close proximity (<5 km) of the proposed SWEC development (Ralston, 2012). Forty nine bird species occur in and around the proposed site in the southern Benguela region. 15 sea bird species breed in the region and of these 7 species are endemic (DEAT, 2004). Twenty five of the species are migratory, fourteen are resident and ten are from the northern hemisphere (Blood and Crowther, 2012). A number of which are endangered threatened or vulnerable. Examples are the "African or jackass penguins (Spheniscus demersus) are vulnerable, cape cormorants (Phalacrocorax capensis) and white breasted cormorants (Phalacrocorax carbo), Cape gannets (Morus capensis), white chinned petrels (Procellaria aequinoctialis), Arctic (Sterna paradisaea) and Antarctic (Sterna vttata) terns, kelp gulls (Larus dominicanus) are all threatened" (Scholl, 2005). The bank cormorants, Black Browed Albatross and Yellow Nosed Albatross are all endangered bird species occurring in the region wherein the proposed site is located (Blood and Crowther, 2012; Lombard et al, 2004). A full list of the pelagic and resident breeding marine bird species can be seen in Appendix D: Figure D - 1 and Figure D - 2 respectively.

All the bird species have the potential to interact with the SWEC as they inhabit the same marine area, although the great variety amongst the species results in any potential impacts being highly variable. The placement of the device in the water body carries a number of specific associated impacts. Fishing birds and deep diving birds such as cormorant in particular, which dive below the surface of the water may risk collision with the device (Waggitt and Scott, 2014; PIER, 2008). The rate of collision would depend upon the foraging areas of the birds, the depth of the device below the surface as well as visibility as birds are highly reliant on their sight (Waggitt and Scott, 2014). This may be further compounded if prey such as foraging pelagic fish (sardine or anchovy) or juveniles of large species, are attracted to the relative protection and diversity of the device thereby attracting more birds (PIER, 2008). The implementation of the device also has the potential to destroy productive habitats and inherently carries the potential to disrupt or enhance food availability (PIER, 2008). The noise factor associated with marine traffic, and pile driving during construction and maintenance may disturb migrating pelagic fish thereby disrupting the birds food stocks (Ralston, 2012). If noise were to alter the migratory routes of pelagic fish such as the anchovies and sardines, there would be severe implications for the survival of the marine birds of the southern Benguela region who feed on fish (beside for gulls) (Ralston, 2012). The major concern with penguins would be that the SWEC is located within the species hunting grounds and acting as an obstruction may prevent them from pursuing prey in typically flat, open, sandy habitat. A further concern is the potential for diving birds or penguins to become entrapped in the air chamber of the SWEC device which would be turbid. Attraction to enter the 'mouth' of the device would need to be mitigated.

The noise impacts of construction, maintenance and decommissioning may also impact the nearby breeding colonies of the birds directly. The pile driving and marine traffic may seriously disrupt the nearby breeding colonies of Dassen Island which host hundreds of thousands of breeding species, including a number endangered species (Ralston, 2012; PIER, 2008). Dassen Island is of particular importance to the breeding penguin colony which is the largest in the Western Cape (Ralston, 2012). Two additional breeding penguin colonies are located at the mouth of Saldanha on Malgas Island and Jutten Island seen in Appendix D: Figure D - 3 (Blood and Crowther, 2012). In addition the noise impacts of construction maybe compounded by being located in the penguins hunting grounds, potentially reducing catch success and productivity of the birds. The likely response to noise disruption is abandonment of the breeding island site, which are already limited within the West coast habitat. Young or eggs may then be left unattended leading to mortality (PIER, 2008).

Penguins may attempt to haul out onto the device platform (PIER, 2008). Depending on the design of the platform which has not been finalised, this may be a potential hazard to the birds. The design of the surfaces and ledges available on the surface component of the SWEC could potentially encourage bird roosting. The proximity of Dassen Island is likely to increase the probability of roosting activities on the device (Ralston, 2012; Hofford, 2011) Along with roosting comes the deposition of bird guano. In substantial cases the guano may react with the device deteriorating its structural integrity (PIER, 2008). Navigational lights on the WEC device may attract some birds to it, especially juvenile birds, increasing interactions (PIER, 2008). The placement of the SWEC in such close proximity of breeding colonies and along a migratory route may increase the risk of collisions of birds with the above surface, device platform. Avoiding development near such colonies would be the most effective mitigatory measure however there are other measures to discourage birds from landing and roosting on the SWEC platform.

The SWEC poses the greatest threat to the nearby breeding islands which contain vulnerable and near-threatened species. The largest potential impact would be to cause abandonment of breeding sites. However there are measures to counter act potential negative impacts of marine traffic and noise pollution which should be pursued to prevent these avoidable impacts. Furthermore the potential for impacts on feeding patterns and collisions remains but definitive answers would only arise from detailed understanding of the SWEC's potential impact in pelagic fisheries and design specifications for collision prevention.

Fish

Fish on the west coast of South Africa can be roughly divided into three main counterparts based on depth. There are demersal fish (associated with the substratum or seabed), pelagic fish (found in the water column) and meso-pelagic fish (found in deep water both on the seabed and in the water column). Fish most likely to interact with a SWEC device based on debt of their habitat are shelf demersal and pelagic fish. The shelf demersal fish community (<380 m) is "dominated by the Cape hake and includes jacopever, Izak catshark, soupfin shark and whitespotted houndshark" (Blood and Crowther, 2012). In the summer months the pelagic goby and West Coast sole can also be found sharing the habitat with the other demersal fish.

The shelf pelagic fish community consists of small and large pelagic species. Most pelagic fish display a seasonal migratory pattern travelling between the West Coast and South Coast. The major spawning areas for pelagic fish (besides the Round Herring) are spread across the continental shelf and extend from south from St Helena bay, adjacent to Saldanha Bay, to Mossel Bay on the South Coast (Blood and Crowther, 2012). Pelagic fish spawn downstream of large upwelling systems in spring and summer, allowing the larvae and eggs to be carried north in surface currents around Cape Point and along the West Coast (Blood and Crowther, 2012). At the start of winter most small juvenile pelagic fish gather in large numbers in coastal waters between St Helena Bay and the Orange River, north of Saldanha. The shallow shelf region acts as a nursery ground as they begin to move south with the surface currents toward the major spawning grounds east of Cape Point (Blood and Crowter, 2012). The success of the spawning also relies on oceanographic nuances, affected by spatial and temporal variability. Thus the productivity of the small pelagic adult and juvenile is highly dependent on environmental conditions (Blood and Crowther, 2012).

Small pelagic species mainly occur within the 200m contour in mixed shoals that can vary in size from hundreds to many thousands. Species include sardine/pilchard, anchovy, chub mackerel, horse mackerel and round herring (Blood and Crowther, 2012). Snoek and chub mackerel are two pelagic species that migrate along the west coast, following sardine and anchovy shoals. Both species enter the south western portion of the coast between April and August where they moving inshore and spawn in June and July before migrating offshore in a northerly direction. This behaviour is of a direct result of the shoaling patterns of the smaller pelagic species (Blood and Crowther, 2012).

Larger Pelagic species tend to inhabit deeper waters, usually more than 300m, but between the deep water and the surface. They are distributed throughout the Southern Ocean with abundance in the mixed boundary layer of the Benguela and the Atlantic being seasonal and dependant on food stocks (Blood and Crowther, 2012). Larger pelagic species include longfin, yellowfin, bigeye, skipjack tunas, Atlantic blue marlin, white marlin, and broadbill swordfish (Blood and Crowther, 2012).

A SWEC unit or full array would offer a hardened surface for propagules to settle and seed on. This then creates the beginnings of an artificial reef. Trapped nutrients and protection will attract a number of fish species, particularly pelagic juveniles, to shelter in the reef as well as an area to feed on trapped nutrients and smaller animals seeking refuge in the reef (PIER, 2008). The artificial reef introduces a unique habitat that is limited in the surrounding environment. As a result of the increased biodiversity food availability and feeding efficiency improves, possibly leading to an increase in larval recruitment in the vicinity of the artificial reef (Frid et al, 2011). However the wave energy and ocean currents are redirected or weakened by the SWEC device, as a result the currents between feeding and breeding grounds impacting on fish egg and larvae transport (Frid et al, 2011). This may be damaging to the productivity of fish populations counter balancing the reef effect, but to determine which effect is likely to be more influential requires experimental study on a fine scale.

Although reef habitat may be beneficial to the productivity of some fish species it is likely to offer a competitive advantage to fish which have a preference to sheltered habitat rather than species adapted to surviving in the open sandy habitat of the south west coast (Frid et al, 2011). Fish diversity may rise in an otherwise relatively simple habitat. However, it has been hypothesised that the noise from the maintenance and running of the devices may impede the devices acting as natural reefs, as reef fish rely on reef noise to be able to settle productively that maybe masked by operational noise (Frid et al, 2011). Marine noise pollution may even prevent some fish species from locating their nursery grounds (Frid et al, 2011). Consequently the interactions between an operating WEC device and fish species on an artificial reef would need to be investigated including the potential effect on the natural habitat’s species richness and distribution.

Despite the main impacts of the SWEC being the introduction of hardened surfaces into the marine environment and the potential noise and current flow impacts, there is also associated infrastructure which may impact the animals. The requirement to transport electricity to shore via sub marine cables may impact on a specific subset of the fish category known as the Elasmobranch fishes (Sharks, Rays and Skates). Elasmobranches are all known to be sensitive to electromagnetic fields that are emitted from the sub marine cables. This issue will be discussed in section 4.4.3. Sharks which occur within the area of the SWEC development are largely pelagic sharks and species include blue (near threatened), short-fin mako and oceanic whitetip sharks. Great white and whale sharks are also known to occur on the south west coast (Blood and Crowther, 2012). Other than the Blue shark which is listed as vulnerable all species are ranked as vulnerable.

The most significant impact of a SWEC development would be on shelf pelagic fish and particularly the smaller pelagic fish due to the close proximity of the device to spawning, feeding and migratory grounds. A full SWEC array may have the potential to alter wave driven currents which would alter the flow dynamics of fish larvae and eggs potentially leading to a large scale alteration on the community on which the entire marine predatory system and human fisheries are based (PIER, 2008). A discernible impact on the medium trophic level in this community carries the direst consequences for ecosystem stability. A full scale study on the complex interactions between fish, the device, current and larvae flow dynamics and oceanographic nuances would be pinnacle to a full understanding of ecosystem functioning and potential impacts of a SWEC array.

Seals

The Cape Fur seal is the dominant seal species and endemic along the West Coast, occurring in 7 breeding and 5 non-breeding colonies. The closest colony to the proposed location of the SWEC development is the Jacob's Reef colony approximately 10km north of the northern most section of the development (Blood and Crowther, 2012). Breeding occurs in November and December yearly for the seal colonies. Four other vagrant species of seal can occur on the west coast including the elephant seal, sub Antarctic seal, crab eater and the leopard seal (Blood and Crowther, 2012). The proximity of a SWEC array to Jacob's Reef colony means that the seals are likely to have direct contact with the device and impacts on the breeding grounds may occur. Seals may attempt to haul out on to the device (Hofford, 2011). This may lead to animals injuring themselves. However at the practical design of the platform of the SWEC could prevent this.

Significant disturbance of seal colonies through movement and noise may have a similar effect to that of bird colonies in encouraging abandonment of breeding sites. This is especially critical as mothers may be forced to abandon their pups and expose them to trampling in the exodus (PIER, 2008). Marine mammals detect noise in two forms. Firstly, ambient noise is perceived directly by the animal. Secondly some mammals are able to use active and passive bio-sonar to locate prey and obstacles (PIER, 2008). Noise impacts on both these senses, altering behaviour by impairing their ability to locate prey or obstacles. Louder and higher frequency noise may cause temporary or permanent damage to these audible senses. Seals have been observed to sense noises such a pile driving up to 80km away with behavioural changes up to 20km away from the activity location (PIER, 2008). Severe artificial noise has been observed to cause permanent hearing loss in seals species at 400m and porpoise species at 1.8km (PIER, 2008). These senses are used for prey location and if submarine platforms are large enough they may entirely limit mammal's ability to pursue prey as the artificial reef would offer uncharacteristic protection (PIER, 2008). This is particularly the case in predators which prey on shoaling fish, dense clusters of crustaceans and krill (PIER, 2008). Predation on shoaling fish or krill (for whales) usually requires large open space, and a large development of obstructive devices may prevent the ability of predators to hunt. The SWEC's presence in the water column may hinder the feeding activities of seals as well as whales who pursue their prey and use sight, sonar (whales) and whiskers (seals) to sense prey (PIER, 2008). This also increases the threat of collision during pursuit. However the SWEC's lack of moving parts would reduce the chances of collision. The overall impact on seals is not expected to be severe. Although the feeding grounds maybe altered in that the pursuit of shoaling fish maybe obstructed by the device, the device may also create habitat where the seals may forage for west coast rock lobster and crab in the artificial reef habitat.

Whales

The south western coast of South Africa forms an important part of habitat for whale species, specifically for two main species of baleen whales, the Right and Humpback whale species (Finlay, 2012). Humpback and Right Whale populations are still recovering from whaling activities pre-protection in the early 1900's. Right whales are still at 25% of their carrying capacity and only increasing at 7% a year. Humpbacks are recovering more rapidly at approximately 10% a year (Finlay, 2012). Historically the Right Whales occur from False Bay and extend eastward to seek out large sheltered bays for their calves in the months of August to December. However with satellite tagging it has been revealed that whale species, especially the Right whale species migrate past Cape Point up the west coast, maintaining a position along the shallower continental shelf as seen in Figure 4-7 (Finlay, 2012). This area would constitute the area in which a SWEC development would occur. In addition to the Right whale, the Humpback whales migrate from the southern ocean where they feed in the arctic waters in summer to the tropical waters of coastal Mozambique, Angola and Gabon seen in Figure 4-8 (Finlay, 2012). The entire southern and western coastal area of South Africa is used as a migratory route for both Baleen species (Finlay, 2012).

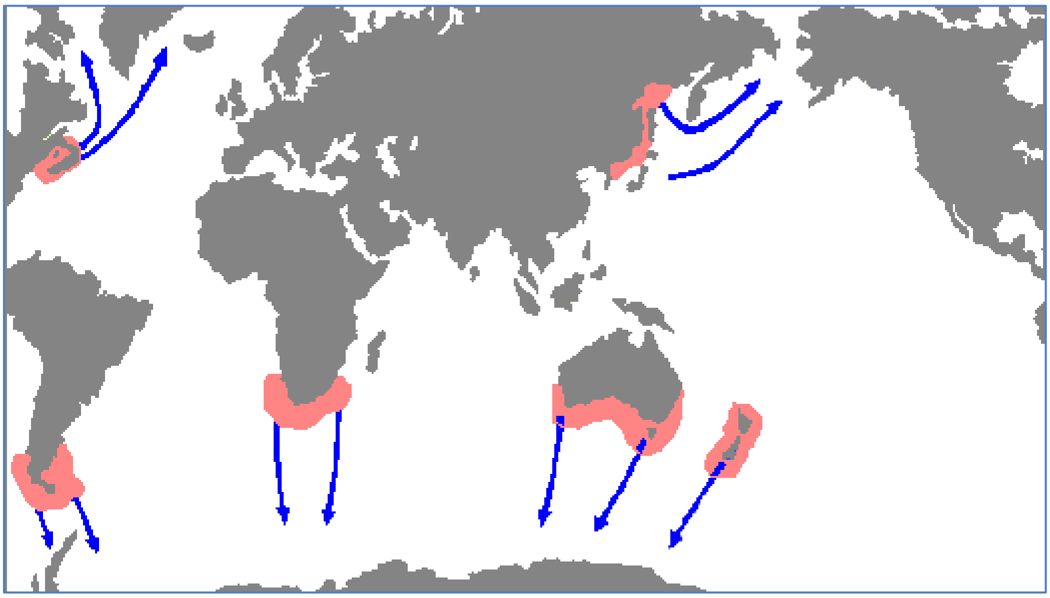


Figure 4-7: Migratory Routes of the Southern Right whale (SCRAN, 2002)

The importance of the upwelling site as a feeding site for whales has only been researched to a limited degree. However it is understood that the two whale species use the shallow sandy bays for rest and to provide their calves with refuge (Finlay, 2012). Female whales that are calving expend enormous amounts of energy to provide their calves with milk while not feeding and simultaneously travelling large distances from the southern ocean to southern Africa. Upon arriving at the Benguela upwelling it is thought that both the Baleen whale species rely on the productive grounds to feed and replenish their energy reserves to continue along their energy stressed migration to the Southern Ocean (Finlay, 2012). However new research has shown that a number of whales in particular some of the Right whales remain on the West coast of South Africa, instead of migrating, utilizing the whole coast as a feeding ground with the epicentre being St Helena Bay (Finlay, 2012). The SWEC site would be included in the extent of the feeding ground for the whales.

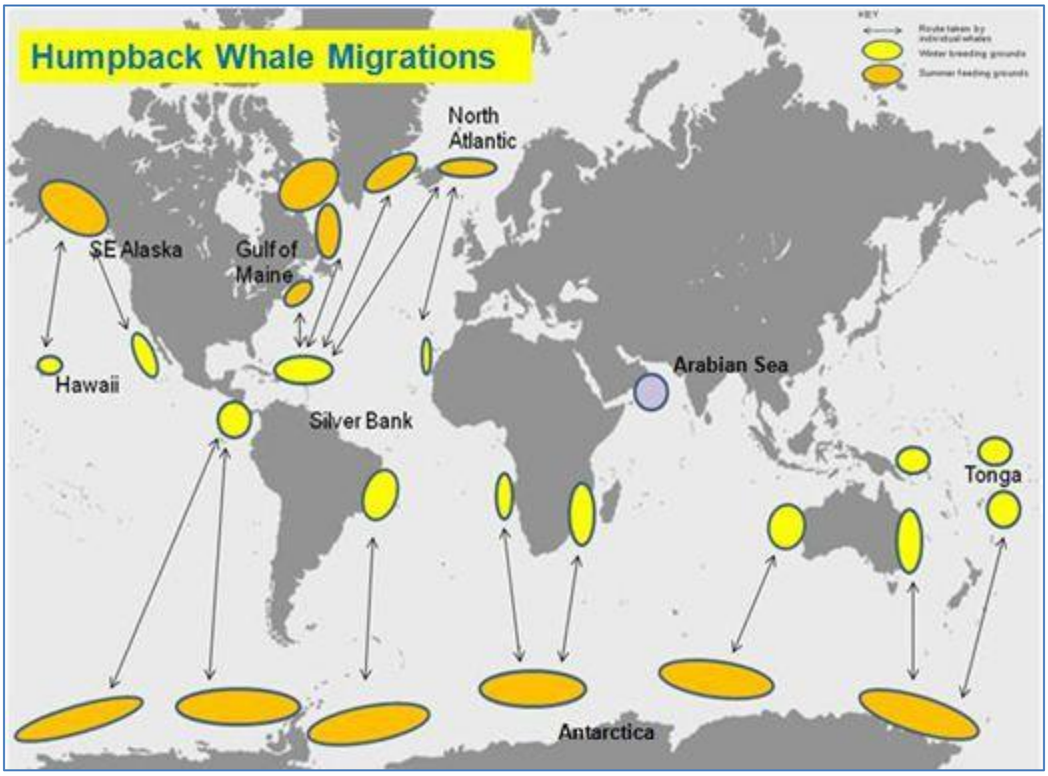


Figure 4-8: Migratory Routes of the Humpback whale (HWRF, 2012)

Additionally calving female whale species are found in 5 to 20m water depths to protect their young from predators and to seek rest on their energy stressed migration (Finlay, 2012). These depths fall within the idealised site for SWEC development. A SWEC array in such water depths would offer a direct obstacle to migrating whales as the energy stressed mammals would have to navigate in between devices approximately every 1 to 2 km seen in Figure 4-9. This could potentially represent an added stress to the migration of the animals as the most direct path is blocked (Finlay, 2012). Reynolds and Rommel (2007), note that the a disruption of animals migratory route, such as SWEC array would pose, may disrupt breeding cycles, cause habitat exclusion while increasing predatory threats and energy use (PIER, 2008). This would be of specific concern to migratory humpback whales which may well delay arrival at feeding and breeding grounds by avoiding a large wave park via moving into deeper water (PIER, 2008). Late arrival could force humpbacks to find alternative food sources in new habitat if shoaling pelagic fish have moved off consequently causing more energy expenditure (PIER, 2008). The deeper water transit would lead to increased exposure to predators such as Great White Sharks and Killer Whales where ordinarily the humpbacks would hug the coastline in shallower waters. Exposure to predation is further increased if mothers are travelling with calves (PIER, 2008). Avoidance behaviour that would likely be encouraged particularly during construction may drive species to deeper water representing the most serious exposure to predation as animals may be in deep water for long periods (PIER, 2008). Effects may be more extreme for species which don’t migrate as any habitat exclusion due to obstruction in open space would greatly stress their ability to pursue prey, breed, and inhibit movement corridors (PIER, 2008). The severity of the impact of obstruction would also depend on the non-migratory whale’s ability to substitute habitats. It is noted that there are a few meters of open water above the device but the animal's ability to pass over and other interaction with the devices would need specific study. In line with the precautionary principle the layout of the plant would need to be considered as animals would have to avoid devices if they were unable to swim over devices. The potential creation of a maze for the animals will add stress which may negatively impact the animals (Finlay, 2012). Without further research it is difficult to say what the result of maze creation may be.

The impact of construction noise (pile driving and seismic surveys) on whales was discussed briefly in section 4.3.4. If percussive noise prevents whales from communicating by covering up the animals calls or injures their sensory organs; a significant threat to their wellbeing would be impaired ability to hear the high frequency communication. Noise may also impair their ability to echo locate. A major concern would be the confusion of and consequently the separating the pod members or mothers and their calves due to lack of communication or locating ability (Finlay et al, 2012). To a limited degree marine traffic may cause similar impacts but the severity is not likely to be of significance (PIER, 2008). Despite the concern of noise pollution Nowacek et al, (2007) observed Humpback whales between 3 and 9 km away from an explosion (generating 150 Db. and 1 micro Pascal of pressure at 1.8km) caused no alteration in the physiology or behaviour of the whales (PIER, 2008). It has also been documented that humpback whales can emit vocalizations of up to 180 Db. in close proximity to each other however the frequency of the vocalizations may vary from that of noise pollution. Uncertainty surrounding this topic would require resolve before large scale construction could continue.

Finlay, (2012) noted that the impacts also may not necessarily be negative as the devices may in fact provide a protective lagoon of calm sea behind the devices where whales may rest and conserve energy in the wave shadow of a SWEC device (Finlay, 2012). The most concerning impact for a whale would be one of entrapment. The concern would be that a weakened whale calf could potentially become entrapped by the high wave energy being focused toward the apex of the SWEC device. Once contained in the "V" shape high energy waves could force the animal to collide with the device resulting in harm to the animal (Finlay, 2012). Impacts on whales described were voiced as potential concerns by an expert with knowledge of the species behaviour and are not proven or observed impacts.

A lesser expected impact may be that animal's impact on the functioning of the WEC device. Biofouling is regularly mentioned as a concern for the functioning and maintenance of the devices but larger species could potentially cause damage as well. Finlay, (2012) suggests that exposed cabling such as mooring cables or electricity evacuation cables maybe at risk as whales often rub themselves against cabling in order to scratch irritants on the skin. This has already been experienced with cabling in the crayfishing industry in South Africa (Finaly, 2012). The mass of a whale can be in excess of 20 tons which is enough to potentially damage mooring or electric cables exposed on the seabed (Finlay, 2012). Devices such as the Pelamis which are moored to the seabed maybe particularly exposed in such a case. The major concern would be whale species scratching on electricity cables and compromising the transport of electricity to shore (Finlay, 2012). The SWEC device however may only be at risk if the electric cables are exposed as they can be buried below the seabed.

A SWEC device would have complex interactions with whale populations feeding, breeding, communication and mobility. A SWEC array spanning 80 km would serve only to compound the impacts, adding to the complexity and cumulative impacts. A number of concerns are raised about certain aspects of whale behaviour which may be affected by such a development, but any definitive assessment would require an in depth, regional species specific study. This section serves only as a guide to potential issues, advised by expert opinion.

Dolphins

The southern and western coast of South Africa is home to a number of dolphin species. The most notable species is the Heaviside Dolphins which are endemic to the west coast of Africa between Cape Point and Angola (Finlay, 2012). The numbers of the dolphin species are not well known but they are not considered endangered (Finlay, 2012). However care should be taken as they are endemic to the coastline, rendering them highly irreplaceable. The habitat in which the construction of the SWEC is planned is critical habitat for feeding and breeding purposes (Finlay, 2012). The construction of such a development could potentially have population impacts on the Dolphin species (Finlay, 2012). Whether the impacts are positive or negative is difficult to determine. The implementation of such devices represents habitat destruction and noise disturbance discussed in section 4.3.4. Conversely the creation of artificial reefs may boost the reef fish stocks which would increase the prey numbers for smaller dolphins. In turn the numbers of smaller dolphins may increase as food availability increases. In addition entrapment may also be an issue with dolphin species as it maybe with weak whale calves. If the wave energy is of significant force, especially when rolling waves are focused toward the apex of the device, entrapment may occur if a small or weakened dolphin or whale calf is forced against the device and become trapped (Finlay, 2012). However the design of the SWEC is expected to allow animals to escape through the head of open water between the top of the device and the surface but more detailed would be required to ensure that entrapment is not a possibility (Retief, 2012). Species specific research would be advisable definitively assess the potential impacts on feeding patterns, noise impacts and device interaction.

4.4.3 Submarine Cabling

A larger number of devices have introduced electromagnetic fields in to the marine environment over the last century (Tricas and Gill, 2011). Although there is a long history of EMF's in marine systems very little is known about the impacts of EMF's on marine animals (Tricas and Gill, 2011). However with the combination of more stringent environmental regulation and the introduction of renewable technologies, EMF interference from large networks cables transporting electricity generated in offshore wind and wave energy plants are much more wide spread. The cables and infrastructure required to transport electricity from an offshore platforms to the grid have multiple environmental impacts over and above those created by WEC device development. A theoretical example of the network of subsea cabling created by a WEC array is displayed below for the proposed SWEC device array.

SWEC layout for subsea cables would be oriented in a configuration to limit shore crossings, so that only every fifth device would have a subsea cable crossing the shore to land. A full array of devices (154 V shaped converters) would require 30 subsea cable crossings roughly one per every 1.25km. Below two of the thirty crossings needed are displayed in Figure 4-9: SWEC array layout and the configuration for the subsea cables (Retief, 2012).

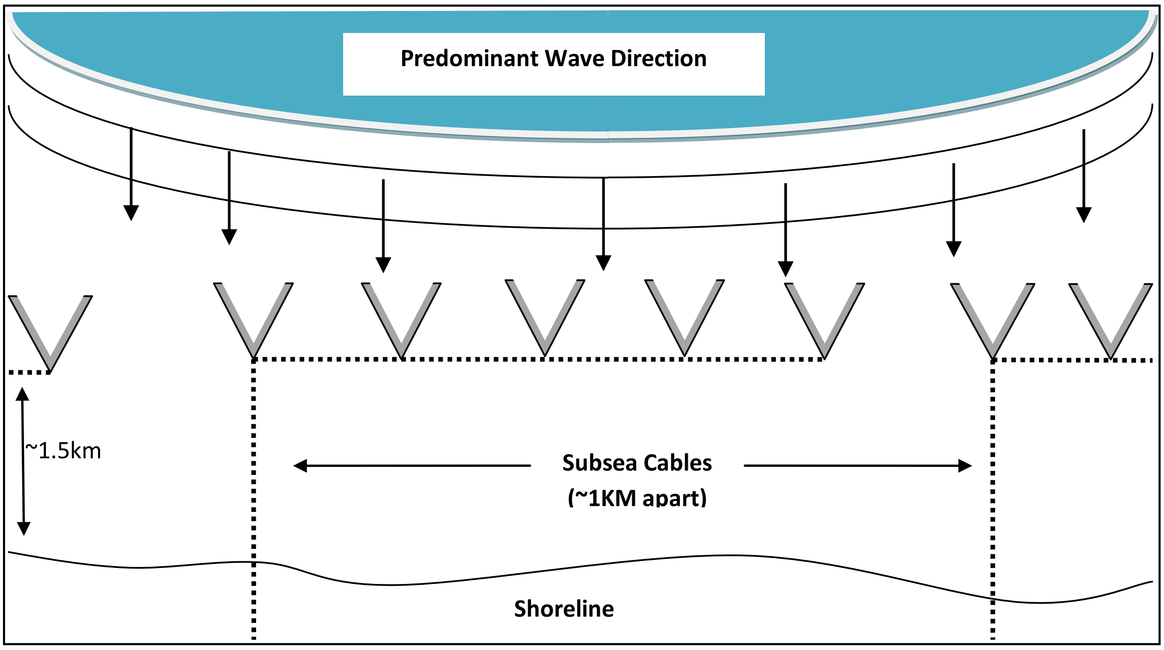


Figure 4-9: SWEC array layout and the configuration for the subsea cables (Retief, 2012)

If two subsea cables are laid for every surf zone crossing and each device connection (double circuit - to ensure supply) then the amount of cabling will increase two fold. This meaning in the event of a damaged cable supply will not be interrupted; but the lengths of cabling will double. However a demonstration plant would only have one bridging cable connecting it to shore.

The first noteworthy impact experienced is in the clearing of the area where the cable is to be laid down. This removes natural vegetation and creates noise impacts. The severity of the impacts will thus depend on the sensitivity of the seabed and the extent of the cabling. Sinclair, (2012) in an interview stated that offshore energy platforms cannot simply rely on a number of connector cables and one bridging cable, as a damaged cable, could decommission the entire platform despite the WEC units being functional. Therefore, more than one bridging and connector cable is used to connect the devices as well as bridge the plant to the shore based substation (Sinclair, 2012). The cable layout can be seen in Figure 4-9. This results not only in high costs but extra construction activities and a larger footprint on the seabed. The consequence is a more significant, negative impact on vegetation, and the reduction of habitat. Another option is to submerge the subsea cables in the soft sediment making up the seabed. This option will require additional activities such as using a cable plough to dig trenches for the cables to be lowered into simultaneously (ABB, 2012). ABB, (2012) reports that they are able to bury cables below sand, rock and reef with their cable plough technology. Jet-trenching is the other option for trench digging and both options would be suitable for soft sandy seabeds. Impacts would largely include be habitat destruction, sediment suspension and noise (ABB, 2012). Although trench digging is required in addition to land clearing, if the cables are under the seabed marine flora can regenerate on the seabed or rock over the buried cable and the system can return to its previous state. Additionally the cabling requires less maintenance and is protected from fouling and heavy wave climates (Sinclair, 2012). Further discussion on the potential influence of electromagnetic fields on specific species is detailed in Appendix E Tricas and Gill, (2011); Presivic, (2004); and Kirschvink, (1990) detail Species which are likely to be the most vulnerable to electromagnetic fields are:

- Elasmobranch fishes (Sharks, Rays and Skates),
- Decapods crustaceans (crabs, shrimp and lobster)
- Baleen whales and toothed whales (Southern Right, Humpback and Killer Whales)
- Dolphins (Common and Bottlenose)
- Sea turtles (Loggerhead, Leatherback and Green turtles)

It has been proven that there are a variety of marine species which would be affected by EMF's both through electro and magneto sensitivity (Tricas and Gill, 2011). However the extent of impacts of EMF's is largely unknown and a knowledge gap remains. This is of special concern if a development of a full SWEC array were to be considered as a complex web of subsea cables would be dispatched. Therefore, the development of a SWEC array without further specialist investigation in to the impacts of EMF's would be unprecedented.

4.4.4 Secondary Impacts

Flow Influence on Feeding Patterns

Turbulence is created by waves and occurs at many scales, and directions encouraging vertical mixing of water bodies. This is beneficial as turbulence cycles nutrients, reduces sea surface temperatures and removes and disperses waste material (PIER, 2008). Turbulence is also beneficial to benthic communities as they carry small particles such as plankton, krill, propagules (material used for propagation) and sediment (PIER, 2008). Turbulence can be increased by placing a large structure such as the SWEC in the ocean. The structure will alter the flow patterns of the localised ocean currents and eddies. In the event of an entire SWEC array spanning 80km^2 the flow alteration will occur on a regional scale. The placement of a large development in the ocean would decrease flow behind the device (by ~30% in the case of the SWEC) while creating turbulence and eddies in the wake of the devices (Retief, 2012; Babarit, 2012). The extent of the turbulence is unknown and would require advanced three dimensional modelling to determine what flows can be expected (PIER, 2008). Flow dynamics would be a key factor in the development of a wave energy converter array as it may begin to have unexpected impacts on the functioning and feeding patterns of marine life (Finlay, 2012; Retief, 2012). As the majority of krill and plankton species are at the mercy of the current flow, alteration of the currents will affect the pattern in which species are typically distributed. As such the dynamics of feeding grounds would be altered in the event of a disturbance of flow alteration as the already patchy nature of krill may become inaccessible and dispersed (Finlay, 2012; PIER, 2008). This would particularly be of major concern for the Hump Back and Right Whale populations (Finlay, 2012; PIER, 2008). Both species use the south-western coast of South Africa as vital feeding grounds. Consequently the development of a SWEC array holds the potential to considerably alter feeding dynamics of the whale populations. Eddies and turbulence may entrap drifting plankton and unevenly distribute the food source for the whales. This would then place further stress on already greatly energy stressed animals (Finlay, 2012).

The SWEC would reduce wave height in the wave shadow behind the device. The resultant reduction in turbulence may result in the reduced delivery of nutrients to the individual blades of marcophyte resulting in lower productivity in the community (PIER, 2008). The impacts without further study are speculative but the potential for changes in wide spread feeding patterns is a reality (Finlay, 2012; PIER, 2008). A complete study of the park effect of Wave energy converter arrays will be required in order to determine complex turbulence flow patterns and in turn understand both the environmental impacts of the SWEC and to improve efficiency in large arrays (Babarit, 2012).

Positive and Negative Impacts

A number of secondary impacts or benefits are suggested with the development of a WEC farm (Nelson et al, 2008). In chapter two it was noted that the creating of artificial reefs had an overall positive impact. The creation of an artificial reef improves habitat diversity but the impact on species diversity is not as well understood (Thorpe, 1999). Diversity is also “not always an attribute when assessing the marine conservation value of an area and the influence of artificial reefs on the population of marine creatures can be unpredictable and vary from species to species” (Thorpe, 1999). Artificial habitat can be very effective in attracting pelagic fish species and which species they attract depend on factors such as water clarity, distance from shore and depth (Thorpe, 1999). Although a WEC may in fact create more habitat for fish species, care must be taken as in large installations as the creation of new habitat may impact on the ecosystem stability affecting population dynamics (Finlay, 2012). For instance an increase in pelagic fish may attract fish eating sea birds and marine mammals (Thorpe, 1999). Consequently the device may provide marine birds and mammals with more feeding opportunities, but the interaction between the animals and the device array highlights other concerns discussed in the whales and dolphin sections.

The seeding process which creates reef habitat can also increase maintenance and potentially device failure (Thorpe, 1999). Thus the SWEC device would be susceptible to a certain degree of biofouling due to hard concrete structure which creates an attachment surface for algae, invertebrates and other fouling organisms. The species composition of the fouling organisms would depend on the species communities found in the vicinity of the development site (Thorpe, 1999). Other locality factors impacting the degree of fouling would be the distance from the shore of the device, water depth, water clarity, sunlight availability, temperature, the device position relative to coastal currents and the current speed (Thorpe and Picken, 1993). In addition there is also seasonal variation in the population sizes and hence in the fouling levels which are the highest during the summer months in South Africa (Thorpe, 1999).

Benefits

Abanades et al, (2014), recognises the reduction of wave energy causes by a wave farm as a key coastal defence tool in the face of climate change, enabling coastal settlements to be protected from high wave climates reducing flooding, and damage to property and coastline. An extensive wave farm could reduce the damaging effects of an extreme event that are more likely to occur in the face of global climate change (Abanades et al, 2014).

Every phase of the wave farm development from construction to decommissioning will create jobs and generate additional income for the coastal communities. A number of support and maintenance industries may develop with the development of a wave farm (Nelson et al, 2008). In addition tourism may increase due to the variety of marine life which may be attracted to the devices as they act as artificial reefs (Thorpe, 1999). The development may also inhibit tourism due to restrictions of fishing and other recreational activities in the vicinity of the WEC's (Nelson et al, 2008). Thus the need for a socio-economic study may arise from such a large marine development. Larger scale benefits of the SWEC device include the reduction of greenhouse gas emissions as the requirement for burning coal and fossil fuels decreases (Lewis and Estefen, 2010). It is likely that the device will also increase local job opportunities as concrete casting and ship yards would experience an increased demand in their services (Lewis and Estefen, 2010). Transport services, maintenance are among the other job opportunities that may become available during construction and operation.

Drawbacks

Risk of wreckage was suggested as concern in South African waters by Retief, (1979). Large volumes of marine traffic are experienced in the vicinity due to Cape Town harbour being a major international freight terminal (Retief, 2012). In addition the productive seas mean there is also a large fishing industry in the Western Cape. As such the shipping lanes and trawling grounds need to be carefully considered during the implementation of a WEC. The shipping lanes are said to be beyond the 50 m depth contour and closer toward the 100 m depth contour seen in Figure A - 1 (CSIR, 2008). If a WEC device falls within the 50 m contour it will not obstruct the commercial shipping lanes. The entire site will fall within the 100 m contour; however sections of the site may lie on the 50 m contour line and may potentially pose a threat to commercial shipping vessels sailing relatively close to the shore. The risk of collision would be low as a significant portion of the commercial shipping traffic will remain well outside the 50 m contour line thus avoiding WEC devices such as the SWEC and oyster. However the Pelamis is a mobile device and as such it may be located in deeper water and may pose a greater risk to marine vessels. There is a lack of electronic representations of shipping and fishing routes in South Africa, consequently CSIR have produced a proxy map of the shipping lanes, compiled using Voluntary Observing Ship data (VOS). This data shows the main routes travelled by ships carrying the VOS systems and is seen to provide a "reasonable approximation as the data is produced by ships travelling along the shipping routes" (CSIR, 2008). These approximations can be seen in Figure 4-10.

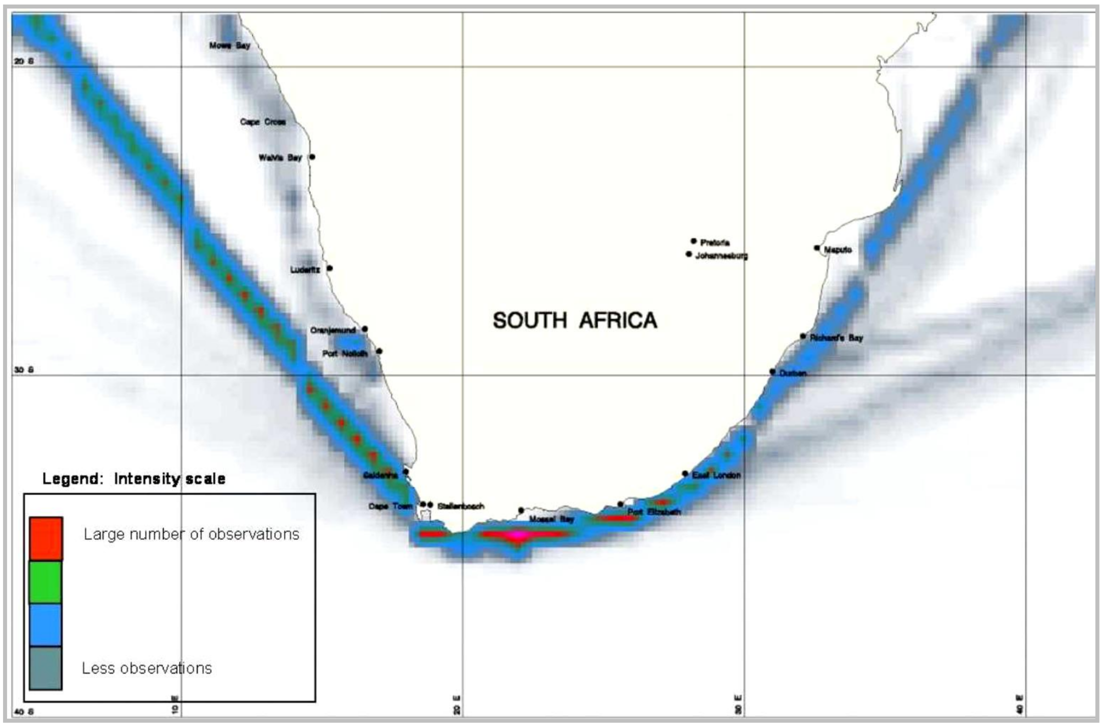


Figure 4-10: VOS data points as a Proxy for the Shipping Lanes along the coast of South Africa (CSIR, 2008).

The risk to of impact may result not only in loss of property, and life but also release of oils and petrochemicals into the sensitive marine environment (CSIR, 2008). The threat of pollution would have to be assessed based on likeliness of ship wreckage. A degree of mitigation would be planned to reduce the risk of wreckage with three navigational lights to be placed at all three points of the SWEC device, but an exclusion zone may have to be incorporated to reduce risk further (Retief, 2012).

Fishing Industry

Commercial shipping liners are not the only vessels that may run the risk of collision. Fishing and recreational vessels may still run the risk of collision as they tend to fish, trawl and travel closer to shore in shallower water (Blood and Crowther, 2012). Fish trawlers may also be impacted due to exclusion zone, from reduced trawl areas or snagging of trawl lines and nets (Thorpe, 1999). The complex array of submarine cables would also introduce additional exclusion zones that would make trawling in the area extremely difficult (Scherzer, 2009). This is particularly the case for vessels utilizing the purse-seine trawling technique to target small pelagic fish species in depths of 50 – 90m. Historical records of the catch areas show that large volumes of their catches occur in the proposed SWEC location meaning these fishing vessels will be directly impacted by the SWEC device development as seen in Figure 4-11: (Blood and Crowther, 2012). Catches vary from year to year but range from 300,000 – 600,000 tons/annum with approximately 5% of the national catch occurring within the survey area seen in Figure 4-11. A considerable impact would be expected on the industry as the highest density landings occur specifically in the proposed SWEC array site (Blood and Crowther, 2012). This would represent a loss of fishing grounds resulting in lower landings and less income for fishermen.

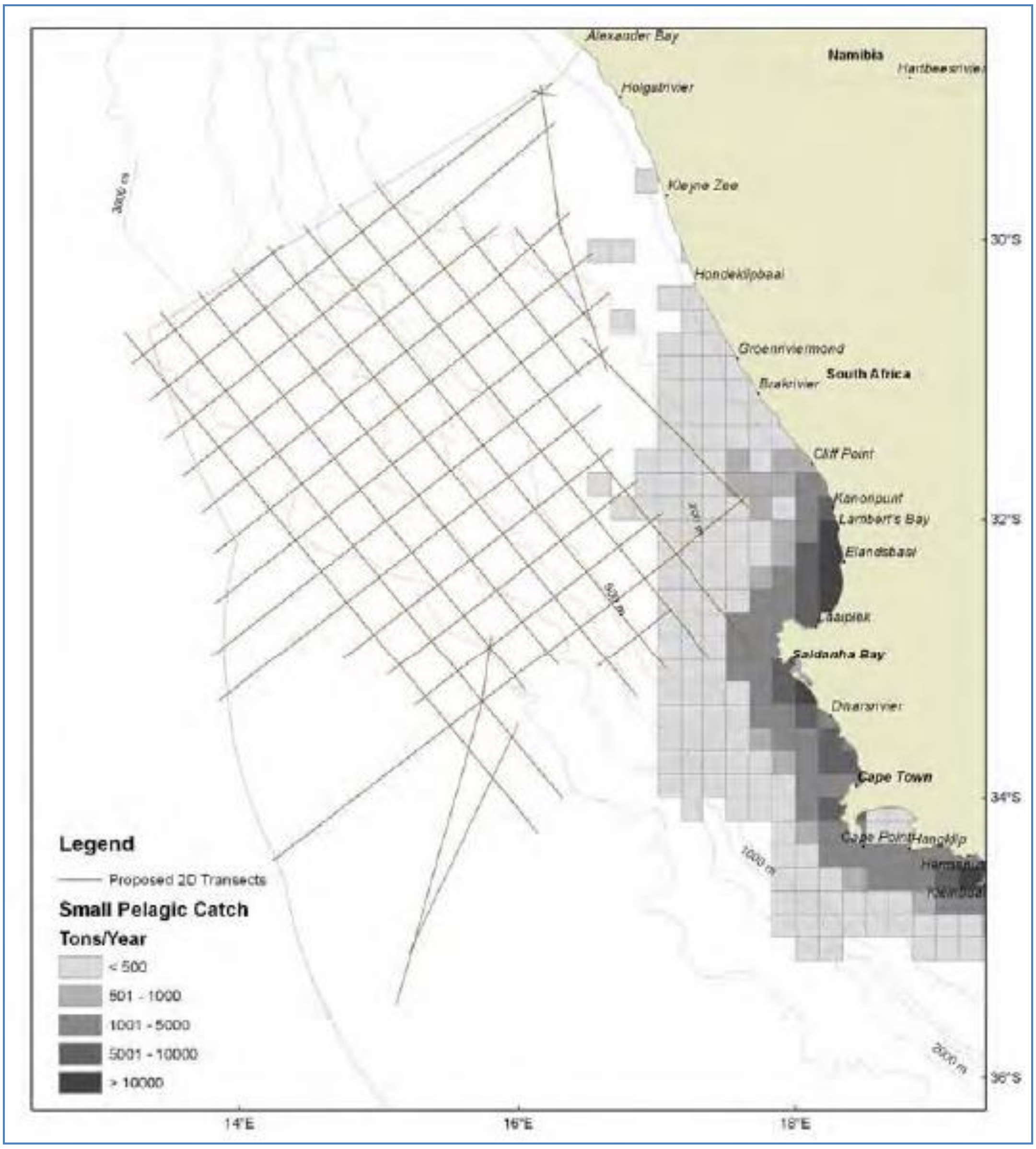


Figure 4-11: Distribution of Small Pelagic Fish Catch per Year (1987 – 2009) using the Purse Seine trawling technique (Blood and Crowther, 2012).

The small pelagic fishery would be the hardest hit with trawling for larger demersal fish species (hake, kingklip and snoek) tending to occur further out to sea (300 -1000 m depth) and would likely be too deep for vessels to interact with the SWEC device (Blood and Crowther, 2012). This is beneficial as the demersal fishery is the most valuable in South Africa responsible for approximately 50% of income generated from fisheries (Blood and Crowther, 2012). However the small pelagic purse seine fishery is the second most valuable fishery in South Africa and is the largest fishery by volume (Blood and Crowther, 2012). The 101 vessels operating with this technique are based largely in St Helena Bay, Saldanha, and Hout Bay. This results in the SWEC not affecting the most valuable trawl industry but directly impacting the trawl grounds of the second most valuable industry. Additionally providing a direct obstruction and risk of wreckage to the vessels associated with the purse seine trawl industry (Blood and Crowther, 2012). This may lead to a number of social and economic implications for the SWEC. Although it is beyond the scope of this thesis such complex dynamics require further study into the potential social implications of the SWEC development for communities reliant on local fisheries.

A smaller fishery which would be impacted by the development of the SWEC is the west coast lobster industry. Focusing on the West Coast Rock lobster occurring in less than 200m depth along the entire coastline on which the site is proposed. The industry is made up to two components the off shore industry operation from vessels in depths of 30m to 100m and the inshore industry operating in up to 30m depths depending of gear (Blood and Crowther, 2012). The offshore industry faces the most significant impact sharing fishing sites with the proposed SWEC development. Of all the areas surveyed two bays over which the SWEC site is planned experience the most active lobster fishing in the Western Cape. The southern bay between Grotto Bay and Yzerfontein experiences the highest density of lobster traps, >35 000 per annum while the northern bay between Yzerfontein and Saldanha experience between 1000 and 5 000 trap per annum despite the near shore environment being a Marine Protected Area seen in Appendix F: Figure F- 1 (Blood and Crowther, 2012). Although the lobster fishery and the development share the same location the impacts of the development are uncertain. Despite the habitat loss/alteration that would occur due to the development, impacts may be limited as lobster traps may still be deployed in and around the devices. In fact the artificial reef may provide more habitat for the lobsters potentially boosting population numbers and making the fishery more productive (PIER, 2008). However the direct interaction between fishermen and the devices may increase the risk of wreckage and threat to life. The converter arms would likely be too deep for small fishing boats to collide with, but the platform may act as an obstacle. Thorpe, (1999) suggests that a device platform may have the opposite effect reducing the risk to life of fishermen who get caught in heavy storm fronts. The suggestion is the device may offer a place to moor and a solid platform to escape the swell, while simultaneously providing an area of calmer water in the wave shadow behind the device. A serious concern would be disembarking the vessel onto the platform in high storm events creating an even greater risk to life (EMEC, 2009).

Other marginal industries which may be impacted by a development are the recreational fishing and tourism industries. Such a development may exclude recreational anglers from using the area. If this were to discourage anglers and visitors it may cause economic losses to local tourism and fishing businesses. However this impact is likely to be limited in the selected site as the northern section of the site known as Sixteen Mile Beach is a Marine Protected area and as such has restricted all fishing beside line fishing from a vessel, West Coast rock lobster and abalone fishing according to the regulations of the Marine Protected Area, declared under Section 43 of the Marine Living Resources Act (Act No. 18 of 1988). If the WEC is located just outside the MPA it may then begin to impact of trawling grounds over its lifetime.

4.5 Decommissioning

The final stage of the WEC's lifecycle would be that of decommissioning and rehabilitation. Since there are only a limited number of devices deployed and most of them have been deployed recently there is little experience decommissioning to date. In addition a large proportion of devices in operation and testing are floating devices. There were a number of options proposed for decommissioning by Retief, (2012), however the decision would likely be determined by the requirement of local government along with the environmental authorization if it were approved. Options for decommissioning include:

- Full deconstruction of the device. Manual jacking up and removal of all sections, components and cabling. This would then require the transport of all the devices and infrastructure back to shore for scrapping or recycling.
- Part deconstruction of the device. All harmful, degradable and valuable materials (rubber, plastics, turbines, scrap metal, etc.) would be removed and transported while the concrete structure would remain intact acting as a rigid artificial reef.
- Explosive deconstruction of the device. This would include the removal of valuable and scrap components such as the tower housing the turbine and the helicopter pad if it were included. Then the remaining concrete structure would be broken down via way of explosion. Larger pieces maybe removed but much of the rubble would remain being left as artificial reef habitat but would be softer and less obstructive than an intact device array

(Retief, 2012)

Decommissioning of the device brings the removal of the device and the entire associated infrastructure as well. One of the decommissioning mentioned methods would have to be selected for the removal of the device. Submarine cables and associated infrastructure would also have to be drawn up from the seabed and removed. The Device sections, components and submarine cables when removed have just as much impact as installation if not more. The removal of infrastructure will require the removal of biological organisms from corals, to flora and fauna habitat that would have grown over a lifespan of the project, a minimum of 20 years (Nelson et al, 2008). Firstly if the option of full removal of devices is selected it would destroy habitat that fish and predators rely on. Additionally an imbalance would be created once again as animals would have adapted to surviving with significantly increased reef habitat due to the device implementation. When the devices are removed this would represent another habitat loss for species which have either migrated to the area for the new habitat or adapted to surviving in the new habitat. Removal of devices and cabling would act as a major stressor to the new inhabitants, the impacts of which are entirely unpredictable so far into the future. Therefore the project would require monitoring of species throughout the operation so that an informed decision can be made as to the method of decommissioning selected (Finlay, 2012). There would be significant amounts of sediment disturbance due to the haul out activity on the seabed although this would be temporary. Although habitat would be destroyed it would eventually recover and likely to a state more similar than before the development. A concern would be once the devices are removed, wave energy reaching the coastline would increase having a host of implications for sediment transport, coastal processes, current, larvae and plankton flows. The impacts may lead to beach erosion and increased transport but further prediction on environmental impacts would be futile. Future impacts could only be determined once the expected impacts from the initiation of the development have been monitored, understood, and confirmed or adjusted (PIER, 2008; Nelson et al, 2008).

If the option of part deconstruction is selected, harmful and valuable parts would be recovered, but with the main segments of the device left intact the new found reef dynamic of the area would remain unchanged with artificial reefs conserved. The part deconstruction of the device would limit habitat destruction to the removal of submarine cables which would have a much lower severity on the artificial reef (Nelson et al, 2008). Sediment disturbance and marine traffic would also be lowered in this scenario. However the intact SWEC device would offer the same obstruction to wave energy, currents and sediment transport post energy production as it did during operation (PIER, 2008). Both full and part deconstruction would have noise implications having impacts similar to those of construction noise impacts. Concerns would be a noteworthy increase in vessel traffic as well as noise associate with breaking down of the SWEC devices and removal, potentially hammering, chiselling, drilling and cutting. These activities have repetitive percussive noise signatures potentially with comparable effects and impacts to pile driving discussed in section 4.3.4 (Nelson et al, 2008). The noise pollution impacts associated with construction noise would be similar to the noise pollution impacts experienced during decommissioning.

If the option to decommissioning explosively was selected the complexity of the operation increases to a degree. This method also offers the benefit of completely removing the structure remains, with positives of restoring the wave energy to the coastline and natural habitat less disturbed. Explosive decommissioning has a larger impact in the very short term however the benefits are realised in a much shorter time period at a lower expense than mechanical decommissioning. Consequently, habitat destruction is of rapid onset and marine fauna would not be able to escape the blast resulting in animal, flora and coral mortality (Finlay, 2012). Whereas the full deconstruction would allow animals such as fish, invertebrates and mammals to move off and avoid mortality (Retief, 2012). Explosion would also scatter debris and suspend considerable amounts of sediment reducing visibility and water quality for marine animals. The resulting debris would also likely not be entirely removed leaving a certain amount of hardened rock in a normally sandy environment despite removing the solid structure and most of the obstruction. Explosion would also generate much noise. The sudden extreme noise and pressure increase from the shockwave would injure or eradicate marine fauna and flora with in the vicinity. It could damage the hearing of the animals with more sensitive hearing sense such as whales, dolphins, and seals. Considerable stress would be placed on a number of animals and impacts may be similar to that of pile driving, if not more severe potentially being compounded if animals are with young (Finlay, 2012). Consequently the explosion would need to be timed carefully and should be done at a time of year when the breeding animals such as whales are not near the site and not calving (Finlay, 2012). Whether a time period is available where none of the sensitive species are in the proximity at the time of detonation, remains to be determined but it would be preferable (Finlay, 2012). This method contains the most risk but also has benefits of rapid removal of the structures.

The removal of the SWEC would expunge the interactions between marine mammals, birds, sharks and fish, which may be harmful or beneficial as discussed. Whether these impacts are positive, negative or negligible is dependent firstly on how animals interact with the device after deployment and speculation on the future consequences would be conjecture. Once an understanding of how marine flora and fauna have interacted with the device is obtained; the second largest determinant of impacts would be which method is utilised for decommissioning of the SWEC device or array. Each method would need to be assessed in combination with a set of mitigation measures for the specific site, as the most effective method at the wrong time of year may be extremely detrimental. A full technology specific assessment of the impacts of decommissioning is limited due to lack of experience, knowledge and research in the industry. Thus no conclusive answers can be drawn from an analysis on decommissioning impacts without first understanding what the potential impacts on marine life would be from the development of the SWEC. A Summary table of all the Impacts discussed and the estimated severity is given in Table 4-3, where an impact is described according to the phase of development in which it falls (Construction, Operation, or Decommissioning). The impact is then assessed according to the receptor or receiving environment, impact duration, and severity based on whether a single unit or full array is installed. Mitigation measures are then recommended and severity of an impact for a single unit or full array is then assessed with a mitigation measures.

4.6 Results and Discussion

Environmental impacts are categorised into the impacts experienced during construction, operation and decommissioning. A multitude of impacts are associated with each of the phases over life time of the plant. Impacts that occur range from noise, habitat destruction, seabed alteration and flow dynamics. The full effect of such impacts is not quantifiable and insight into them is currently limited to a mixture of expert opinion and experience from other cases or studies internationally. As such the impacts discussed (listed in Table 4-3) can only be discussed in terms of the certain behavioural criteria in a number of different categories of species. Indications of impacts are based on expert opinion, raising what they have experienced the most vulnerable aspects of certain species, process of ecosystems in the event of the construction of a SWEC unit or array. By no means is it argued that these are the impacts which will occur. Rather this chapter strived to raise species specific and case specific issues which are unique to a development in the coastal waters of South Africa. The goal is to provide guidance as to what unique behavioural aspects of species' interactions with a wave energy converter would need to be considered and researched further.

A detailed list of environmental impacts are outlined in Table 4-3, where impacts are detailed according to:

1. phase in which they occur
2. type of impact with in that phase

Impacts are then ranked according to:

a. value of the receptor or the receiving environment
b. impact duration or the period over which the impact is experienced
c. severity of the impact if a single SWEC unit is installed
d. severity of the impact if an 154 unit SWEC array is installed
e. possible mitigation measures for the impact if they exists
f. severity of the impact with the mitigation measures if a SWEC unit (U) or array (A) is installed
g. likelihood of occurrence of the impact, whether the impact is likely to occur, has a fair chance of occurring or is improbable.

Construction and decommissioning have the most significant impacts in terms of habitat disturbance and noise impacts through marine traffic, pile driving and deconstruction (both explosive and haul out). Noise impacts can be considerably damaging, carrying the possibility of causing injury or mortality, however there is contradictory evidence from Nowacek et al, (2007) with reference to humpback whales. The operational phase is not expected to have the same level of impact in terms of noise, as it is limited. The deployment of the devices is expected to create new habitat for animals however it remains to be seen whether the existing species will thrive in the new environment created in a biozone regarded as critically endangered by Lombard et al, (2004). Conversely in a report the Council for Scientific and Industrial Research, (2008) in their bid to select a site for a WEC, noted the proposed SWEC site on the South West Coast as preferable location (see Figure 4-5) when designated selection criteria were applied (CSIR, 2008). The alteration of ecosystem and sediment transport dynamics is the critical issue during the operational phase spanning 20 years. The potential up the chain impacts and fundamental imbalance that could be created by an 80km wide SWEC array is of the utmost importance requiring a multitude of in depth specialist investigations from a species specific to regional scale. The requirement of an environmental impact assessment that is the requirement of law may need to be upgraded to a Strategic Environmental Assessment (SEA) which would consider the entire area and cumulative impacts, in order to follow the precautionary principle and err on the side of caution.

In practice a number of the impacts concerned may have a much lower severity if they impact at all. An untested device with little local experience leads to a broad spectrum of concerns many of which may prove to be unjustified. This follows on to the importance of a robust monitoring and reporting programme that supports the industry and can address or discount many of the concerns early on. Two key areas that need specific attention in South Africa are the sensitive ecosystems, and the fishery industry. The ecosystems will need in depth study across the multitude of species functioning in the productive west coast upwelling. The Second point is directly related and concerns the local fishing industry and the small coastal communities who rely on fishing as a livelihood. Although it was beyond the scope of this thesis it is the natural next step for research progression as stakeholder buy in is key at an early stage when devices may impose no-catch zones and added marine traffic.

Table 4-3: Summary table of the Potential Impacts during Different Phases of the Project Lifespan

Item	Description of Impact Potential	Value of Receptor	Impact Duration	Impact Severity (1 unit)	Impact Severity (Array)	Mitigation Measure	Impact Severity with Mitigation	Likelihood
#	Impact Description	Low/ Medium/ High	Short/ Medium/ Long term/ Permanent	Low/ Medium / High (1 unit = 1x SWEC)	Low/ Medium/ High (Array = 154 Units)	Measure Description	Low/ Medium/ High Unit (U) or Array (A)	Improbable Fair Likely
Construction								
1	**Destruction of marine flora and fauna**							
1.1	-cable trenching in the intertidal environment which is unique (100% Irreplaceable)	High	Medium term	Medium	High	Directional drilling instead of trenching may reduce impacts	Medium (U); High (A)	Improbable
1.2	-piling in shallow-deep photic which is threatened biodiversity (40-60% irreplaceable)	Medium	Short term	Low	Low	Timing piling to occur out of calving season, breeding seasons would reduce impacts	Low (U); Medium – High (A)	Improbable
1.3	-Device set down – crushing organisms	Medium	Short term	Low	High	If on site marine biodiversity is considered, crushing maybe reduced	Low (U); Medium (A)	Fair
2	**Noise**							
2.1	-Seismic surveys/ piling/ directional drilling. Percussive hammering will drive away or injure marine mammals and fish with whales being particularly sensitive to noise.	High	Short term	Low	High	With mitigation and piling limited to specific times of the year the impact may be reduced however piling would likely occur over long extended periods for an array.	Low (U); High (A)	Likely

Item	Description of Impact Potential	Value of Receptor	Impact Duration	Impact Severity (1 unit)	Impact Severity (Array)	Mitigation Measure	Impact Severity with Mitigation	Likelihood
2.2	-marine traffic will likely affect marine birds, and mammals. Potentially driving birds away from their nesting sites on Dassen Island nearby.	Medium	Short term	Low	Medium	Consider migratory routes and periods for birds and whales and reroute vessels away from bird nesting sites.	Low (U); Low (A)	Improbable
Operation								
3	**Habitat alteration –** introduction of a hardened in the Deep to sub photic area (10-30m depth roughly 1.5km offshore)							
3.1	-Artificial reef would: • Attract reef type species altering the sandy bottom ecosystem dynamic. -Up the chain impacts: • Increased shelter may decrease predation. • Reefs may also attract predator to the reef environment • If the exclusion zone for fishing is enforced the area may form part of a larger Dassen island MPA. • Bio-fouling of device	High	Long term	Low	High	Mitigation is difficult as the outcomes of altering habitat is so unpredictable. It may be regarded as a positive impact as it increases the population of the under-pressure mid trophic level fisheries, however it may be regarded as negative if new varieties of species (predators) begin to inhabit the area as this represents fundamental population dynamic alteration	Uncertain	Uncertain
4	**Reduction of Wave Energy**							
4.1	- Reduced energy behind the device is known as the wave shadow. This shadow will impact physical processes reliant on wave energy and alteration in the energy	High	Long term	Low	High	The park effect requires detailed modelling of the potential effects should be undertaken to design an array layout which would limit the:	Low (U); Medium - High (A).	Likely

Item	Description of Impact Potential	Value of Receptor	Impact Duration	Impact Severity (1 unit)	Impact Severity (Array)	Mitigation Measure	Impact Severity with Mitigation	Likelihood
	reaching the shore will alter the process dynamics.					• Reduction in Wave energy		
4.2	-sediment transportation alteration leading to beach accretion in certain areas and erosion in others. Reduction of long shore drift transportation.	High	Medium term	Low	High	• Alteration of sediment transportation patterns	Low (U); Medium (A)	Fair
4.3	-coastal process's, such as vertical mixing of stratified layers of water being reduced altering the sea surface temperatures and potential species composition.	Medium	Long term	Low	High	• Alteration of coastal process's.	Low (U), Medium (A)	Uncertain
4.4	-food transport (plankton), the reduction of dissolved and particulate material delivery to benthic (bottom dwelling) organisms	Medium	Long term	Low	Medium	• Inhibit food transportation.	Uncertain	Fair
4.5	- Competitive advantage and habitat alteration (Shallow to deep photic). Less wave energy resistant species of algae and Kelp. Additionally dispersal reproducers and drift feeders maybe impacted negatively.	Medium (Threatened habitat)	Long term	Low	Medium	• Limit the reduction of wave energy.	Low (U) Uncertain (A)	Fair
4.6	-habitat alteration (Near shore). Higher wave energy environment is required for certain invertebrate	High	Long term	High	High	Need to ensure design of the wave energy park would allow enough wave energy to remain to sustain	Medium (U),	Fair

Item	Description of Impact Potential	Value of Receptor	Impact Duration	Impact Severity (1 unit)	Impact Severity (Array)	Mitigation Measure	Impact Severity with Mitigation	Likelihood
	species, wave energy flux would alter population dynamics. (Near shore Intertidal habitat regarded as entirely irreplaceable)					near shore processes	High (A)	
5	**Obstruction**							
5.1	- A maze effect maybe created hindering the navigation or increasing energy use of marine species (whales being most affected, dolphins, sharks, tuna, diving birds, penguins). Device(s) would obstruct migratory and hunting species which would usually move in open waters. - Devices may protect migratory animals from high wave energy environment in the wave shadow.	High	Long term	Low	High Or Medium (Positive)	Designs should allow for enough navigation space between devices and between devices and the shore. Tighter designs would also offer more protection from high energy storms. Spread out designs would lower the protection potential of a device.	Low (U) High (A) Low (A) (Positive)	Improbable
5.2	-Risk of wreckage. Deeper drafting ships are more at risk from collision with the SWEC sitting ~10m below the surface.	Low	Long term	Low	High	Clear navigational beacons & deem SWEC array area or a no sail zone/ exclusion zone.	Low-None (U) (A)	Fair
6	**Entrapment**							
6.1	- Entrapment is possible for small to medium animals who dive and may surface in the air chamber within the device. - Entrapment due to the force of the	Low	Long term	Low	Medium	Measures to discourage animals from approaching the submerged opening of the chamber may assist but options are uncertain	Low (U) Uncertain (A)	Improbable

Item	Description of Impact Potential	Value of Receptor	Impact Duration	Impact Severity (1 unit)	Impact Severity (Array)	Mitigation Measure	Impact Severity with Mitigation	Likelihood
	waves rolling word the apex of the device may force larger species into the "V" and if weakened would struggle to escape over the top of the device.							
7	**Exclusion zones**							
	-protects fish from fisheries -reduced fishing areas but may increase catches	Low	Long term	Low (positive)	Medium – High (Positive)	Areas may be opened to fishing but this could increase the risk of wreckage and endanger human lives	Low (U) (Positive) Medium (A) (Positive)	Fair
8	**Electromagnetic fields**							
	- EMF's may hinder sensitive animal's ability to navigate and behaviour.	Low - Medium	Long term	Low	Medium	Increased shielding and burring of cables may reduce/ remove effects of EMF's	None (U), Low (A)	Fair
Decommissioning								
9	**Vegetation disturbance/destruction**							
	-removal of the device(s) -removal of cabling	Medium	Short term	Low	High	If it is deemed to be less destructive devices can be left as artificial reefs reducing disturbance.	Low (U) Medium (A)	Likely
10	**Noise**							
	-hammering -marine traffic -explosive decommissioning	High	Short term	Low	High	With decommissioning limited to specific times of the year and certain methods the impact may be reduced.	Low (U) Medium (A)	Likely

Item	Description of Impact Potential	Value of Receptor	Impact Duration	Impact Severity (1 unit)	Impact Severity (Array)	Mitigation Measure	Impact Severity with Mitigation	Likelihood
11	**Pollution**							
	-debris -leaking of oils/lubricants	Low – Medium	Short term	Low	Medium	With careful practices the effects of marine pollution can be reduced if not removed	Low (U), Low (A)	Fair
12	**Increased wave energy**							
	- Disturb **e**cosystems having reached a new equilibrium during the 20 year operational lifespan then would need to readjust signalling a similar shock to that of construction.	High	Long term	Low	High	If it is deemed to be less destructive devices can be left as artificial reefs with only the hazardous components removed.	Low (U), Medium – High (A)	Uncertain

5 Policy and Implementation Planning

South Africa has a multitude of complex policies which need to be complied with, in order to achieve the goal of implementation. The constitution of South Africa advocates the right to a healthy environment and sustainable supply of services including electricity. To this end developments of electricity supply are required to adhere to the two key policies the National Environmental Management: Environmental Impact Assessment Regulations and the Integrated Coastal Management Act. There are also a number of mandatory permissions to obtain such as the electricity generation policies, and mineral resources clearance. Finally there are a number of additional permits or consents to be obtained of which not all are legislated but are requirements of a full permitted development. The permitting requirements for the development of a wave energy converter will be unbundled in the following chapter with relevance to a specific site off the south west coast of SA.

5.1 Permits

According to Maia et al, (2011) only two permits and an environmental impact assessment are required for implementation by the South African authorities:

- The electricity generation permit issued by NERSA
- And a Land use permit for the site selected for generation and infrastructure.
- An environmental impact assessment (EIA) be undertaken and authorisation received before a wave energy installation can be approved.

In this chapter it has been uncovered that the permitting process is in fact far more complex than the three permits Maia et al, (2011) suggests. Table 5-1: Permits Register details all the formal permits and permissions that would be required before implementation. Permits and consents are listed in order of when they should be applied as some permits require the impact assessment to be underway or complete. Table 5-2 lists the additional permits, permissions, or adherences which would be required from a number of private and municipal entities.

Table 5-1: Permits Register of Formal Permits Required

Statute:	Consent:
NEMA: Integrated Coastal Management Act	20 Year lease with condition to exclusive water use rights from the Department of Environmental Affairs
NEMA: Integrated Coastal Management Act	Lease for temporary occupation of land with in coastal zone
National Environmental Management Act, 107 of 1998 (NEMA)	Environmental Authorization for the electricity generation plant, associated activities and associated infrastructure (gridline).
NERSA Electricity Regulation Act	Electricity Generation Licence
NERSA Electricity Regulation Act	Power Purchase Agreement
Mineral and Petroleum Resources Development Act, 28 of 2002 ("MPRDA") – Section 53	Consent in terms of section 53 to use land contrary to the objects of the MPRDA
National Environmental Management Biodiversity Act (NEMBA), Provincial Nature Conservation Ordinances, and regulations promulgated under them	Biodiversity Consents: the removal of certain sensitive fauna/flora, permission is required from the Department of Environmental Affairs ("DEA") or the Department of Agriculture, Forestry and Fisheries ("DAFF"). Permit to be applied for during the Environmental Impact Assessment
Sea Birds and Seals Protection Act	Permit for the disturbance of Sea Birds and Seals. To be undertaken during the Environmental Impact Assessment
National Heritage Resources Act, 25 of 1999 ("NHRA") – Section 38	Required notification of the relevant heritage authority. Notification to occur as part of the Environmental Impact Assessment
National Heritage Resources Act, 25 of 1999 ("NHRA")	Heritage Approval and any destruction permits or related permits for an impact on a heritage site or object. If any artefact is discovered notification of the relevant authority is required. Assessed during EIA by the relevant authority.
Civil Aviation Act, 13 of 2009 ("CAA")	Aviation Consents, particularly if there is the intention to have helicopter landing pads on the device platform. To be applied for once device location and designs finalised.
National Building Standards Act, 103 of 1977	Building plan approval required prior to the commencement of any construction on the Project Site.

Table 5-2: Permits Register of Additional Consents Required

Statute:	Consent:
Additional Permits/ Consents	
Electronic Telecommunications Act 36 of 2005 – Section 29 *Applicable to: (Transnet, SANDF, Eskom, Telkom, Neotel, Sentech, and Mobile operators such as Vodacom, MTN, Cell C)*	Consent from the relevant telecommunications operators to ensure the development does not disturb their transmission activities. Application to occur during the EIA phase.
Permission to install cabling/construct infrastructure across servitudes. *Applicable to: (Eskom, Telkom, Transnet, Municipal Servitudes, Neotel and Sentech)*	Permission required to cross existing infrastructure (Telecommunications cables, power cables/ lines) with infrastructure (cabling, roads). Application to occur during the EIA phase.
Municipal By-laws	Miscellaneous Local Authority Consents
Mineral and Petroleum Resources Development Act No. 28 of 2002	Mining Permit for excavation and use of materials onsite
Hazardous Substances Act, Act 15 of 1973 (HSA)	Necessary requirements of the HSA need to be adhered to and addressed in the Environmental Management Plan.
Occupational Health and Safety Act, Act 85 of 1993 (OHSA)	Adherence to Occupational Health and Safety Requirements
National Environmental Management: Protected Areas Act, Act 57 of 2003	Proximity to Protected Areas needs to be considered and interaction with the Department of Environmental Affairs is required.

5.2 Environmental Impact Assessment for the SWEC

Need for EIA

The listed activities under the 2010 National Environmental Management Act (NEMA) Environmental Impact Assessment (EIA) Regulations, are the list of activities as amended in the Government Notice (GN) Regulation (R)

Listing notice 1: 543 (for Basic Assessments)
Listing notice 2: 544 (for a full Environmental Impact Assessments)
Listing Notice 3: 546 (Assessments for specific geographical areas)

These lists of impact assessment triggering activities were promulgated under chapter 5 of NEMA (Act 107 of 1998) in 1997, 2006 and most recently published in Government Gazette 33306 on the 18th of June 2010. Given the quantity of electricity to be generated and the grid connected nature of the project, such a wave energy conversion project requires an environmental impacts assessment and the associated environmental authorization from the National Department of Environmental Affairs (DEA) prior to the commencement of activities on site (DEA, 2010). The proposed project requires full Scoping and Environmental Impact Reporting (S&EIR) in terms of GN.R545 of the 2010 EIA regulations, and also includes activities listed in GN.R544 (requiring basic assessment) and GN.R546 (for specific geographical areas).

5.2.1 Government Notice Listed Activities

All activities discussed are described in terms of the listed activities detailed in Appendix G: Table G- 1: List of Activities Triggered by the SWEC. Both off-shore and shored based wave energy technologies have environmental impacts, no matter how small, due to their associated activities, (Boud, 2003). The NEMA: EIA regulations provide listing notices describing activities and what type of study they would require whether it be a basic assessment report (BAR) or a full environmental impact assessment report (EIA). The activities associated with the SWEC device will be considered in terms of the listed activities in order to determine which activities trigger environmental study and what study is required.

In the National Environmental Management Act, EIA Regulations there are a number of listed activities which would be triggered by the development of a single SWEC unit or an array of SWEC devices. Listing Notice 1 (GN R 544); Listing Notice 2 (GN R 545) and Listing Notice 3 (GN R 546); listed activities and competent authorities which are identified in terms of section 24(2) and 24D. These sections state that a triggering activity requires a Basic Assessment if contained in notice 1; a scoping report and full environmental impact report if in notice 2; and a basic assessment if in notice 3. Table G- 1 contains a table of all the listed activities for a single unit or array development which would trigger an environmental study. The table explains the environmental measures required for the activities involved in the deployment of either a single WEC or an entire WEC array with the associated infrastructure, construction, deployment, operation, maintenance and decommissioning.

5.2.2 Listed Activity Type

The activities which are required to construct a development, the nature of the activity during operation, the size of the development and the location, all define the type of environmental assessment which is required. The SWEC device is regarded as infrastructure for the generation of electricity. Under the NEMA, Environmental Impact Assessment regulations Listing Notice 1 (GN R 544); an activity which generates in excess of 10MW is required to undertake a basic assessment. As the SWEC device is rated at 5MW per unit it will not be required to undergo a basic assessment on generation as long as its foot print is less than one hectare. While one unit is below the 10MW threshold a two or three SWEC devices would be within the 10MW - 20MW range requiring a basic assessment under notice 1/1. A full SWEC array would be well beyond the 20MW threshold requiring a full EIA under listing notice 2/1 (GN R 545) of the Environmental Impact Assessment regulations 2010 as seen in Table G- 1.

However development footprint is another condition of activity 1/1 in the table contained in Table G- 1 which could trigger a basic assessment (GN R 544). The SWEC has two converter arms each of which are 160m long and lie at a 90° angle. The effective breadth of the device is 226m at its widest. This translates into the total area that a single unit device covers as 12800m^2 which is equal to 1.28 hectares. This means that total area which is covered by the device is larger than the 1 hectare maximum buildable area size above which requires a basic assessment under activity no.1 in listing notice 1 (1/1) (GN R 544) (Table G- 1). However despite the footprint of a device being larger than one hectare, a single unit development is likely to be classed as a demonstration plant and may apply to be exempt from a full EIA, only undertaking a basic assessment. Exemption is allowed provided a demonstration unit does not feed into the grid/sell electricity. As such the commencement of any listed activity without an environmental authorisation is an offence under section 24F of NEMA (DEA, 2010). Failure to comply may result in a sentence of up to 10 years imprisonment or a fine of up to R5 million (or both). Therefore in all cases where the deployment of a WEC array exceeds 1 hectare in area or 10 MW power they would require a basic assessment or a full environmental impact assessment (EIA) when in excess of 20 MW power generation. Full EIA's may become common place due to the relative uncertainty regarding WEC deployment and this would be a likely scenario for all WEC developments in South Africa (Boud, 2003).

5.2.3 Construction Activities

The fact that construction will take place on property that is deemed public property held in trust by the government requires the development to undergo an environmental assessment under listing notice activity 14 (1/14) in Table G- 1, which accounts for the temporary structures associated with construction. The associated infrastructure for generation activities requires a basic assessment or full EIA for cabling rated between 33 and 275kV or above 275kV respectively as stated in notice 1/10, 1/11 and 2/8. Construction in the sea involving earth moving equipment, dredging, infilling, island construction, removal of shells and/or permanent anchoring requires either a basic assessment or full environmental impacts assessments based on the scale of such an activity as listed in notices 1/16, 1/18, 1/ and 2/14, 2/24. Along with construction the decommissioning of electrical generation or transport infrastructure in excess of 10MW or 132kV would also require a basic assessment under notice 1/27. Basic assessments will also be required for a number of types of expansion activities for WEC's. Expansion of electricity generation and transportation facilities by more than 10MW or in excess of 275kV will require a basic assessment under notice 1/29 and 1/38. Basic assessment is required for expansions in coastal public property, in the sea within 100m of the high water mark, or expansions of islands or permanent anchored platforms on the seabed under notice 1/43, 1/45, and 1/54 respectively. In addition any phased activities such as plant expansions which individually remain below the 10 MW level but together exceed the 10 MW threshold for a generation plant require basic assessment under notice 1/56. Full descriptions of activities and conditions are detailed in Table G- 1.

5.2.4 Development Location

The location of a development may alter the conditions which need to be adhered to for that activity. Provincial boundaries may come with their own preconditions for particular activities such as construction, expansion and vegetation clearance. The preconditions set by the Western Cape Provincial government are detailed in listing notice 3 (GN R 546) and summarised in Table G- 1. Vegetation clearing of more than 300 square meters or more of which 75% is indigenous, inside an area declared to be critically endangered or endangered triggers a basic assessment as listed in notice 3/9. Similarly a basic assessment is triggered if vegetation of one hectare or more is cleared (where at least 75% is indigenous) and the site is seaward of the coastal setback line, within a core biosphere, within 10 km of a national park or within 5 km of a protected area as listed in notice 3/1. Notice 3 also requires basic assessment for roads wider than 4 m, small landing strips, construction in water bodies, phased activities, buildings and cableway expansions as delineated by province in notices 3/4, 3/8, 3/16, 3/26, 3/24 and 3/9 respectively.

National Environmental Management Act (NEMA) as the primary environmental legislation is complemented by a number of sector specific laws governing marine living resources, mining, forestry, biodiversity, GMO's, protected areas, pollution, air quality, waste and integrated coastal management. Among which the ICMA or NEMAQA means national environmental management: integrated coastal management act (ICMA), NEMBA national environmental management: biodiversity act 10 of 2004. In addition to the criteria outlined by NEMA: EIA regulations the criteria of the NEMA: ICMA act have to be considered in a decision by any relevant authority with jurisdiction over a development.

5.3 Integrated Coastal Management Act

A number of sections of the Integrated Coastal Management Act have not been enforced particularly pertaining to coastal leases. Consequently the Sea Shore Act 21 of 1935 still legislates the maritime zones. Although a number of sections do not apply as they have not been entered into force they will be discussed in context as they will define the lease and construction terms, when remaining sections are enforced. Further consultation between government departments is needed before the listed sections in 2.5.5 enter into force. The consultation primarily surrounds the "technical aspects of how best to deal with leases and concessions within the proclaimed port areas" (DEA, 2012). The departments which will be involved in further consultation are the department of environmental affairs, the department of Public Enterprises and Transnet (the national utility which has ownership of the freight and transportation networks) (DEA, 2012).

According to the Integrated Coastal Management Bill, "authorisation of marine and coastal structures is a provincial competence" (CSIR, 2008). The sea bed forms part of the coastal public property and as such cannot be purchased or owned by any individual in terms of section 11 of the Integrated Coastal Management Act of 2008 (DEA, 2009a). Therefore a lease agreement from the DEA needs to be arranged for a development on the sea bed (DEA, 2009a; Rossouw, 2008). It is entrusted to the state to ensure that coastal public property is used in the interest of the community (DEA, 2009a). The use of seabed for the production of renewable electricity maybe seen as in the interest of the community as it would produce clean electricity to be supplied to the local grid to help alleviate the electricity shortage being experienced in South Africa. In addition renewable energy would replace greenhouse gas emitting coal fired power stations, contributing to a cleaner environment and preventing climate change. The state is also required to take measures to conserve coastal public property (DEA, 2009a).

Permissions from the Relevant Authority

Before any development can commence a number of permissions need to be in place. The device design has to be finalised, financial backing has to be established and a development site needs to be located. Ordinarily a developer in the renewable industry would purchase or lease a piece of privately owned land and have exclusive right assigned to them by the owner. However developing an offshore wave energy converter (WEC) is complex as the land required is owned publicly and held in trust by the state. Therefore a lease agreement needs to be agreed with the state for publically owned land and the exclusive right to that land. In this regard the representative of the state's consent is required for a coastal lease and this is legislated to be 'The Minister' (Minister of the Department of Environmental Affairs) (DEA, 2009a).

The Minister whose responsibility it is to oversee the application is primarily, but not limited to the minister of the department of environmental affairs in all cases. In certain cases other ministers are given authority over developmental decisions if a development would impact on that minister's management portfolio (DEA, 2009a). Cases where this would occur are in the event of the planning scheme affecting the navigation of vessels on the sea or if the scheme restricts vessels from entering or leaving a harbour (DEA, 2009a). Alternatively, if a development would threaten the possibility of mineral prospecting and mining activities the relevant authority would not remain solely as the Minister of DEA (DEA, 2009b).

"Possible competent authorities:

- Department responsible for Environmental Affairs;
- Department of Mineral Resources (mining decisions);
- Provincial departments dealing with environmental issues;
- Municipalities (if so delegated)."

(DEA, 2009b)

In addition under section 57 of the ICMA, a coastal planning scheme, which is allocated by the minister, does not create any rights for land or coastal water use (DEA, 2009a). As such no rights could be guaranteed to a WEC development for the duration of the plant life span. Under section 59 if the minister has reason to believe that the development will threaten the coastal environment, then the minister has the authority to issue a written coastal protection notice to prohibit an activity or take action to prevent environmental damage. The notice may instruct the applicant to investigate the impacts of an activity on the coastal environment in line with Chapter 5 of the NEMA: ICMA, to mitigate impacts or halt an activity altogether (DEA, 2009a).

In line with this authority of coastal protection, section 60 provides some risk to a development such as the SWEC. The section states that any structure placed in the ocean that "is having or is likely to have an adverse effect on the coastal environment by virtue of its existence," may be liable for either the repair or removal of the device if deemed pertinent by the Minister or MEC (DEA, 2009a). Reason for liability would be due to the condition of the device, abandonment or the construction contravenes the ICMA or any other law (DEA, 2009a). A minister may issue such a repair or removal notice in writing to the person responsible for the structure after the minister or MEC has consulted with any other organ of state that authorised the development and allowed the person issued with the notice time to make representations. Non-compliance is a criminal offence.

Because the area in which the SWEC would be located is in territorial waters, the sea bed must be used in a manner that is in line with the designated purpose of the territorial waters zone and be used for the benefit of the people for whom the land/seabed is held in trust. A WEC development may be deemed to be in the public trust and must be motivated as such due to the device providing clean, renewable electricity. If an area of the seabed is zoned as a coastal protection zone such as 16 mile beach then the activities that occur in that zone have to be in line with the goals of that zoned area. As such the development of a WEC would have unavoidable consequences, which is stated as a condition not to allow a positive environmental authorization in the ICMA. There may be a number of consequences which would prevent such a development occurring. Negative impacts result in "irreversible or long term adverse effects to any aspect of the coastal environmental that cannot be adequately mitigated," by activities which are "likely to be significantly prejudiced by dynamic coastal processes" or would not be beneficial to the whole community (DEA, 2009a). Consequently such a development would not be in line with the goals of the MPA as stated in section 17 and thus no development would be allowed within 16 Mile Beach MPA (DEA, 2009a). An amicable solution maybe to use the SWEC development zone as an exclusion zone for both vessel sailing and a fisheries no catch zone. The goal of this would be to enlarge the no catch protection zone of 16 Mile beach providing additional breeding habitat for marine species. This action would feed directly into the goals of Cape Nature and the Dassen Island Wild Life Reserve which is to extent the protected area from Dassen Island to 16 Mile Beach and create a one large Marine reserve (Du Plessis, 2012). If the SWEC could be aligned as a project to bridge the zone between Dassen Island and 16 Mile Beach reserves to create a single large no catch and no sail zone, significant support maybe rallied from nature organisations, local government and the public.

Although subsection (2) of section 63 of the ICMA rules out the development in the coastal protected zone, there are circumstances which would warrant development to continue. A competent authority may thus issue an environmental authorisation if the very nature of the development requires it to be located in the coastal public property of a coastal protection zone. A wave energy converter would qualify for this characterization as it relies on coastal wave energy however this may not be enough to encourage establishment of a MPA. Under section 64 (1); with special permission and consultation between the Minister and the MEC of the province, a project may be authorised if the development is overwhelmingly in the interest of the whole community despite the adverse impacts. This is possible if irreversible impacts are mitigated and further appropriate studies are conducted to accompany the application (DEA, 2009b).

5.3.1 Leasing Coastal Public Policy

Future Lease Policy under the ICMA

As coastal public property is held in trust for the public of South Africa, the land required for the development may not be purchased. According to section 65 (1) of the ICMA no person may occupy, construct or erect any structure in coastal public property (DEA, 2009a). Hence a lease agreement would need to be negotiated with the national government who retains control over the coastal public property (DEA, 2009a). The construction area required for the placement of a WEC such as the SWEC would therefore need to be leased (DEA, 2010). The award of such a lease for a concession area would limit a development to the leased area in coastal public property and may be awarded in terms of the ICMA or marine living resources act. In terms of section 65 of the ICMA the only person or body that has the right to exploit a specific coastal resource is one that is empowered by national legislation or an authorization has been awarded. This is often the occurrence with activities, often mining, which have gained leases concessions under the marine living resources act or previous sea shore act. Alternately an exclusive right may be obtained via a coastal concession or lease authorised by the minister in terms of the ICMA, and in the case of a WEC development the minister of the DEA is the relevant official (DEA, 2009a). A coastal lease or concession may be awarded to a person applying to the minister or if the minister decides to award a lease in any specific case, where the application has undergone a prescribed bid process (DEA, 2009a).

A number of lease and concessionary terms exist which are listed in section 65 and 66. A lease application is required to comply in order for it to be authorised. Section 65 (4), states a “coastal lease or concession application must be completed in the prescribed manner” (DEA, 2009a). No provision is made in the act detailing such “prescribed manner”. Therefore an application for the development of a WEC device such as the SWEC would need to be made on a specific case basis. It is subject to any prescribed conditions or any conditions determined by the minister for that specific development (DEA, 2009a). A lessee or concessionaire on authorization is not exempt from complying with or gaining other authorizations in terms of the ICMA or other legislation (DEA, 2009a). Consequently a WEC development would need environmental authorization from the DEA, generation licences from NERSA and additional permissions are discussed in paragraph 5.5. Section 66 requires the lease for an appropriate WEC site to be for a set period of time of no more than 20 years. Rent for the lease area is required to be of “a reasonable amount” (DEA, 2009a). The lease agreement for a WEC device would require the exclusive rights to use the water for specific purposes. This condition is possible and should be activated for the development according to the ICMA section 66 (2) for a lease on partially or entirely submerged land in the coastal public property (DEA, 2009a). Finally an organ of state may not allow a lease for an activity that will have a negative impact on the environment without first considering the outcomes of an EIA report (DEA, 2009b). Therefore a positive record of decision (ROD) and an environmental authorization (EA) would encourage the conclusion of a lease. This document would also be useful in the submitting of applications for lease agreements and EIA's (DEA, 2009b).

In addition to a 20 year lease, a lease for temporary occupation of land within the coastal zone, in terms of section 67 of the ICMA, will be required during the construction and maintenance periods. A lease for the temporary occupation of land would be utilised during the construction phase as a lay down area to store materials and components. It may be utilised for placing of components or material during maintenance or repair of damaged parts of a WEC device. A temporary leased area would also allow for space which could be valuable when responding to a pollution event or emergency (DEA, 2009a). Terms of the lease of a temporary occupation area would allow for the removal and utilisation of stone, gravel, sand and other material. The deposition of material on to the area for storage and the construction and use of temporary works such as lifting or assembly equipment is sanctioned under the lease if it were required by the WEC device design (DEA, 2009a). Permission for a temporary occupation lease can be gained from the minister or an MEC, provincial, or department official if powers have been delegated by the minister.

In order to level the site on which a WEC may be located dredging of the sea floor would be required. Dredging of the sea floor is listed as an activity to trigger an EIA; consequently the relevant permissions would be addressed and obtained in an EIA. Dredging may also be a requirement for laying of submarine power cables however this is dependent on cable design and seabed conditions. As such a large amount of material would be removed from the construction sites. To avoid an already high capital cost it is likely that the dredged material would need to be disposed of at sea as an alternative to being transported and disposed of onshore. In a case of sea disposal a dumping permit would be required under section 71 of the ICMA (DEA, 2009a). A dumping permit would need to be applied for in writing to the Minister in a form stipulated by the Minister, and a fee paid, in order to authorise waste or other material to be loaded aboard a vessel or structure to be dumped at sea (DEA, 2009a).

Section 83 of the ICMA entitles the Minister to make regulations which outline the procedures to be followed in order to apply for an authorization or lease. Procedures to be defined would include:

- The required fees for the lease.
- The type and format of data required for monitoring the coastal environment.
- Which authorities consent is required for an authorization.
- Factors which should be consider in the bid process when an application for a coastal lease is launched. The conditions which should furnish an authorization notice.
- The security which is given to the lessee in respect of any obligation that may arise from carrying out activities authorised by permits, coastal leases as well as the form of that security.
- An MEC may also make such regulations with the permission of the minister on condition that they do not conflict with national regulations.

Such a lease agreement and terms would have to be negotiated on a case-by-case basis with The Minister of Environmental Affairs. There is no generic application but requirements are highlighted in section 83. Thus to gain a lease, a written application should be lodged and negotiations would take place leading to the finalization of a lease.

Finally, in the event of historical rights for a leased area that were awarded in terms of the marine living resources act or sea shore act, the lessee’s rights are not void due to the ratification of the ICMA. If a lease or concession was granted for prospecting rights by the repealed sea-shore act, they would simply have to be renewed under the ICMA act. If a holder of the concession failed to notify the department and concession has lapsed, a section 53 or any mineral right would no longer apply (DEA, 2009a).

Current Lease Policy and the Sea Shore Act

As previously stated sections (11, 65, 66, 95, 96, 98) of the Integrated Coastal Management Act (ICMA) have not entered into force. The result being the Sea Shore Act 21 of 1935 and its subsequent amendments form the basis for the lease and concession agreements until the ICMA is fully enforced. Section 3 of the Sea-shore Act states that any portion of the sea-shore or sea (water and the sea bed below) which is owned by the state president (in trust) may be leased if the minister deems it to be pertinent. Consequently under the Sea-shore act an application to lease the sea bed and water (above) for the construction of a WEC would have to be made to the Minister of the national Department of Environmental Affairs. The minister would stipulate the conditions for activities such as dredging and fees payable for the lease under section 10 (f) and (c) respectively (RSA, 1997). This application can only be made on property which is owned by the state president in trust for the general public of South Africa. Applications cannot be made on property for which alienable rights are already held such as harbours and ports. Lease applications can be made with the intent to;

(g) erect structures,
(k) the carrying out of any public work of public utility (if the facility is Eskom owned),
(m) laying of cables,
(o) “carrying out of work which in the opinion of the minister serves a necessary or useful purpose”

(RSA, 1997)

Clause (o) remains a reason to lease on condition that the planned activity is in the public interest or will not considerably deteriorate the public’s enjoyment of the sea shore and sea area.

A private coastal lease is justified under section 5 the government may use or lease any portion of the sea shore or sea area that is owned by the State President (public property). Under section 6, any other letting of public property that is not accounted for by the Sea-shore Act or any other law will require approval from the National Assembly (RSA, 1997). In the event that it is deemed no legislation applies to a WEC a decision may need to be taken at the National Assembly, the highest decision making process. This would be an onerous process, and might only occur in the case of significant uncertainty surrounding permitting, a particularly cautious approach and a lack of information. If a proposal for a leased property were to be taken to the National Assembly for approval, the Department of Environmental Affairs is required to consult the local authority and the development would require consensus (RSA, 1997). Hence an application for a lease should be taken to the National Assembly for approval after submission to the national government unless prior to submission, powers have been delegated to local government under section 4 of the Sea shore act (RSA, 1997). This is potentially beneficial as the assembly may consider national strategic objectives such as energy security and diversity of supply over provincial objectives. Therefore the National Assembly may take a more holistic view and award the coastal lease due to a wave energy project's potential strategic importance. The Sea-shore act regulations for lease agreements are the regulations which need to be adhered to until the relevant ICMA sections, on concessions and lease agreements, are entered into force.

5.4 Influential Policies

5.4.1 Provincial Policy

The Western Cape Renewable Energy Action Plan shows promise in that in legislates uptake of 12% renewable energy by 2014 and 30% by 2030. However the province is to a large degree not able to select electricity sources as electricity supply is provided by Eskom for the significant majority. There are only a limited number of municipal run electricity generators nationally and there is no significant municipal generation from renewable sources (DEA&DP 2009). This policy may be beneficial to the promotion of renewable energy, however the mix of renewable technologies is not stipulated. Consequently ant tender for a quota of renewables may be too small for the SWEC to be economical. In addition fringe technologies such as wave energy will face much competition from other more established and cheaper renewable technologies. The Renewables Action Plan Being a broad based policy doesn't specify the technologies to be utilised, thus, is likely to exclude wave energy altogether. Resultantly provincial policy is unlikely to encourage the uptake of wave energy.

The Western Cape Coastal Management Programme (CMP) (2003) would be the CMP mandated by the Integrated Coastal Management Act (ICMA) and applicable for the SWEC site selected (DEA, 2009a). CMP's have the benefit of streamlining lease agreements occurring under the ICMA Act. The CMP along with objective 9 of the supporting Western Cape Spatial Development Framework (2009) both encourage the introduction of renewable energy in the Western Cape (DEA&DP 2009; DEA&DP 2003). However, Goal D3 of the CMP aims to ensure that the use of renewable resources does not compromise the functioning of the ecosystem (DEA&DP, 2003). If such a coastal planning scheme is applied to an area and that area is more than 500m seaward from the high water mark or affects the protection or use of marine living resources then; the planning scheme to streamline the development may only be established with the consent of 'The Minister' (Minister of Environmental Affairs) (DEA, 2009a). The merits of this approach to gaining permission for development are uncertain but one legislated avenue to pursue.

5.4.2 Maritime Zones

The Maritime Zones Act (No.15 of 1994) stipulates a coastal boundary for the Maritime Cultural Zone located 24nm seaward of the baseline (low water mark) seen in Figure 5-1: Ocean and Policy Boundaries Adapted from the White Paper on Sustainable Coastal Development (DEAT, 2000). Thus the boundary overlaps with the entire contiguous zone. Previously the National Heritage Resources Act (No.25 of 1999) was limited to the terrestrial land in South Africa. Thus the Maritime zones Act formally extends the reach and protection of the Heritage Resources Act over archaeological and historical objects within the zone. The Heritage Resources Act by implication impacts on any coastal development seaward of the low water mark and must be considered in any seaward development. Heritage resources act "focuses specifically on cultural and historical resources, which are a key component of our coastal heritage." "Coastal resources of historical, archaeological, cultural and scientific value shall be identified and preserved, protected or promoted (DEAT, 2000)." The entire 200nm span of the EEZ is "subject to the legal regime established in the United Nations Convention on the Law of the Sea under which the coastal state (South Africa) has certain rights and jurisdiction" (Lombard et al, 2004).

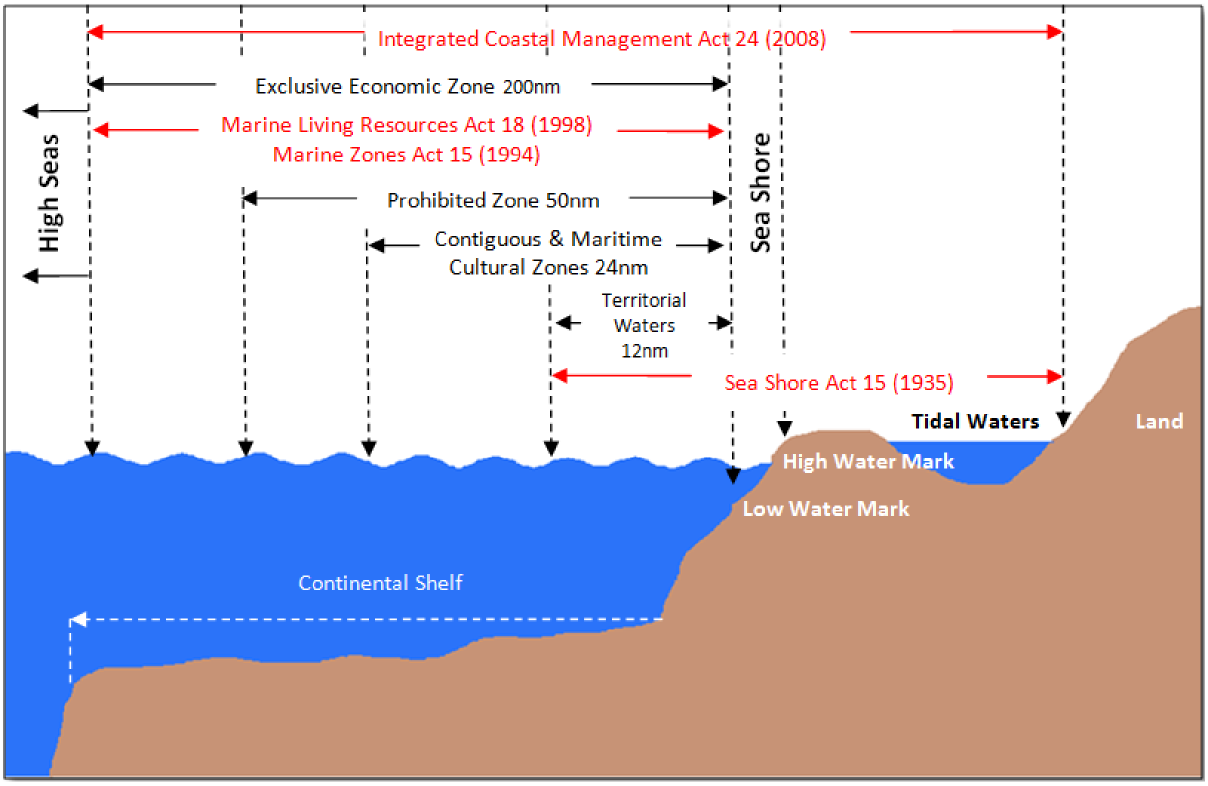


Figure 5-1: Ocean and Policy Boundaries Adapted from the White Paper on Sustainable Coastal Development (DEAT, 2000)

MPA's

Marine Protected Areas (MAP) offer the same conservation value that terrestrial nature reserves protect land animals. South Africa was the first country to pronounce a MPA in 1964 (WWF, 2012). Currently there are now 21 MPA's, 8 of which are no take zones meaning no fishing may commence in the borders of the MPA (WWF, 2012). The promulgation of the Sixteen Mile Beach MPA in the area between Langebaan and

Yzerfontein under the Marine Living Resources Act No. 18 of 1998 means that this study will have to consider the relevant policy in the implementation of such a device. Under the Marine Living Resources Act (no.18 of 1998) section 43 (2), no person may erect buildings or structures on any land or water over a marine protected area. Additionally dredging, removal of sand, gravel or any destruction of the environment is not permitted (DEA, 1998). However the Minister with consultation from the forum may give written permission to undertake any prohibited activity where the activity is required for the proper management of the MPA (DEA, 1998). Unless it can be motivated that a SWEC device is required for proper management; construction within a MPA will not be sanctioned.

The MPA covers the northern half of the site intended for deployment of the SWEC. Thus this study will need to investigate the possibility of a development within a MPA and the permission required for the implementation of such a device. All activities in this site have been restricted besides certain types of recreational fishing according to the Marine Recreational Activity Information Brochure as the site is a Marine Protected Area, declared under Section 43 of the Marine Living Resources Act (Act No. 18 of 1988). Du Plessis, (2012) and the Dassen Island Nature Reserve have proposed the extension of the sixteen mile beach nature reserve to incorporate the whole of Dassen Island and a substantial area of the surrounding marine environment. A project such as this would likely make an entire SWEC array unfeasible due to the widespread habitat alteration that would occur. However the opportunity may lie in a limited scale development to act as an exclusion zone along with the extended marine reserve.

Figure 5-2: Cape Nature Proposed Marine Protected Area for the Dassen Island Nature Reserve (Du Plessis, 2012).

5.4.3 Sea Birds and Seals Protection Act

The Sea Bird sand Seals Protection Act (no 46 of 1973) prohibits the capture, killing, wilful disturbance, collection of eggs or young in the exclusive economic zone (EEZ), unless sanctioned by a permit attained from the Minister of the Department of Environmental Affairs and Tourism (DEAT) (DEAT, 2004). The act therefore protects islands and rocks which offer unique habitat to both seals and seabirds. This includes any area that is used for breeding for haul out either on terrestrial land or an island by seals, penguins or marine bird (DEAT, 2004). Jacob's Reef is the regional seal colony. Dassen Island, Jutten Island and Malgas Island are the regional bird colonies which are located within 10km of the proposed SWEC site (Blood and Crowther, 2012). Section 3.1.1.8 of the act stipulates that it aims to reduce "Mortality due to traffic and other forms of development" (DEAT, 2004).This aims at protecting species from development within their habitat as well as marine traffic causing mortality which are potential impacts of the SWEC (Ralston, 2012). Section 3.1.1.9 aims to prevent starvation of birds and seals by protecting their food resources (DEAT, 2004). The policy aims to ensure sustainable food availability for both seals and birds. The SWEC may pose a significant threat to these animals' food resources by altering ecosystem dynamics or disturbance of the food resources (PIER, 2008).

Section 3.1.2 of the act stipulates increasing the production of seal and sea bird species. The policy aims to achieve this by protecting against "inadequate food resources" (3.1.2.1) particularly near breeding grounds. The SWEC may threaten food sources and precautions would need to be taken to ensure that the SWEC development didn't threaten stocks. Section 3.1.2.2 "Displacement of birds from breeding sites," section 3.1.2.3 "Degradation of breeding habitat," and section 3.1.2.4 "Disturbance by humans" are impacts that the act aims to prevent. Although the SWEC is not located on any breeding site, the proximity of the development to seal and bird colonies means that noise impacts from marine traffic, pile driving, deconstruction, or explosion could disturb animals and cause animals to abandon breeding sites, prohibited by this act. As interactions between marine birds and seals are likely to attempt to roost or haul out on the SWEC conditions of the act need to be considered carefully. In fact section 4.7 of the act states that when development conflicts with animals included in the act, the burden of funding measures that will prevent conflict fall onto the developer and are obligatory (DEAT, 2004). As such any activity associated with the construction operation or decommissioning of the SWEC that may disturb seals or sea birds would require a permit from the Department of Environmental Affairs and Tourism, currently known as the Department of Environmental Affairs (DEA, 2012; DEAT, 2004).

5.5 Additional Permissions

Many permissions and notifications of activities are facilitated by the environmental impact assessment process. A number of permissions need to be gained from different stakeholders who will be affected by the development of a WEC. The required permissions and the stakeholders from which they need to be obtained are identified in the public participation process carried out as part of the EIA. Public participation and stakeholder engagement is legislated in chapter 6 of the NEMA environmental impact assessment regulations and the

Integrated Coastal Management Act (DEA, 2009a; DEA&DP, 2006). Under this legislation stakeholder engagement is mandatory and the extent of permissions required, are uncovered during the EIA process. In this regard a formal letter of notification would have to be constructed and distributed to a representative of affected organisations, responsible for such decisions. The letter would have to detail the proposed project, design, layout, areas where the third party would be affected and what consent is required from said party. In the case of the SWEC device, a unique mixture of stakeholders would be involved due to the sensitive area in which the device would be deployed. Stakeholders involved in the shipping, mining, tourism, wildlife conservation, telecommunications and fishing industries would all need to be involved.

5.5.1 Mineral Rights Permissions

Mineral rights constitute a large part of the country's economy and are regarded as having a highly strategic value. Considering the strategic value any planned development is subject to authorisation from the Department of Mineral Resources. This is to ensure the mining potential of an area is not threatened by a proposed development. The Mineral and Petroleum Resources Development Amendment Act (no.49 of 2008) updates the Minerals and Petroleum Resources Development Act (No. 28 of 2002) (RSA, 2009). The Amendment to Section 53 precludes the development or any land use on the surface of any land which may "detrimentally affect the mining of mineral resources" (RSA, 2009). Any land as referred to in Section 53 means all land regulated by South Africa which includes the entire coastal zone, and exclusive economic zone.

A section 53 application is concerned with the sterilization of mineral resources (of any geological material including sand, gravel, clay topsoil etc.) The department of mineral resources aims to ensure that through this Act that any material of value is not compromised by a development such as the SWEC. Thus a section 53 consent application to sterilise the prospective area concerned must be submitted to the Department of Mineral Resources' regional office in the Western Cape (RSA, 2009). As indicated by the department of energy, consent from the Minister of Mineral Resources under section 53 of the minerals and petroleum resources development act (Act No 28 of 2002) (MPRDA) and the amendment act (no 49 of 2008) must be presented for new power generation facilities under the IPP procurement programme (RSA, 2009). The proposed development of a wave energy converter would need to apply for the section 53 permit from the Department of Mineral Resources in order to 'sterilise' the area of all mineral rights and ensure that the development will not infringe on any land that may be advantageous for resource extraction. This is important for the proposed SWEC site as there are a number of prospecting rights for natural gas held for the areas which border the west coast site as seen in Figure 5-3: (PASA, 2012). However the map does not indicate any current mining or prospecting activity which would improve the potential utilisation of that section of the coastline. A section 53 is also likely to be more problematic for a SWEC device than a floating device such as the Pelamis due to the large footprint the SWEC has on the seabed, effectively excluding that surface area from potential mining activities.

The area under mineral application may overlap with the furthest extent of the proposed SWEC site although the majority of prospecting and mining rights are located some distance offshore. Additionally a floating WEC such as the Pelamis has the potential to be located greater distances offshore. Thus the Pelamis may intrude into leased mineral rights areas. As such a Section 53 application would be advisable and 3rd party consent maybe required to ensure neither the SWEC nor a Pelamis device would threaten possible mineral extraction activities.

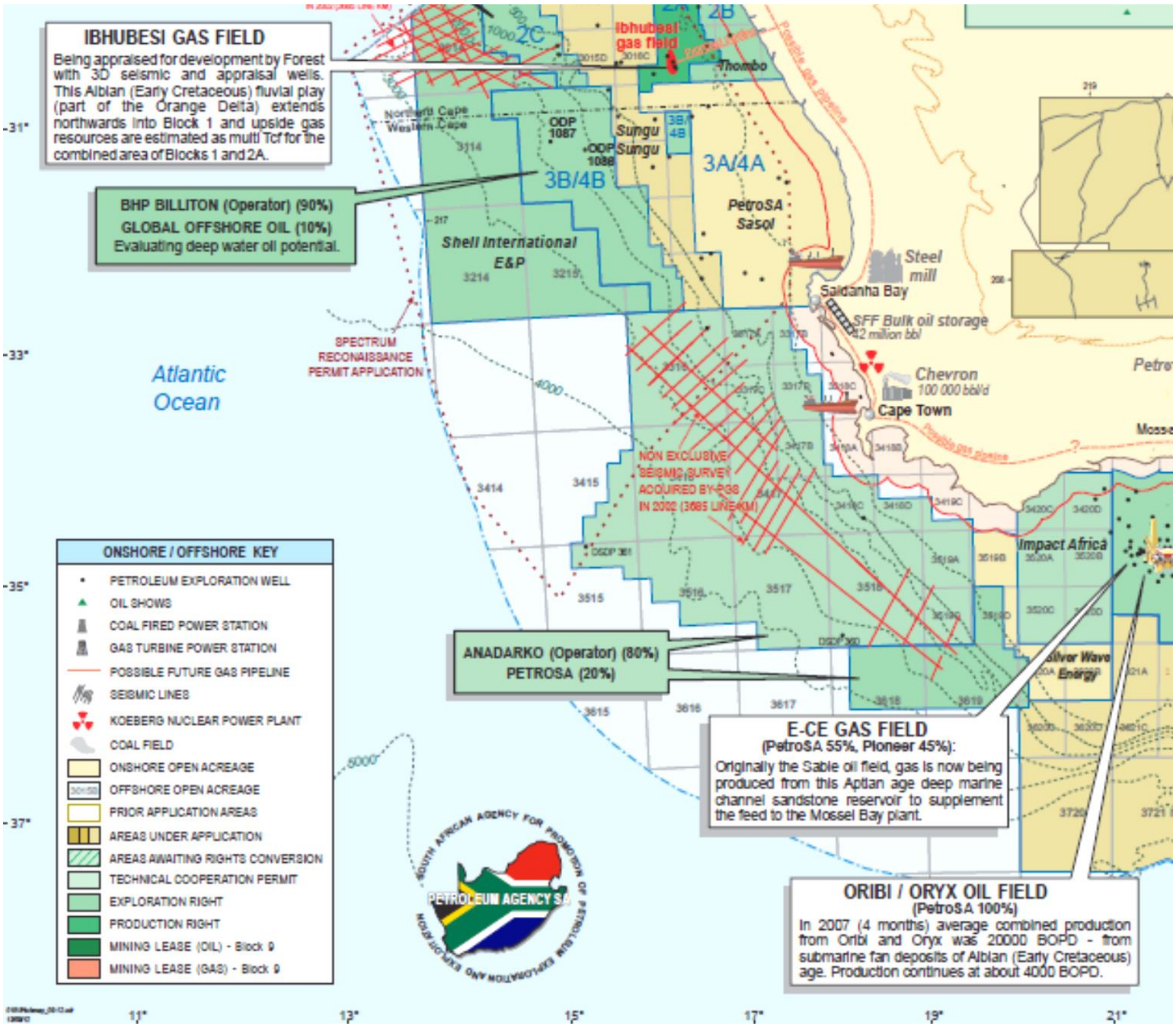


Figure 5-3: SA Off-shore Minerals Rights and Prospecting Exploration Opportunities (PASA, 2012).

5.5.2 Department of Transport Permissions

Another major department which would have to approve the development of the SWEC is the Department of Transport and Transnet as the operator of ports. Reasoning would be to ensure that shipping lanes are not obstructed as the south west coast experiences heavy marine traffic. The SWEC is an offshore device typically designed for deployment 1-2 km beyond the high water mark. Thus the SWEC is located in territorial waters. In this zone there is a discernible level of maritime shipping activity as seen in Figure 4-10: VOS data points as a

Proxy for the Shipping Lanes along the coast of South Africa (CSIR, 2008)., as indicated by the blue shading (low activity) and green shading (medium activity) (CSIR, 2008). Although the location of the device is not within the lanes of high shipping activity as shown by CSIR, (2008) the SWEC is still located in an area of significant marine traffic. This would warrant further study as the possibility of wreckage on the WEC device is of concern. As such permission or consent from the relevant shipping authorities would be required before any development take place. The party that would need to be contacted with regard to the intrusion of shipping lanes would be the Minister of the National Department of Transport and the Department of Defence and the South African Navy in particular. Consultation with the Departments of Transport and Defence could be facilitated through the EIA process, independent engagement would be advised for first of their kind developments. There is no formal structured application but a detailed location and description of the intended activities as well as project construction and operational timeframes would need to be provided to the Departments.

Maritime Safety

The South African Maritime Safety Authority (SAMSA) is constituted by South African Maritime Safety Authority Act 5 of 1998. This act establishes SAMSA as the maritime safety body responsible for vessel and maritime sailor's health and safety and licencing. Letters would have to be drafted to notify the relevant person at South African Maritime Safety Association (SAMSA) and requesting comment and requirement on this unseen development. Intrusion of the shipping lanes would pose the largest safety concern and provisions would have to be taken in partnership with SAMSA to mitigate any risk to life or property.

National Monuments

Despite there being no monuments located within proximity of the development site there are over 2000 shipwrecks along the South African coastline, some of which are regarded as national monuments. Most of these wrecks occur along the west coast in relatively shallow water (less than 100m depth) (Blood and Crowther, 2012). There are reported to be twenty wrecks between Milnerton and Saldanha Bay located in water depths under 100m. National Monument status is assigned to wrecks which are older than 50 years of age (Blood and Crowther, 2012). It will need to be determined if any historical wrecks are located in the vicinity of the proposed site. This will need to be confirmed with the National Heritage Resources Agency (SAHRA) and their involvement would be needed during the EIA process. If any historical artefact is at risk permission via a destruction permit would need to be obtained from SAHRA before undertaking a large scale development. If any artefact or historical discovery is uncovered during construction, site works have to be halted immediately and a relevant authority from SAHRA would be required to determine the course of action.

Wildlife Conservation

There are two major nature reserves which will need to be contacted before any development would commence. They are the Dassen Island Wild Life Reserve and the West Coast Nature Reserve controlled by SANParks. The West Coast reserve encompasses the Marine Protected Area referred to as Sixteen Mile Beach which is the coastal side of the SWEC development in the northern bay between Yzerfontein and Saldanha bay (Du Plessis, 2012; Ralston, 2012). Cape Nature and SANParks (both representative bodies of the Western Cape Governments Department of Environmental Affairs and Development Planning) would need to be contacted for permission and to provide them the opportunity to comment and raise concerns about the development (Du Plessis, 2012). Any vegetation removal would require specific written permission from the Minister of the DEA in terms of the Marine Living Resources Act (no.18 of 1998) section 43 (2).

Department of Fisheries

Given the trawling location of purse seine pelagic trawlers and rock lobster fisheries in relation to the proposed site for SWEC deployment certain fishing grounds or trawling routes will be impeded. The Department of Agriculture Forestry and Fisheries (DAFF) would need to be consulted in order to obtain consent for the development (Wilkinson and Japp, 2005). There is no legislation as to the consenting process from DAFF or specific fisheries but both DAFF and independent fisheries would need to be registered as Interested and Affected Parties during the Environmental Impact Assessment process and provided the opportunity to comment and object to the development. Objections and discussions would need to be facilitated on a case by case basis as impacts on fisheries would vary according to WEC device type and location. The SWEC is likely to have a significant impact on fisheries given the area of seabed converted and deemed a no catch zone. An advisable course of action would be for DAFF and local fisheries to be contacted directly at an early stage in development for consultation, comment and permission so that a developer would be aware of any issues or objections. A detailed notice of the intended activity location, description and timeframes would be required.

Tourism

Impacts on the local tourism industry are ambiguous with Boud, (2003) suggesting that a WEC array could become a tourist attraction. However PIER, (2008) claims that WEC arrays may have visual impacts associated with installation and operation, removing from the sense of place of certain maritime environments. The SWEC device would have tower containing the air turbine protruding from the ocean creating a visual impact while devices such as the Pelamis would float low in the water resulting in lower or negligible visual impacts. Whether the impacts stand to be positive or negative the local tourism industry would need to be identified and notified on the proposed development to allow them to comment and interested and affected parties to be involved in the public participation process. Bodies which would have to be notified and contacted would be the Western Cape Governments, Department of Economic Development and Tourism, and local tourist offices such as Yzerfontein Tourism Bureau, Saldanha Tourism Bureau and the West Coast Nature reserve offices. A number of these bodies and interested and affected parties would be invited to comment on visual impacts within the environmental impact assessment (EIA) and a full assessment of visual impact would be required by a specialist within the impact assessment. In turn any potential impacts on tourism would be addressed during the EIA and informed by the specialist studies.

5.6 Implementation Plan

The implementation plan produced in Figure 5-4 is a “pre-implementation plan” according to the strict definition of strategic management (Li et al, 2008). The plan produced has a number of aspects associated with the “Organising Implementation” which is the second major phase of the four stages in producing a complete implementation plan according to Li et al, (2008); and Mindzberg, (1990). The implementation plan produced considers the hard and soft factors included in the first two phases but does not deal with the latter key aspects in project development of ensuring buy in, fostering collaboration and monitoring results or operation. These actions would be implemented in the next phase of development when a commercial device is ready for deployment and the developer can begin to seek project finance, investors, appoint design and construction contractors and identify a business model, whether it be for government tender or in a free electricity market situation. Although Figure 5-4 details these steps in their chronological order, they are not analysed in this thesis.

As suggested by the Li et al, (2008) the basis of the plan was founded by gathering view points from a number of specialised stakeholders. Viewpoints were gathered with regards to three key scopes; device costing, environmental impacts and government policy. Questionnaires and interviews were utilised as the recommended means of data collection by Li et al, (2008), along with literature review. Questionnaire and interviews were structured according to the SWOT model and facilitated to support the pre-implementation and organising implementation phases of an implementation plan.

A suggested by Kelman, (1984) the implementation plan takes a critical look at policy. Policy requirements leave a complex mesh of environmental approvals, regulatory permissions and additional consents to be obtained during the development process. These areas are discussed individually in the relevant chapters. In reality all these areas need to be combined within the development process before the physical implementation of the SWEC device. The hard factors as described by Li et al, (2008) associated with implementation are summarised at high-level for the SWEC device. The steps to be followed through the implementation process are outlined in Figure 5-4. This simple flow diagram represents the chronological process of development areas involved in the pre-implementation process. It begins with the land acquisition phase and details of the coastal lease policy. Issues surrounding the lease policy are found in Section 5.3.1. A detailed site specific energy measurement and analysis would be the next phase in the process. This is a hard factor, not addressed as Geustyn, (1983), and confirms the Cape south west coast as the area with the highest wave energy resource and to date is considered the most comprehensive wave energy analysis (Joubert, 2008; Van Niekerk, 2008; Retief, 1984). A specific energy measuring program would form part of an implementation plan to further the location of the device units. Between Langebaan and Grotto Bay has already been identified as the highest resource area of the practically feasible sites. Such a detailed study would likely be contracted out to an able supplier but research into this is beyond the scope of this thesis.

The identified study area is small enough that it can be addressed by an environmental impact assessment and site specific elements could be determined further down the development process. Beginning the environmental impact study is the next phase and the process and issues surrounding the impact studies are described in Section 5.2. Beyond the environmental impact studies there are a number of regulatory and additional consents required before commercial agreements and ultimately construction can take place. The permit requirements are described in Sections 5.1 and 5.5. The implementation plan detailed in Figure 5-4 is available to guide the development process and reduce uncertainty to streamline the implementation process. The steps following the pre-implementation process are detailed in Figure 5-4, but serve as reference to the final two steps of a strategic implementation plan, namely the managing implementation and sustaining performance.

There are number of aspects excluded from the implementation plan and these are made up of mixed and softer factors. Socio-economic factors affecting local fishing communities, job creation opportunities, stakeholder buy-in, site specific designs, financial investment, and power purchase agreements are all excluded from the implementation plan as the device is not at a stage where those goals can be achieved. The goal of the prefeasibility plan is to highlight the permitting process and the potential environmental impacts as well as cost barriers that would be required not only for the SWEC but any other wave energy converter entering the market.

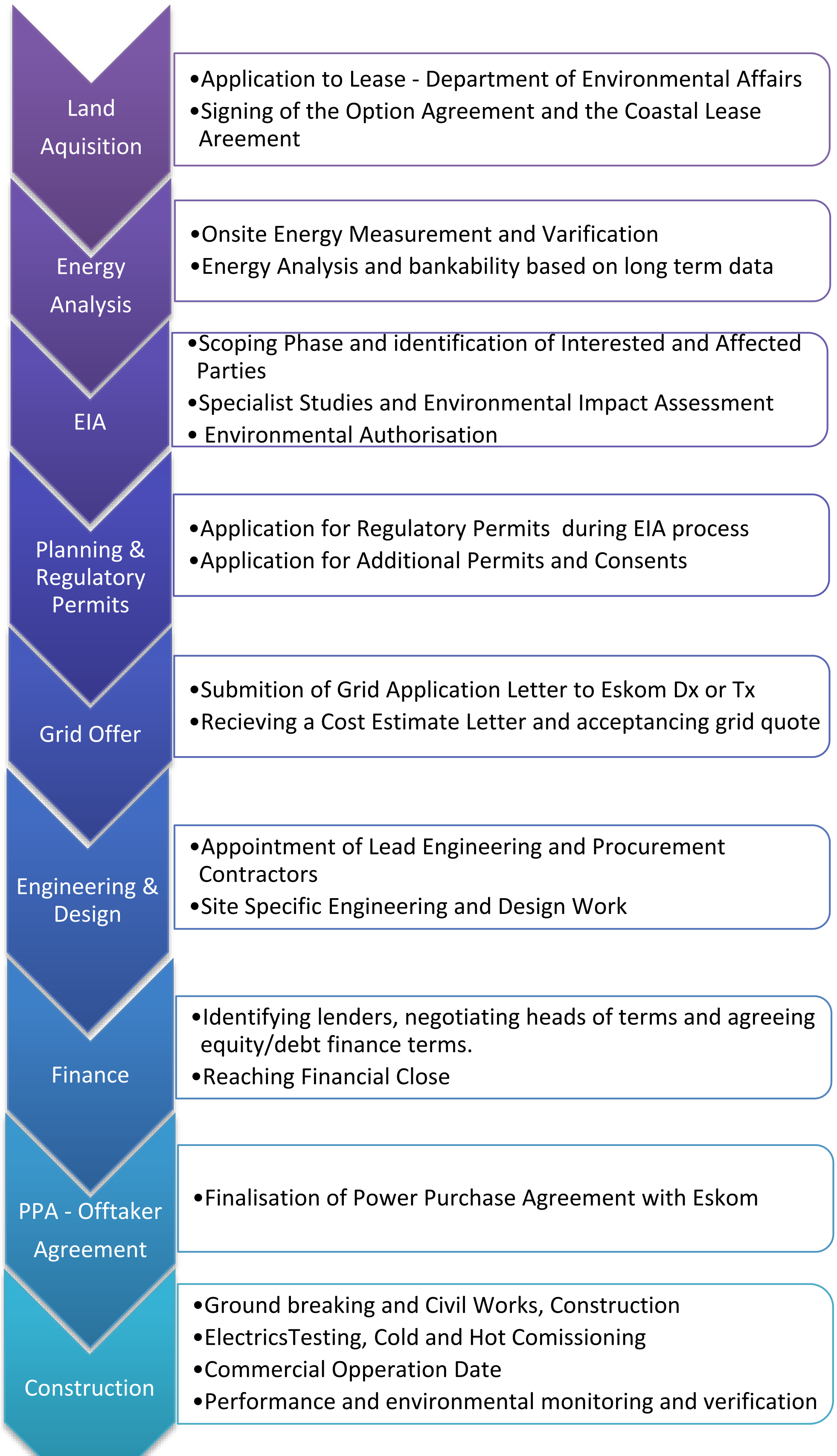


Figure 5-4: SWEC Development Implementation Plan

5.6.1 Policy Changes and Additions

The REBID programme under the DOE's REIPPPP initiative forms an important renewable energy development tool, however it displays highly exclusive qualities, exempting wave energy and fringe technologies from bidding. This is a concerning situation if the plan is to remain locked into only the three most established renewable technologies as it threatens a major objective of the IRP. The overarching objective of generation diversification is ultimately limited if the build plan of the IRP remains the same (DoE, 2011). This results in less diversity in the electricity generation market, putting wave energy at a developmental disadvantage. The continuation of this trend may lead to perverse outcomes in the market ensuring dominance by the Wind and Solar Photovoltaic industries. Diversity of the market is stagnated leaving reliance on a limited number of renewable technologies, ultimately increasing risk. Correction of this would require a portion of the renewable energy quota in future rounds to be allocated to fringe technologies such as wave energy or remain unallocated and available for all other renewable technologies to participate. In the longer term the subsequent IRP may hold the key to encouraging wave energy development especially if the exclusivity of the IRP is reduced. Regular revision of the policy is stated in the policy and remains significant that any new developments have the opportunity to be included in new build programmes.

Wave Energy technologies could contribute to the displacement of carbon dioxide emissions and help with carbon tax concessions in the future, support objectives of the Department of Energy's (DOE) White Paper on Energy and the Subsequent strategy on Renewable Energy (Winkler, 2005). Herein lies great potential for the Wave energy industry in South Africa, however there are also major obstacles. The carbon tax could offer significant developmental assistance to WEC developers, however the National Treasury is reluctant to 'ring fence' any revenues from this tax or any broader tax category. In this scenario wave energy would be competing with Education and Health infrastructure both of which are a priority for the South African government (Winkler, 2005). An enabling environment would be required for the development of wave energy. Power Purchase Agreements (PPA's) with Eskom, access to the grid and creating a market for green electricity are all avenues that should be pursued (Winkler, 2005). Securing funding is a common problem for any project but sources may be available in the international markets although encouraging investment in a new technology in a market with little certainty for wave energy converters will be problematic. Special purpose grants maybe the best bet for funding such as foreign governments trying to establish global markets for local industries such as wave power. Similar funding deals have occurred in South Africa with in the renewables industry where project funding has been secured from foreign governments on condition that wind turbines or solar panels from the respective grantors countries are utilised on the project.

Policy would also be required to protect a potential wave energy industry in South Africa. WEC devices would have to be screened as there are many pilot technologies on offer and screening would identify and confirm the feasible and commercially viable technologies. Consequently programmes such as the WaveHub programme in the United Kingdom may have to be developed in SA in order to test technologies in local waters and optimise them for local conditions (WaveHub, 2012). NERSA would have to ensure that only screened technologies are incorporated into renewable energy policy and are available for development in SA. SABS would then need to provide a SABS/ SANS certificate. For this, standards would need to be determined and set by SABS, which in itself is a huge undertaking.

Given the complex political barriers, a creative solution to encourage the implementation of the SWEC may be more effective. An initiative such as dovetailing the development of a SWEC unit in combination with the extension of a nature reserve such as the Dassen Island reserve may offer the attractive solution which could push a relatively unattractive development to become feasible both technically and environmentally.

6 Results and Conclusions

6.1 Summary of Results

Detailed results are provided on a chapter by chapter basis with a synopsis of findings discussed in this chapter. Key points are highlighted and linked across disciplines to lead into the conclusions provided in section 6.2 and 6.3.

6.1.1 Cost of the Stellenbosch Wave Energy Converter

The simple LCOE calculation indicates power from the Stellenbosch Wave Energy Converter being priced at 2056c/kWh assuming a capacity factor of 51%, discount rates of 15% and excluding cabling costs. Higher discount rates resulting from more risk associated with lending to a project is the immediate price driver and this is visible from Table 3-1. Estimated costs are lower than what is provided in the literature as the Carbon Trust, (2011) estimates WEC prices between R4.80/kwh – 6.60/kwh, although these are influenced by the exchange rate conversions. The inclusion of subsea cabling costs tend to add in the region of 50c/kWh to the levelised cost of electricity for a wave converter and this price is highly variable based on the electrical redundancy requirement and method for cabling used. Never the less it is an influential cost center that should not be excluded from any costing exercise.

The cost break down of the SWEC seen in Figure 3-2 contrasts to traditional fossil fuels, high fuel costs with operations and maintenance costs and capital costs sharing the overall cost approximately 45% to 55% over the thirty year life time of the SWEC plants operation. The economics of the SWEC would decline if the government continued to only commit to twenty year PPA’s as they currently do in the REIPPP programme. Given that traditional fossil fuel plants don’t operate in the same extreme environment thus being able to offer higher availability rates over a longer life time means the economics of traditional fuels are difficult to outperform on a purely economic front without valuing the cost to the environment.

When utilising the SNAPP model a wider variation of factors are considered such as learning rates of a certain technology. Literature reports learning rates of above 10% for wave energy devices, and this contributes strongly to the future competitiveness of wave energy particularly in periods when interest rates are high as seen in Figure 3-4 and Figure 3-5 (ARUP, 2011; RUK, 2010). At high interest rates the SWEC may become cost competitive with other established technologies such as wind and solar PV around 2030 if the strong learning rates (15-19%) are realised. However in normal market conditions (i = 8%) cost competitiveness will not be reached in the long term unless the SWEC’s capital cost can be reduced or the operating life time can be extended.

When undertaking a cost comparison between the SWEC and the Oceanlinx were compared where prices were drawn from literature for the Oceanlinx. The SWEC is significantly more expensive to implement as seen in Table 3-2. This is largely due to the further development of the Oceanlinx which has been through more development and has had prototypes tested. In an optimistic scenario where the SWEC faced discount rates of 8% and aggressive learning rates of 16.9% per annum, the costs of both devices are comparable with the SWEC being more cost competitive. However with learning rates likely to be more moderate and the discount rates likely to be higher given the risk involved in the development of the SWEC, the LCOE is likely to be significantly higher than a WEC comparative device. The greater expense is largely due to the high capital cost of the SWEC which results from the large volumes of material and siting requirements of the SWEC. The full extent of costing for such a device cannot be entirely addressed in a cost estimate exercise, and costs in reality are likely to be higher and less certain. Devices may require site specific design attributes for seabed conditions and specific wave climates. Transmission costs are uncertain as cable lengths can be predicted but infrastructure such as transformers which maybe require in the land based substations is not predictable and can run up bills in the hundreds of millions of rands for a single connection point. In South Africa Eskom is cash constrained and a developer is unlikely to have the costs of a grid connection covered by the state utility. Experience from other devices being developed will help in estimating the appropriate learning rates to use in a costing exercise but these will vary from market to market significantly (Carbon Trust, 2006). However the many assumptions required in light of the lack of data and experience limit the estimate exercise to being used only as a reference point for the performance of the SWEC against a similar establish wave energy device and other technologies in the South African electricity market. The estimate exercise indicates the SWEC as uncompetitive due to immaturity of development and large capital expense while operating over a relatively short operating life time. For the situation to change economies of scale, along with strong learning rates and low interest funding is required that will likely only precipitate from strong energy policy encouraging the uptake of wave energy. Such policy is discussed in section 5.6.1.

6.1.2 Environmental Impacts

Environmental impacts occur at all stages of the plant lifetime with varying receptors and severity. The research undertaken focuses largely on the negative impacts of the SWEC device. It is noted that a number of strong benefits exist which are either not mentioned or are understated.

Impact severity aligned with implementation of the SWEC, is highly dependent on whether a full SWEC array is implemented or only a single unit. The degree to which a receptor is impacted tends to increase to a level where moderate impacts become severe when a full array of devices are implemented. The most significant impacts occurring during the development or early construction phase of the project would be noise impacts from seismic surveys required to determine the seabed stability that is used to site the bottom mounted devices such as the SWEC. Entering the construction phase further noise impacts through pile driving activities are of particular concern. The percussive hammering of pile driving and the low, loud tones from seismic surveys have the potential to injure or kill marine mammals in the site vicinity and affect animals up to 15km (Frid et al, 2011). Right Whales being the most directly impacted are the foremost concern given their migratory route from Cape Point up the west coast, placing them at most risk (Finlay, 2012). Noise impacts are also a key feature during decommissioning, especially in a scenario where explosive decommissioning would be utilised to remove devise from the seabed. The measures to mitigate these impacts are limited to timing the noise generating activity to periods where sensitive marine species are not in the area or using alternate techniques to reduce noise. The ability to utilise these mitigation techniques is limited to technology in the case of seismic surveys and timing of noise activities may not help as differing sensitive marine life may occupy the area at different periods of the year.

Habitat destruction is the second key impact associated with construction activities as cable trenching, surface levelling and device set down damage large areas of habitat. This destruction is then repeated during deconstruction where the baseline environment is again altered with the removal of bottom mounted devices such as the SWEC (Nelson et al, 2008). A 12800 m^2 footprint is the area that would be converted by a single device excluding cable trenching. Consequently the impact severity is dependent on whether a full array of devices are installed where impacts will be high or where a single unit is installed and impacts are negligible. Considering the receiving habitat on the west coast is considered critically endangered in the National Spatial Biodiversity Assessment, expert summation the effects of a full array being installed could be calamitous (Lombard et al, 2004). This results in the habitat destruction impact being rated as ‘high’ and occurrence ‘likely’ according to Table 4-3. Further site specific study in combination with a detailed monitoring programme pre-installation is necessary to feed information in order to form a robust mitigation plan for limitation of habitat destruction during construction and decommission.

The operational phase will largely affect the dynamics of ecosystems and coastal process as the SWEC device acts a terminating device lowering the wave energy to the leeward side of the device (Zettler-Mann, 2010). A benefit of the reduction of wave energy may directly benefit coastal settlement by offering protection from storm event by lowering the wave energy before it reaches the shoreline (Abanades et al, 2014). The reduction of energy also critically alters erosion and deposition rates by and estimated 30% (Retief, 2012). This changes the slope of the beach and may fundamentally alter the shoreline habitat. The SWEC array being located in a sandy bottom environment would introduce a large number of hardened surfaces, encouraging seeding ground for an artificial reef and potentially attracting marine species not endemic to a sandy bottom environment. The combination of these factors have the potential to alter the ecosystem dynamics of a critically endangered and sensitive marine environment, resulting in the rating of a SWEC array impact as ‘high’. In addition a number of large devices would provide a physical barrier to migrating whales and other marine predators active in the productive marine environment located along the west coast (Finlay, 2012). Diving marine birds are also at threat particularly if devices are sites in shallower water environments. Mitigation methods for marine predators and birds would be deeper water siting although this does come with a higher construction and maintenance cost. The proximity of a well-documented bird breeding island, Dassen Island is a distinct concern and should be monitored carefully for disturbance from marine traffic and noise. At a high level the impact is estimated to be moderate with likelihood of occurrence uncertain. Since the SWEC site is likely to be a no catch zone for the purpose of marine safety, it poses negative impact to the fishing industry. However the impact of reducing the fishing grounds for trawling and lobster catching, a dual benefit may be reached by extending the Sixteen Mile Beach marine protected area to include Dassen Island and the extent of the SWEC site as a no catch zone into one large marine reserve. This may act a much needed protected breeding ground for under pressure commercial fish stocks. This proposal would need further investigation but may offer solace to lost fishing grounds for local fisheries.

A number of the impacts identified may occur with unknown certainty and severity. Variation is likely to be significant between sites, water depths and device type. As such conclusive results would require further expert study with this thesis guiding the specific avenues for further research as suggested in section 6.5.

6.1.3 Permitting Under South African Policy

Nineteen key permits are determined for the permitting process for a wave energy converter as listed in Table 5-2. Once a coastal lease is secured from the state, the Environmental Impact Assessment process facilitated under the National Environmental Management Act (NEMA) forms the key permit in the development of a wave energy converter. Given the aforementioned proximity to Dassen Island as a marine bird breeding ground a bird specialist report would be required as part of the EIA to assess the impacts. This is important to comply with the Sea Birds and Seals Protection Act (no 46 of 1973) (DEAT, 2004). Along with an environmental authorisation the EIA process facilitates comment and consent from a number of other bodies from whom consent is required. South African Heritage Resources Agency (SAHRA) is an example of such a body as a permission in terms of the heritage resources is granted through this process. Comment would also be required from the South African Navy and local fisheries for the purpose of the EIA, but would also open up engagement for the request of consent from those bodies for the development of a WEC. However, DAFF and local fisheries need to be contacted directly at an early stage in development for consultation, comment and permission so that a developer would be aware of any issues or objections. A detailed notice of the intended activity location, description and timeframes would be required.

Further the development is approximately 5km from two major marine reserves (Dassen Island and West Coast Reserve or Sixteen Mile Beach) mentioned in section 6.1.2. The proximity of the project means consultation with SANParks and Cape Nature in necessary in regard to the development. Terrestrial renewable developments have to maintain a 5km buffer from nature reserves however the SWEC development would be on the boarder of the 5km buffer and may need to encroach depending on the unit specific siting. Consent from both parties is a requirement and early interaction is recommended.

Consent in terms of mineral rights is necessary in the form of a section 53 consent for the development and clearance of a portion of land or seabed from existing mineral rights from the Department of Mineral Resources (RSA, 2009). However if mineral rights do exists a further 3rd party consent would be required from the holder of the prospecting or mineral right. Another department to be consulted is the Department of Transport along with Transnet as the entity charged with the operation of ports and body overseeing the transport of goods.

Permission is required as the development site is in proximity of major shipping lanes and will likely be deemed as a no sail zone as deep berthing ships may wreck on the SWEC device. Engagement early on in the development process is vital as permission from Transnet could be a major stumbling block if the develop negatively impacts safe shipping routes.

Research on required permissions is structured into a stepwise implementation plan outlining the development process including the required permissions and their phases of application, finance and power purchase agreements. The plan can be seen in Figure 5-4. Once all permissions are in place and a cost estimate letter has been received from Eskom stating the cost of a grid connection, then the developer may go about engaging with Eskom to meet the grid code requirements and connect to the national grid. However finding a procurer for the electricity at a premium over established renewable and traditional energy technologies is a separate challenge. This is ultimately the key factor threatening the feasibility of the SWEC device. Once this stumbling block is overcome the key permission which will be the most difficult to obtain is the environmental authorisation, considering the plethora of uncertain potential environmental impacts that will need further study and monitoring. Results are not aimed to discourage the development of the wave energy industry but rather to outline all the major potential stumbling blocks so that creative solutions can be determined for a complex issue.

6.2 Core Conclusions

Three key aspects of implementation are considered for the deployment of the SWEC device on the south west coast of South Africa. Aspects of cost competitiveness, environmental impact and policy influence incorporating the required permitting procedures. From the detailed discussion three core conclusions can be drawn.

> **The levelised cost of electricity produced by the SWEC is not economical and currently not competitive with comparative wave energy converters at the current power price.**
>
> **A single SWEC unit will have a number of significant, negative environmental impacts, the majority of which can be mitigated. However the development of an entire 154 unit SWEC array comes with considerable uncertainty regarding the long term ecosystem functioning as a consequence of a multitude of direct and cumulative impacts. The balance of the environmental impact without mitigation results in a negative environmental effect.**
>
> **Of the many permits required for the implementation of the SWEC, the majority of the processes are well defined, however the use of outdated or wave energy exclusive policy complicates permitting and acts as a barrier to implementation of wave energy devices. Fisheries, marine protected areas and mineral rights are the three most important permissions to overcome for a WEC development on the west coast.**

In combination the economic cost, environmental threat and political challenges represent major barriers to the development of a local economically feasible and environmentally acceptable wave energy industry in South Africa. South African energy policy is tailored to enable only certain established, low cost types of renewable energy to enter the market. Entry of new technologies has been left to the means of the private sector while government focuses on rapid uptake of relatively cheaper technologies to avoid driving up the cost of electricity. This ultimately discourages uptake of the relatively capital intensive and risky technologies such as the SWEC. The SWEC has the ability to become cost competitive in the long run with other renewable technologies due to the relatively high capacity factors experienced in the South African wave climate. Even if cost and policy is addressed, trade-offs between environmental preservation and large scale wave energy output remains a stumbling block. Given the distinct lack of site specific data detailed investigations into site specific and regional scale environmental impacts of the SWEC on coastal processes, marine flora and fauna, are required. It is suggested that long term modelling of the park effect, monitoring on a demonstration unit and assessment of potential cumulative impacts are necessary before a considered decision on full array implementation can be authorised. An amicable solution, such as using the SWEC development to form a large marine reserve, will be required to gain the support and buy-in required to see the deployment of a full SWEC array. A high-level chronological implementation plan for the SWEC detailing the different development areas has been produced to guide the implementation process and is seen in Figure 5-4.

6.3 Broader Conclusions

A number of further conclusion are drawn from each of the three key aspects.

Levelised cost of electricity for the SWEC:

- Reliable and accurate cost estimates are difficult to uncover for wave energy converters due to the lack of experience within the industry.
- As such assumptions have to be made. Thus assumptions also become a key determinant in the resultant levelised cost of electricity for the SWEC.
- Risk associated with the uncertainty surrounding a SWEC development raises the cost of capital and increases the price of an already capital intensive project.
- Large learning rates need to be achieved in order to cut cost to a point where the SWEC can be cost competitive with other renewable technologies.
- Operations and Maintenance is a significantly large cost center for the SWEC than for more conventional onshore renewable and fossil fuel plants.
- Operating offshore transmission costs are far more significant than the transmission costs of onshore power plants.

- In reality many external costs such as specialised vessel availability and weather windows in which construction can occur will be vital contributing factors in price that cannot be accounted for in levelised costs.

Potential Environmental Impacts of the SWEC:

- A local scale site study is required for the SWEC site to determine the true sensitivity of the specific site as different reports rate the area with different criteria resulting in confusion.
    - The National Spatial Biodiversity Assessment deems the SWEC site moderately irreplaceable surrounded by highly irreplaceable habitat, with the broader biozone ranked as critically endangered (Lombard et al, 2004).
    - Whereas CSIR, (2008) deemed the proposed SWEC site to be a preferred site for wave energy conversion, determining impacts not to be significant.
- The SWEC creates a hardened surface for seeding of coral to occur creating an artificial reef in the process. This will fundamentally alter the naturally flat sandy bottom environment which currently exists on the south west coast. Impacts of a single unit are likely to be limited but the installation of 154 unit array will have a wider spread of impacts such as:
    - Alteration of ecosystem dynamics.
    - Changes in population densities at different levels of the food chain.
    - Habitat creation for reef type species not naturally occurring in the sandy bottom area.
    - The most significant effect is likely to be the impact on the feeding and breeding patterns of the large population of mid trophic level pelagic fish.
- The reduction in wave energy due to the SWEC being a terminator type device may have a number of direct and cumulative impacts that would be exaggerated by the implementation of 154 unit array. Impacts may include:
    - Reduction of energy available to drive sediment transportation and coastal processes such as sediment recycling, and long shore drift.
    - Reduced energy may impact the transport of food and thus availability of food for filter feeders and marine species breeding via dispersal breeding.

- The most significant threat of a SWEC array development would be the potential impacts on the baleen whale species and marine birds which have sensitive breeding sites in proximity to the proposed site.
- A SWEC array may also form a marine reserve as the reef would increase shelter, the area may be declared a no catch and a no sail zone, all contributing to increasing the populations of marine species. Additionally the wave shadow created behind the device may offer respite to species during high wave energy events.
- Creating an exclusion zone around the SWEC site may benefit fishery stocks as well and reducing the risk of wreckage.

- Impacts maybe mitigated but the extent to which mitigation can occur is uncertain due to the fact that the severity of the impacts is uncertain. Therefore a demonstration unit with environmental monitoring is suggested. Gaining any definitive assessment would require an in depth, regional species specific study.

The methods used for determining the environmental impacts of a wave energy convertor leads to the championing of negative environmental impacts while many environmental benefits may be understated. Thus the thesis focuses largely on negative environmental impacts. This is potentially the largest limiting factor of the thesis as the highlighting of negative impacts is aimed at providing transparency.

Influential Policy and Required Permits:

- A large number of permits are required in the developmental process and uncertainty around a new technology in a zone which is not common place would slow or stall the permitting process.
- A SWEC unit or array will require a full Environmental Impact Assessment and a number of the required permissions are facilitated by the environmental impact assessment process.
- Coastal Public Property cannot be purchased and will have to be leased for the development.
- Until certain sections of the Integrated Coastal Management Act are entered into force, the Sea Shore Act is the relevant Policy governing Coastal lease agreements.
- Issues surrounding leasing of coastal public property need to be clarified through the outstanding sections of the Integrated Coastal Management Act being enforced or detailed consultation with the Department of Environmental Affairs.
- Implementation of a government controlled Independent System and Market Operator (ISMO) may open up the market to wave energy in terms of policy but any new entrant would likely have to be cost competitive with other established technologies, with wave energy implementation reliant on the selection criteria of the ISMO.
- Current Energy Policy excludes the entry of wave energy converters into the electricity market acting as a barrier by not making allowances for fringe technologies.
- New policy is required to remove barriers such as the ISMO Bill which would open the electricity market to electricity generators and consequently new technologies such as the SWEC.

6.4 Recommendations

Core actions to address the high level issues identified, the actions to be prioritised are listed.

More detailed industry related cost estimates need to be utilised in order to accurately qualify whether the SWEC will be economically viable into the future. Fine scale investigation into specific impacts is the next step in unbundling the

potential threats to the marine environment at the SWEC site. Policy needs to be revisited and lobbying for the inclusion of wave energy technologies in new policy is a key aspect to open the electricity generation market in South Africa.

Levelised costing of electricity for the SWEC was completed with incomplete data, drawing on a number of assumptions. There is much room to improve the accuracy of the cost estimate and it is recommended that:

- Levelised cost of electricity calculations should be reworked with more accurate data to reduce assumptions and increase accuracy.
- A detailed costing exercise be undertaken as it would be beneficial where members of industry are asked to give quotes for the development and production of different SWEC components.
- Where possible experience should be drawn from the wave energy industry as devices are deployed and experience is gained.

The development of a full SWEC array will have significant impacts and potentially much opposition to its development. The implementation of a device or an array would need to be carried out in an open, consultative manner allowing for community buy in as well and offering environmental benefits instead of just the potential impacts development may carry. As such it is recommended that:

- Detailed environmental monitoring is undertaken on a full scale demonstration unit before an array is considered for development.
- Additionally detailed modelling of the potential park effects are examined along with the potential impacts of wave energy reduction from a large number of device. A design should then be chosen to optimise the level of energy available at the near-shore environment to continue to drive coastal processes.
- The SWEC development should be used as a further exclusion zone to bridge the Marine Protected Areas of 16 Mile Beach and Dassen Island Wild Life Reserve. This may form a useful strategy as an environmental motivator for the development of a SWEC array. It could offer dual benefits of increasing the stock of pelagic fish in the under pressure fishery, therefore improving fishery catches as well as offering a large protected habitat for marine animals where they are not under threat from fishery activities.
- Further in-depth study into the merits and demerits of this strategy are vital before it is adopted.
- A number of potential environmental, physical and socioeconomic benefits are recognised but further study into the specific benefits would be meaningful in the development of the industry. Specific investigation into the benefits of wave energy convertors being integrated into coastal defence systems could serve a dual benefit in the face of global climate change.

Marine policy tends to be complex with a number of policies that do not accommodate the implementation of the SWEC device. A long list of permits and permissions slow the development process. Recommendations proposed for the permitting process and policy moving forward are stated.

- The establishment of wave energy park where all the permitting and permissions are obtained upfront therefore allowing potential developers to connect to a pre-laid power cable, effectively plugging into the grid. The park should be able to accommodate a number of developers allowing them to demonstrate, test and monitor device in terms of performance and environmental impacts.
- Lobbying is required to make allowances for wave energy and other fringe technologies in future renewable energy development policies. Cost cannot be the only determinant of generation selection. Strategically beneficial technologies should be selected that can benefit the economy and electricity sector simultaneously. Wave energy as a developing technology offers South Africa an opportunity to become a leader in a new industry which has the potential to benefit the economy.
- Correction of the current bid programme would require the allocation of a certain number of MW's allocated to emerging technologies that have to be taken up and will allow for a higher price to stimulate technology development locally.
- The ISMO should be implemented and allowance should be made for the support of strategically important emerging technologies such as Wave Energy or Local Nuclear technologies.
- A number of sections of the Integrated Coastal Management Act have not been entered into force, adding complexity to coastal policy. These sections should be ratified to simplify the coastal land leasing procedure, and to prevent reliance on outdated policy such as the Sea Shore Act.

6.5 Further Research

- A detailed cost analysis of the SWEC could formulate a standalone research topic and also inform updated levelised cost of electricity calculations.
- Research focussing specifically on the positive impacts (social and environmental) of a wave energy converter would be valuable in contributing to a weighted judgment on the value of wave energy converters in South Africa, as this concentrates on potential negative environmental impacts.
- Further research is suggested for each of the mentioned environmental impacts on a smaller site specific scale.
- Key environmental focus areas would be the impacts on the fishing industry from a large scale SWEC development and the associated no-catch zones, marine traffic, impacts on fisheries and social impacts on the local fishing communities.
- Determining the park effect of an entire SWEC array would provide highly valuable data which would allow an individual to quantify potential wave energy reductions and thus draw more accurate conclusions as to what the impacts on the ecosystem maybe.

- A policy analysis of the impact of current and future energy policy on market penetration of fringe renewable energy technologies would help in identifying barriers entry for technologies such as wave energy.

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8 Appendices

Appendix A. Bathymetry along the south west coast of South Africa (CSIR, 2008).

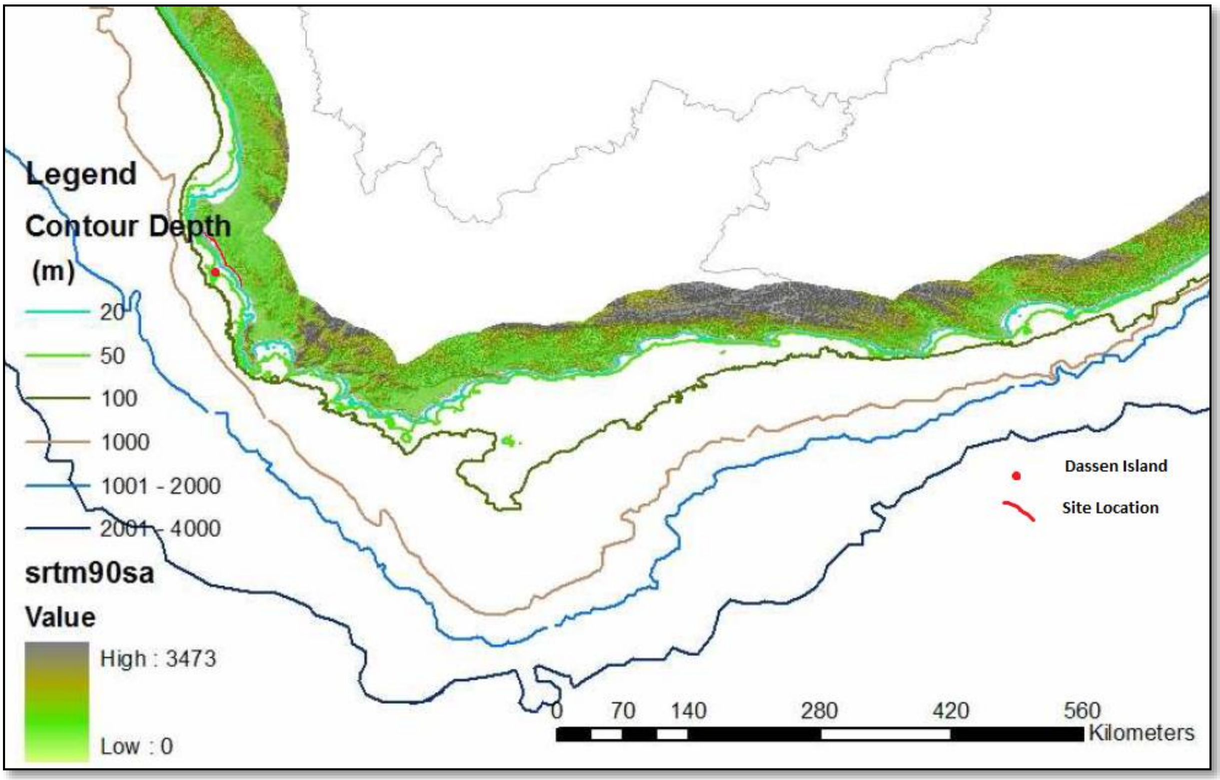


Figure A - 1: Bathymetry of the west coast of South Africa (CSIR, 2008)

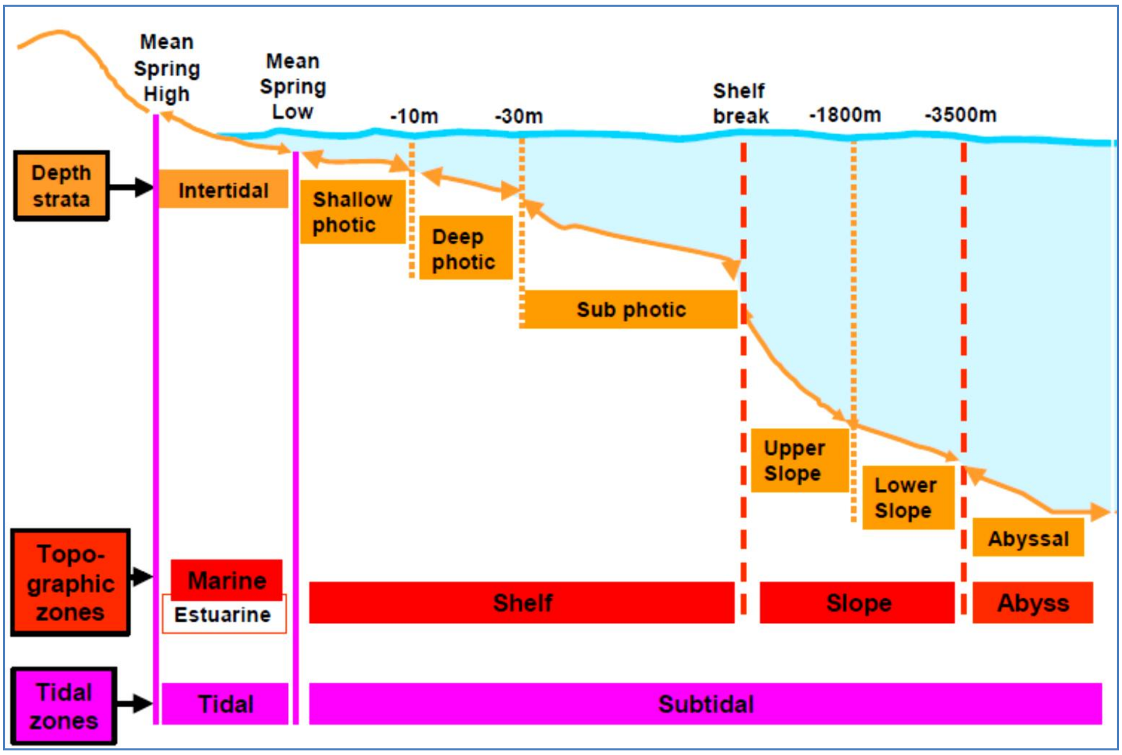


Figure A - 2: Subdivision of the sub tidal environment (Lombard et al, 2004

Appendix B. National Spatial Biodiversity Assessment: Technical Report 2004 (Lombard et al, 2004)

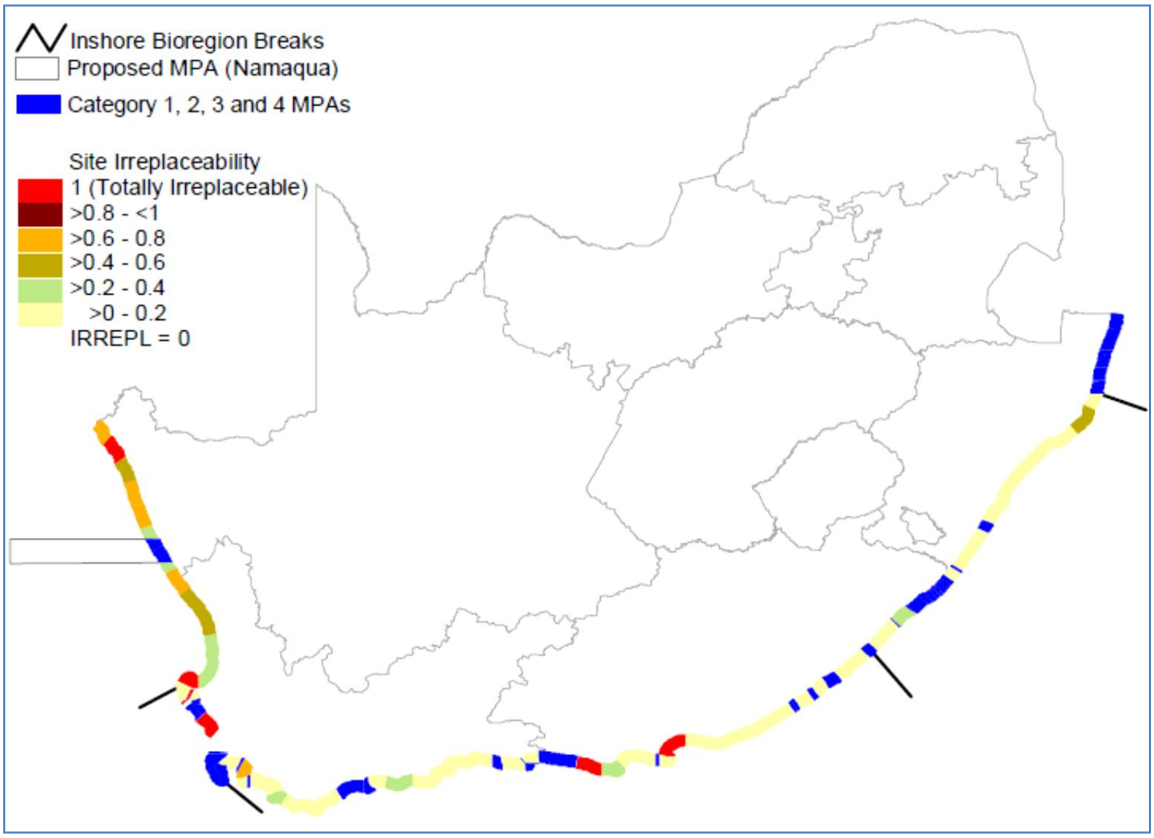


Figure B - 1: Irreplaceability analyses of intertidal habitats (50km) (CSIR, 2008)

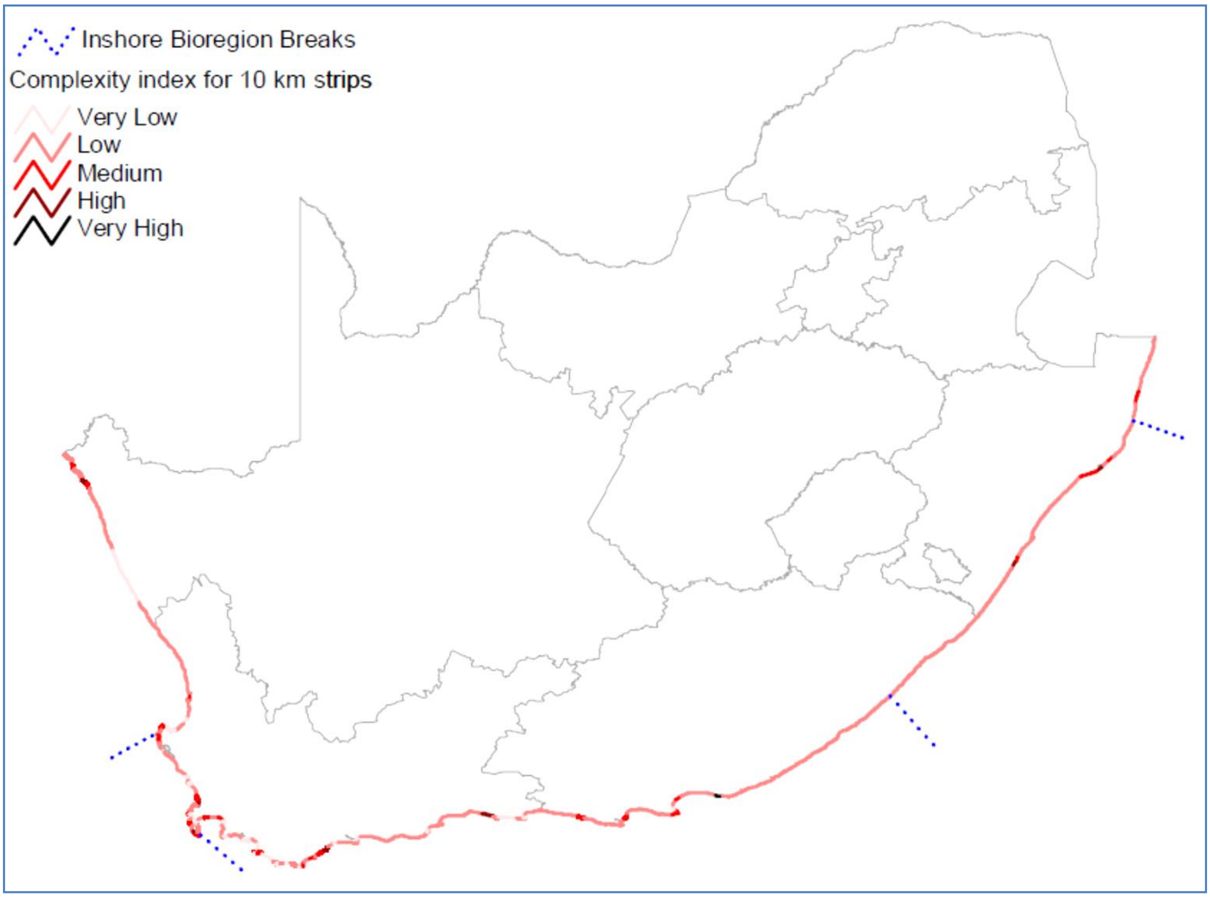
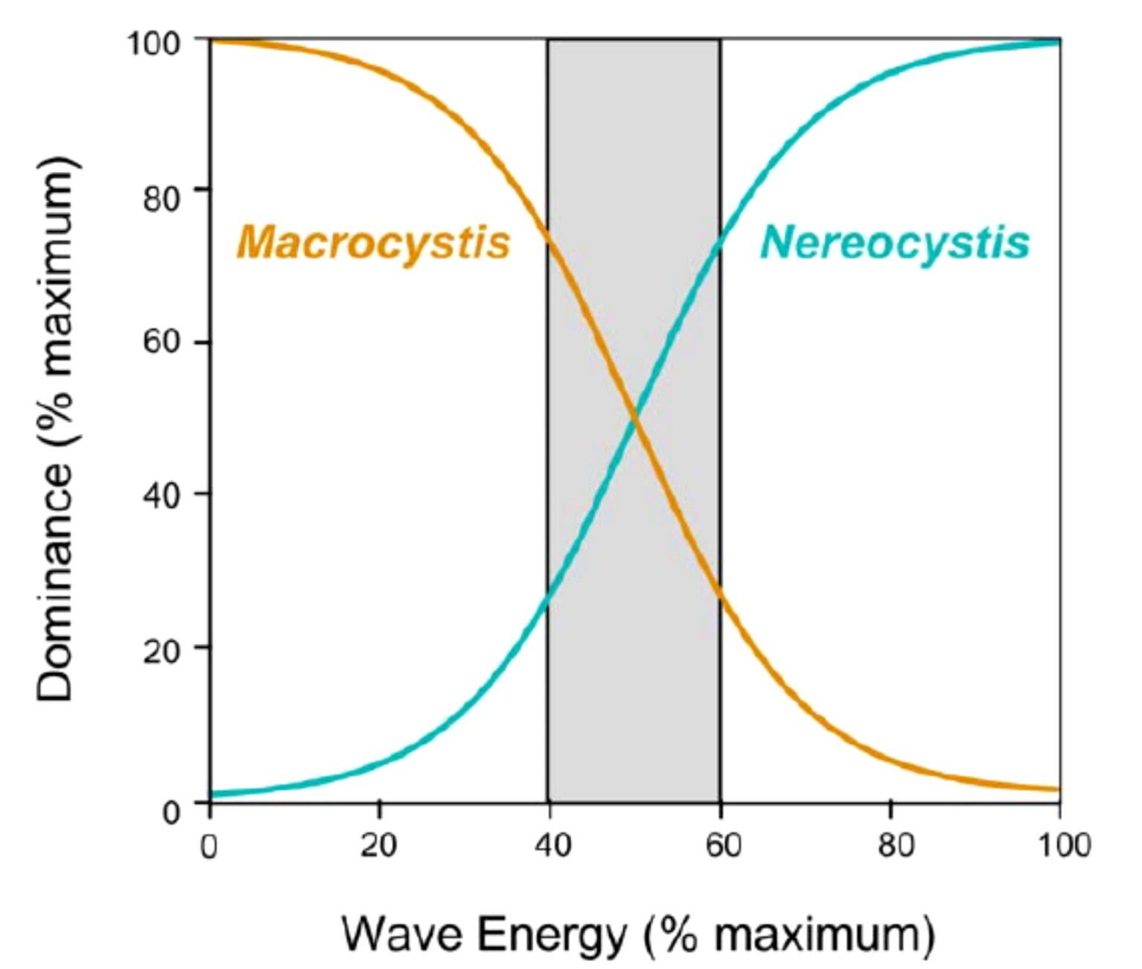


Figure B - 2: Deep Photic Complexity (resolution 10km) (CSIR, 2008)

Appendix C. Ecosystem Dynamics



*Note: The shaded area represents the threshold at which small changes in wave energy would create large changes in kelp dominance.

Figure C - 1: Wave Energy and Kelp Dominance Differing Species (PIER, 2008)

Appendix D. Marine Bird species occurring along the south west coast

Common Name	Species name	Global IUCN
Shy albatross	*Thalassarche cauta*	Near Threatened
Black browed albatross	*Thalassarche melanophrys*	Endangered[1]
Yellow nosed albatross	*Thalassarche chlororhynchos*	Endangered
Giant petrel sp.	*Macronectes halli/giganteus*	Near Threatened
Pintado petrel	*Daption capense*	Least concern
Greatwinged petrel	*Pterodroma macroptera*	Least concern
Soft plumaged petrel	*Pterodroma mollis*	Least concern
Prion spp	*Pachyptila* spp.	Least concern
White chinned petrel	*Procellaria aequinoctialis*	Vulnerable
Cory's shearwater	*Calonectris diomedea*	Least concern
Great shearwater	*Puffinus gravis*	Least concern
Sooty shearwater	*Puffinus griseus*	Near Threatened
European Storm petrel	*Hydrobates pelagicus*	Least concern
Leach's storm petrel	*Oceanodroma leucorhoa*	Least concern
Wilson's storm petrel	*Oceanites oceanicus*	Least concern
Blackbellied storm petrel	*Fregetta tropica*	Least concern
Skua spp.	*Catharacta/Stercorarius* spp.	Least concern
Sabine's gull	*Larus sabini*	Least concern

Figure D - 1: Pelagic Bird Species - Southern Benguela (Blood and Crowther, 2012)

Common name	Species name	Global IUCN Status
African Penguin	*Spheniscus demersus*	Vulnerable
Great Cormorant	*Phalacrocorax carbo*	Least Concern
Cape Cormorant	*Phalacrocorax capensis*	Near Threatened
Bank Cormorant	*Phalacrocorax neglectus*	Endangered
Crowned Cormorant	*Phalacrocorax coronatus*	Least Concern
White Pelican	*Pelecanus onocrotalus*	Least Concern
Cape Gannet	*Morus capensis*	Vulnerable
Kelp Gull	*Larus dominicanus*	Least Concern
Greyheaded Gull	*Larus cirrocephalus*	Least Concern
Hartlaub's Gull	*Larus hartlaubii*	Least Concern
Caspian Tern	*Hydroprogne caspia*	Vulnerable
Swift Tern	*Sterna bergii*	Least Concern
Roseate Tern	*Sterna dougallii*	Least Concern
Damara Tern	*Sterna balaenarum*	Near Threatened

Figure D - 2: Breeding Marine Birds West Coast (Blood and Crowther, 2012)

Figure D - 3: West Coast Migration and Breeding areas (Blood and Crowther, 2012).

Appendix E. Discussion on the Influence of Electromagnetic Fields (EMF's) on Specific Species (Tricas and Gill, 2011).

Subsea electric cabling is not expected to have a negative impact on whale species and there is no evidence to suggest so according to Finlay, (2012). However it has been hypothesised that one reason for mass beaching of whales is due to geomagnetic anomaly (Finlay, 2012). As such it would be worth investigating what the potential effects of a magnetic field would be on whale species considering their prevalence in the proposed SWEC site (Finlay, 2012). None the less the probability of many impacts on whales decreases when submarine cables are buried. The oil and gas industries have discernible experience in submarine cabling however typically those industries utilised oil insulated cabling (Previsic, 2004). This had the added drawback of the risk of oil spills if cabling was damaged. Despite the insulation electromagnetic fields were still experienced and were strongest directly above the cables decreasing in strength with distance (Tricas and Gill, 2011). This relationship depends on the proximity to other cables and the voltage in the cables. At a standard frequency and across a variation of voltages Tricas and Gill, (2011) were able to determine that at 5 meter circumference around a cable the magnetic field was approximately 2.5% of the strength it is at the cable location. At ten meters it was 0.5% of the strength at the cable location (Tricas and Gill, 2011). Due to the strong magnetic field directly around the cables the surrounding environment was shielded from the direct electric field from cables with conductive sheathing such as galvanised steel wire (Tricas and Gill, 2011). Oil-based insulated cables bring their own risk in that they are located in high energy climates such as surf zones. In such high energy environments the potential for failure increases which increases the risk of an oil leak into sensitive habitat (Presivic, 2004). However with more stringent environmental regulations the offshore renewable industry has seen the introduction polymeric insulated cables instead of the oil-based insulation due to the superior insulating properties (ABB, 2012; Presivic 2004). Some of the most advance HVDC cable designs by ABB are able to greatly reduce or eliminate the electromagnetic field experienced by marine life with a combination of polymetric insulation and the of burying cables in soft sediment (ABB, 2012). It is important to note the induced electric field from the movement of currents and animals are highest when the movement is perpendicular to the direction of the cables and is more significant in Direct Current (DC) cables (Tricas and Gill, 2011). This is due to Alternating Current (AC) cables as the induced current experiences a reversed polarity of the same frequency as the AC magnetic field therefore reducing the likelihood that the current would be detectable by electro-sensitive organisms (Tricas and Gill, 2011).

However traditional subsea cables pioneered the oil and gas industries used an oil insulator to reduce the electromagnetic fields produced by cables. The oil based designs and more cost effective thus more widely used but are also less effective at shielding magnetic fields (Tricas and Gill, 2011). In addition many submarine cables are designed to be secured on the seabed and may be only partially buried in the surf zone from the low water mark. This method is used as it reduces cost and requirements for highly specialised cable plough vessels (ABB, 2012). In this design the electromagnetic fields are much stronger as they lack an intermediary shielding material. Thus the environmental risk to marine animals is much higher. Tricas and Gill (2011), discuss a number of potential impacts which may arise from electromagnetic fields, noting the stronger the magnetic field the larger the effect on the marine animals is likely to be (Tricas and Gill, 2001). A number of animals are affected by fields including sharks and rays. Tricas and Gill, (2011) provide a list of affected marine fish in Table E- 1 and affected marine mammals in Table E- 2 as well as the natural functioning or behaviour which could be impacted by magnetic fields.

Table E- 1: Marine Fish and Impact on Life Function (Tricas and Gill, 2011)

Electro- (E) and magnetosensitivity (M) in marine fish – summary of knowledge.

Species	Species Groups	Type of Sensitivity (No. of studies)	Evidence Basis[a]	Life Functions Potentially Affected
Elasmobranchs	Dogfish	None (1)	B	None?
	Nurse sharks	E (1)	B	Feeding, predator or conspecific detection
	Mackerel sharks	E/M? (2)	B, A	Feeding, predator or conspecific detection, navigation
	Cat sharks	E (4)	B, P	Feeding, predator or conspecific detection
	Hound sharks	E (3)	B	
	Requiem sharks	E (4)	B	
		E/M? (1)	B, A	Feeding, predator or conspecific detection, navigation
		None (1)	B	None?
	Hammerhead sharks	E/M (1)	B, A	Feeding, predator or conspecific detection, navigation
		E (1)	B, A	Feeding, predator or conspecific detection
	Torpedo rays	E (1)	B	
	Thornback rays	E (1)	P	
	Skates	E (4)	A, T, P	Feeding, predator or conspecific detection
		E/M? (2)	B, A	Feeding, predator or conspecific detection, navigation
	Stingrays	E (4)	B, T	Feeding, predator or conspecific detection
		E/M (1)	B, P	Feeding, predator or conspecific detection, navigation
		M? (1)	T	Navigation
Other Fishes	Lampreys	E (3)	P	Feeding, predator or conspecific detection
	Ratfishes	E (1)	P	
	Sturgeons	E (2)	B, P	
		E/M (1)	B	Feeding, predator or conspecific detection, navigation
	Eels	E/M (2)	P, B, A	
		M (1)	P	Navigation
	Sea catfishes	E (1)	P, A	Feeding, predator or conspecific detection
	Salmonids	M (5)	B, A	Navigation
		M/E? (1)	P, B, A	Navigation, feeding, predator or conspecific detection
	Cods	E (1)	B	Feeding, predator or conspecific detection
	Scorpionfishes	M (1)	P	Navigation
	Grunts	M? (1)	B	
	Mackerels	M (1)	B, A	
	Righteye flounders	None (1)	No toxicity (M)	
		M? (1)	B	Navigation

[a] B=behavioral, A=anatomical, P=physiological, T=theoretical; refer to Tables 4.2-1 and 4.2-3 for details

It is well documented that Elasmobranch fishes (Sharks, Rays and Skates) are affected by electromagnetic fields with all species encompass ampullae of Lorenzini which are jelly-filled pores or electroreceptors used for detecting the weak electrical field generated by the contracting muscles of an Elasmobranche’s prey. The receptors are typically used for prey location sure as prey buried under the sand. Sharks have the most sensitive electroreceptors, thus are the most vulnerable to power full electric fields (Tricas and Gill, 2011). Ratfishes also have advanced electro sensory system, but few invertebrates have ever been tested for electro senses (Tricas and Gill, 2011). Recently there has been some evidence suggesting crabs, lobster and shrimp (decapods crustaceans) also react to electromagnetic field stimulus but they do not possess electro sensors (Tricas and Gill, 2011). Evidence from Lohmann and Willows, (1987) and Lohmann et al, (1991) demonstrated that molluscs and arthropods have the ability for magneto reception and can derive location based on the earth's magnetic field (Tricas and Gill, 2011). However large gaps in the knowledge remain (Tricas and Gill, 2011).

Other than direct impacts on electro sensory organs in Elasmobranches (sharks and rays) and decapods crustaceans (crabs, shrimp and lobster) much physiological, anatomical and behavioural evidence exists for the detection of electromagnetic fields among a wide range of species. Marine mammals such as Baleen whales and toothed whales as well as sea turtles maybe impacted by electromagnetic fields with the major concern being an effect on the whales and turtles ability to navigate by utilizing their magneto sensitivity with no evidence for marine mammals being impacted due to electro sensitivity (Tricas and Gill, 2011). Species of specific concern are the Humpback whales, Right whales and dolphin species (common and bottlenose) as there is statistical evidence by Kirschvink, (1990) that these species navigation are reliant on magnetic fields. The primary use for these species magneto sensitivity is as a map, navigating by following contours of magnetic fields and as a timer based on regular fluctuations in magnetic field (Tricas and Gill, 2011). The practical concern would be whales beaching themselves due to interference with their navigation due to the magnetic fields produced from subsea power cables, which reciprocate Finlay's, (2012) concerns (Tricas and Gill, 2011). Although the study by Kirschvink, (1990) did not include South Africa's endemic Heaviside dolphin, navigational and behavioural concerns would be the same as for bottlenose and common dolphin.

Sea turtles such as the Loggerhead, Leatherback and Green turtles occurring off the South west coast of South Africa may have their detection systems over short distances negatively impacted by artificial electromagnetic fields (Tricas and Gill, 2011). The Leatherback turtle is a critically endangered turtle species that would also be of conservation importance when considering a cable installation however this species tends to occur further north where its feeding grounds are located in deeper waters where turtles can dive down to 600 m (Blood and Crowther, 2012; Lombard et al, 2004). Loggerhead and Green turtles listed as endangered face a greater threat of having navigation systems impacted. This is specifically the case when DC cables are utilised over AC cables as the natural magnetic field may be altered by as much as 0.5 μT (Tricas and Gill, 2011). This is particularly an issue at night when turtles rely more heavily on this detection system. Concerns are that hatchlings may become disorientated by the magnetic fields. However it is speculated that the navigation over long distances should not be significantly affected by magnetic interference and that as turtles near their destination the use other points of reference to navigate (Tricas and Gill, 2011). Thus if cables are not sited near turtle nests the impacts are expected to be negligible (Tricas and Gill, 2011). Although, evidence in regard to magnetic and electro sensory interference is largely theoretical further investigation into the navigation of whales, dolphins and turtles would be pertinent. A study of this nature would be pivotal to the mitigation of potential impacts from animal interactions with large cabling networks that would be required for the SWEC array.

In the same manner as marine mammals and turtle species, Invertebrate's ability to navigate using magneto sensitivity may also be affected by EMF's. However there may also be some fundamental physiological effects on Crayfish, Lobster and Sea urchins but the extent of such effects have currently not been experimentally proven (Tricas and Gill, 2011). A considerable gap in the knowledge of electromagnetic fields (EMF's) and their impact on marine organism's anatomy, behavioural patterns, and physiology remains a crucial challenge in the development of an offshore platform where the electricity would have to be evacuated to shore (Tricas and Gill, 2011). It is clear from Tricas and Gill, (2011) is that EMF's from alternating current (AC) power cables are far less likely to be detected, therefore impact on marine organisms than direct current (DC) power cables. This may offer a mitigatory measure but the technical feasibility of AC cables has not been determined.

Table E- 2: Mammals, Invertebrates and Turtles and Impact on Life Function

Electro- (E) and magnetosensitivity (M) in marine mammals, sea turtles, and invertebrates – summary of knowledge.

Species	Species Groups	Type of Sensitivity (No. of studies)	Evidence Basis[a]	Life Functions Potentially Affected
Marine Mammals	Baleen whales	M (2)	T	Navigation
	Toothed whales	M (13)	T, B, A	Navigation
		None (3)	T	None
Sea Turtles		M (4)	B, T	Navigation
Invertebrates				
Mollusks	Snails	M(1)	B	Orientation
	Bivalves	None (1)	No toxicity (M)	
		M (1)	P	Uncertain
Arthropods	Isopod	None (1)	No toxicity (M)	
		M (1)	B	Orientation
	Amphipod	M(1)	B	Orientation
	Shrimp	None (1)	No toxicity (M)	
	Lobster	None (1)	P	
	Crayfish	M (1)	P	Orientation
		E (2)	B	Feeding, predator detection.
	Spiny lobster	M (1)	B, A	Navigation
	Crab	None (1)	No toxicity (M)	
Echinoderms	Sea urchin	M (2)	P, embryonic development	Reproduction

[a] B=behavioral, A=anatomical, P=physiological, T=theoretical; refer to Tables 4.2-7, 4.2-13 and 4.2-17 for details

Appendix F. Spatial Distribution of Lobster Traps

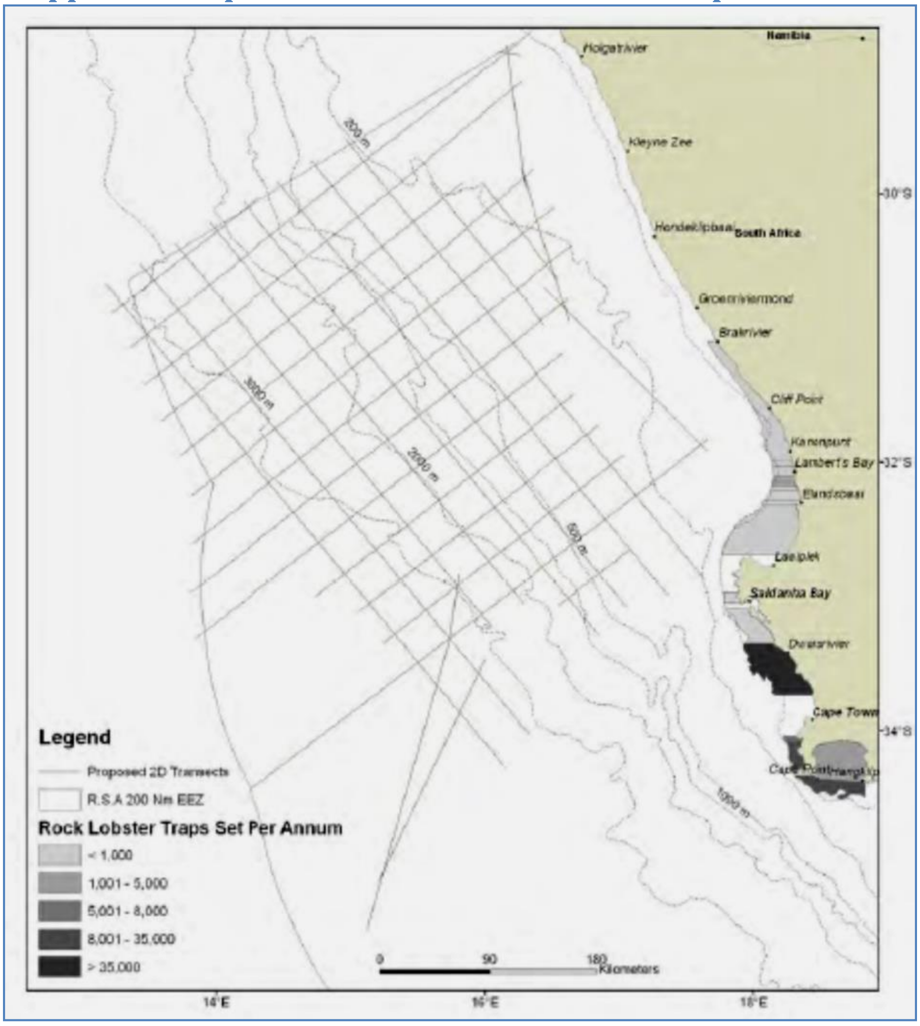


Figure F- 1: Site Location in Relation to Lobster Traps (Blood and Crowther, 2012)

Appendix G. Listed of Activities and Competent Authorities

Table G- 1: List of Activities Triggered by the SWEC

Summary Table of Listed Activities (Notices R 544, R 545 and R 546)			
Listing Notice/ Activity No.	**Activity** (Triggering activity occurring during the construction and operation of the SWEC device)	Relevant Authority	Requirement
	Construction of a single WEC unit		
1 /1	the construction of facilities or infrastructure for the generation of electricity where: (i) Electricity output is more than 10 megawatts but less than 20 megawatts: or (ii) The output is 10 megawatts or less but the extent of the facility covers an area in excess of one hectare.	Provincial Environmental Authority	Basic Assessment
1/10	The construction of facilities or infrastructure for the transmission and distribution of electricity - (i) outside urban areas or industrial complexes with a capacity of more than 33 but less than 275 kilovolts; or (ii) in side urban areas or industrial complexes with a capacity of 275 kilovolts or more.	Provincial Environmental Authority	Basic Assessment
1/11	The construction of: (xi) infrastructure or structures covering 50 square metres or more where such construction occurs within a watercourse or within 32 metres of a watercourse, measured from the edge of a watercourse, excluding where such construction will occur behind the development setback line.	Provincial Environmental Authority	Basic Assessment
1/14	The construction of structures in the coastal public property where the development footprint is bigger than 50 square metres, excluding (iii) the construction of temporary structures within the beach zone where such structures will be demolished or disassembled after a period not exceeding 6 weeks.	Provincial Environmental Authority	Basic Assessment
1/16	Construction or earth moving activities in the sea, an estuary, or within the littoral active zone or a distance of 100 metres inland of the high-water mark of the sea or an estuary, whichever is the greater, in respect of-	Provincial Environmental Authority	Basic Assessment

	(iv) rock revetments or stabilising structures including stabilising walls; (v) buildings of 50 square metres or more; or (vi) infrastructure covering 50 square metres or more– but excluding (a) if such construction or earth moving activities will occur behind a development setback line; or (c) where such construction or earth moving activities is undertaken for purposes of maintenance of the facilities mentioned in (i)-(vi) above; or		
1/18	The infilling or depositing of any material of more than 5 cubic metres into, or the dredging, excavation, removal or moving of soil, sand, shells, shell grit, pebbles or rock or more than 5 cubic metres from: (ii) the sea; (iii) the seashore; (iv) the littoral active zone, an estuary or a distance of 100 metres inland of the high water mark of the sea or an estuary, whichever distance is the greater but excluding where such infilling, depositing , dredging, excavation, removal or moving; (a) is for maintenance purposes undertaken in accordance with a management plan agreed to by the relevant environmental authority; or (b) occurs behind the development setback line. [Corrected by “Correction Notice 2” of 10 December 2010, GN No. R. 1159]	Provincial Environmental Authority	Basic Assessment
1/26	Any process or activity identified in terms of section 53(1) of the National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004).	Provincial Environmental Authority	Basic Assessment
Decommission of a WEC			
1/27	The decommissioning of existing facilities or infrastructure, for - (i) electricity generation with a threshold of more than 10MW; (ii) electricity transmission and distribution with a threshold of more than 132kV; 2006 made under section 24(5) of the Act and published in Government Notice No. R. 385 of 2006, or Notice No. 543 of 2010.	Provincial Environmental Authority	Basic Assessment
In the event of Expansions from a single unit to a complete array of WEC’s			
1/29	The expansion of facilities for the generation of electricity where: (i) the electricity output will be increased by 10 megawatts or more, excluding where such	Provincial Environmental	Basic Assessment

	expansion takes place on the original development footprint; or (ii) regardless the increased output of the facility, the development footprint will be expanded by 1 hectare or more;	Authority	
1/38	The expansion of facilities for the transmission and distribution of electricity where the expanded capacity will exceed 275 kilovolts and the development footprint will increase.	Provincial Environmental Authority	Basic Assessment
1/43	The expansion of structures in the coastal public property where the development footprint will be increased by more than 50 square metres, excluding such expansions within existing ports or harbours where there would be no increase in the development footprint or throughput capacity of the port or harbour.	Provincial Environmental Authority	Basic Assessment
1/45	The expansion of facilities in the sea, an estuary, or within the littoral active zone or a distance of 100 metres inland of the high-water mark of the sea or an estuary, whichever is the greater, for – (iv) rock revetments or stabilising structures including stabilising walls; (v) buildings by more than 50 square metres; (vi) infrastructure by more than 50 square metres; (vii) facilities associated with the arrival and departure of vessels and the handling of cargo; (viii) piers; (ix) inter- and sub-tidal structures for entrapment of sand; (x) break water structures; (xiii) structures for draining parts of the sea or estuary;	Provincial Environmental Authority	Basic Assessment
1/54	The expansion of an island, anchored platform or any other permanent structure on or along the sea bed, where the expansion will constitute an increased development footprint.	Provincial Environmental Authority	Basic Assessment
1/56	Phased activities for all activities listed in this Schedule, which commenced on or after the effective date of this Schedule, where any, one phase of the activity may be below a threshold but where a combination of the phases, including expansions or extensions, will exceed a specified threshold; -	Provincial Environmental Authority	Basic Assessment
Construction of a WEC Array and associated Infrastructure			
2/1	The construction of facilities or infrastructure for the generation of electricity where the Electricity output is 20 megawatts or more.	Provincial Environmental Authority or The	Scoping Report and full Environmental

		Minister w.r.t. this Act if the activity listed in section 24C (Table G- 2).	Impact Report
2/8	The construction of facilities or infrastructure for the transmission and distribution of electricity with a capacity of 275 kilovolts or more, outside an urban area or industrial complex.	Provincial Environmental Authority or The Minister w.r.t. this Act if the activity listed in section 24C (Table G- 2).	Scoping Report and full Environmental Impact Report
2/14	The construction of an island, anchored platform or any other permanent structure on or along the sea bed excluding construction of facilities, infrastructure or structures for aquaculture purposes. [Corrected by "Correction Notice 2" of 10 December 2010, GN No. R. 1159]	Provincial Environmental Authority or The Minister w.r.t this Act if the activity listed in section 24C (Table G- 2).	Scoping Report and full Environmental Impact Report
2/24	Construction or earth moving activities in the sea, an estuary, or within the littoral active zone or a distance of 100 metres inland of the high-water mark of the sea or an estuary, whichever distance is the greater, in respect of: (i) facilities associated with the arrival and departure of vessels and the handling of cargo; (iii) inter- and sub-tidal structures for entrapment of sand; (iv) break water structures; (ix) underwater channels; but excluding —	Provincial Environmental Authority or The Minister w.r.t this Act if the activity listed in section	Scoping Report and full Environmental Impact Report

	(a) activities listed in activity 16 in Notice 544 of 2010, (b) construction or earth moving activities if such construction or earth moving activities will occur behind a development setback line; (c) where such construction or earth moving activities will occur in existing ports or harbours where there will be no increase of the development footprint or throughput capacity of the port or harbour; or (d) where such construction or earth moving activities takes place for maintenance purposes.	24C (Table G- 2).	
Construction of Infrastructure and Vegetation Clearance			
3/4	The construction of a road wider than 4 metres with a reserve less than 13,5 metres. **(d) In Western Cape:** ii. All areas outside urban areas; (aa) Areas zoned for use as public open space within urban areas; and (bb) Areas designated for conservation use in Spatial Development Frameworks adopted by the competent authority, or zoned for a conservation purpose.	Head of the Provincial Environmental Department or delegated Minister as stated in Table G- 2.	Basic Assessment
3/8	The construction of aircraft landing strips and runways 1.4 kilometres and shorter. **(d) In Western Cape:** i. All areas outside urban areas; (aa) Areas zoned for use as public open space; (bb) Areas designated for conservation use in Spatial Development Frameworks adopted by the competent authority or zoned for a conservation purpose. [Corrected by "Correction Notice 2" of 10 December 2010, GN No. R. 1159]	Head of the Provincial Environmental Department or delegated Minister as stated in Table G- 2.	Basic Assessment
3/9	The construction of above ground cableways and funiculars; **(a) In Eastern Cape, Free State, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape and Western Cape:** ii. Areas outside urban areas; iii. In urban areas: (aa) Areas zoned for use as public open space;	Head of the Provincial Environmental Department or delegated	Basic Assessment

	(bb) Areas designated for conservation use in Spatial Development Frameworks adopted by the competent authority or zoned for a conservation purpose; (cc) Areas on the watercourse side of the development setback line or within 100 metres from the edge of a watercourse where no such setback line has been determined. (dd) Areas seawards of the development setback line or within 1 kilometre from the high-water mark of the sea if no such development setback line is determined. [Corrected by "Correction Notice 2" of 10 December 2010, GN No. R. 1159]	Minister as stated in Table G- 2.	
3/12	The clearance of an area of 300 square metres or more of vegetation where 75% or more of the vegetative cover constitutes indigenous vegetation. (a) Within any critically endangered or endangered ecosystem listed in terms of section 52 of the NEMBA or prior to the publication of such a list, within an area that has been identified as critically endangered in the National Spatial Biodiversity Assessment 2004; (b) Within critical biodiversity areas identified in bioregional plans; (c) Within the littoral active zone or 100 metres inland from high water mark of the sea or an estuary, whichever distance is the greater, excluding where such removal will occur behind the development setback line on erven in urban areas.	Head of the Provincial Environmental Department or delegated Minister as stated in Table G- 2.	Basic Assessment
3/13	The clearance of an area of 1 hectare or more of vegetation where 75% or more of the vegetative cover constitutes indigenous vegetation, except where such removal of vegetation is required for: (1) the undertaking of a process or activity included in the list of waste management activities published in terms of section 19 of the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008), in which case the activity is regarded to be excluded from this list. (2) the undertaking of a linear activity falling below the thresholds mentioned in Listing Notice 1 in terms of GN No. 544 of 2010. **Northern Cape and Western Cape:** ii. Outside urban areas, the following: (aa) A protected area identified in terms of NEMPAA, excluding conservancies; (bb) National Protected Area Expansion Strategy Focus areas; (cc) Sensitive areas as identified in an environmental management framework as contemplated in chapter 5 of the Act and as adopted by the competent authority;	Head of the Provincial Environmental Department or delegated Minister as stated in Table G- 2.	Basic Assessment

	(dd) Sites or areas identified in terms of an International Convention; (ee) Core areas in biosphere reserves; (ff) Areas within10 kilometres from national parks or world heritage sites or 5 kilometres from any other protected area identified in terms of NEMPAA or from the core area of a biosphere reserve; **(gg) Areas seawards of the development setback line or within 1 kilometre from the high-water mark of the sea if no such development setback line is determined.** iii. In urban areas, the following: (aa) Areas zoned for use as public open space; (bb) Areas designated for conservation use in Spatial Development Frameworks adopted by the competent authority or zoned for a conservation purpose; **(cc) Areas seawards of the development setback line;** (dd) Areas on the watercourse side of the development setback line or within 100 metres from the edge of a watercourse where no such setback line has been determined.		
3/14	The clearance of an area of 5 hectares or more of vegetation where 75% or more of the vegetative cover constitutes indigenous vegetation, except where such removal of vegetation is required for: (2) the undertaking of a process or activity included in the list of waste management activities published in terms of section 19 of the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) in which case the activity is regarded to be excluded from this list; (3) the undertaking of a linear activity falling below the thresholds in Notice 544 of 2010. **(a) In Eastern Cape, Free State, KwaZulu-Natal, Gauteng, Limpopo, Mpumalanga, Northern Cape, Northwest and Western Cape:** i. All areas outside urban areas.	Head of the Provincial Environmental Department or delegated Minister as stated in Table G- 2.	Basic Assessment
3/16	The construction of: (i) jetties exceeding 10 square metres in size; (ii) slipways exceeding 10 square metres in size; (iii) buildings with a footprint exceeding 10 square metres in size; or (iv) infrastructure covering 10 square metres or more where such construction occurs within a watercourse or within 32 metres of a watercourse, measured from the edge of a watercourse, excluding where such construction will occur behind the development setback line. **(d) In Western Cape:**	Head of the Provincial Environmental Department or delegated Minister as stated in Table G- 2.	Basic Assessment

	ii. Outside urban areas, in: (aa) A protected area identified in terms of NEMPAA, excluding conservancies; (bb) National Protected Area Expansion Strategy Focus areas; (cc) World Heritage Sites; (dd) Sensitive areas as identified in an environmental management framework as contemplated in chapter 5 of the Act and as adopted by the competent authority; (ee) Sites or areas identified in terms of an International Convention; (ff) Critical biodiversity areas or ecosystem service areas as identified in systematic biodiversity plans adopted by the competent authority or in bioregional plans; (gg) Core areas in biosphere reserves; (hh) Areas within 10 kilometres from national parks or world heritage sites or 5 kilometres from any other protected area identified in terms of NEMPAA or from the core area of a biosphere reserve; (ii) Areas seawards of the development setback line or within 1 kilometre from the high-water mark of the sea if no such development setback line is determined. iii. Inside urban areas: (aa) Areas zoned for use as public open space; (bb) Areas designated for conservation use in Spatial Development Frameworks adopted by the competent authority or zoned for a conservation purpose; (cc) Areas seawards of the development setback line or within 100 metres of the high water mark where no setback line. [Corrected by "Correction Notice 2" of 10 December 2010, GN No. R. 1159]		
3/21	The expansion of above ground cableways and funiculars where the development footprint will be increased. **(a) In Eastern Cape, Free State, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape and Western Cape:** i. In an estuary; ii. All areas outside urban areas; iii. In urban areas: (aa) Areas zoned for use as public open space; (bb) Areas designated for conservation use in Spatial Development Frameworks adopted by the competent authority or zoned for a conservation purpose;	Head of the Provincial Environmental Department or delegated Minister as stated in Table G- 2.	Basic Assessment

	(cc) Areas seawards of the development setback line or within 1 kilometre from the high-water mark of the sea if no such development setback line is determined. [Corrected by "Correction Notice 2" of 10 December 2010, GN No. R. 1159]		
3/24	The expansion of (c) buildings where the buildings will be expanded by 10 square metres or more in size; or (d) infrastructure where the infrastructure will be expanded by 10 square metres or more where such construction occurs within a watercourse or within 32 metres of a watercourse, measured from the edge of a watercourse, excluding where such construction will occur behind the development setback line. **(d) In Western Cape** ii. Outside urban areas, in: (aa) A protected area identified in terms of NEMPAA, excluding conservancies; (bb) National Protected Area Expansion strategy Focus areas; (cc) Sensitive areas as identified in an environmental management framework as contemplated in chapter 5 of the Act and as adopted by the competent authority; (dd) Sites or areas identified in terms of an International Convention; (ee) Critical biodiversity areas as identified in systematic biodiversity plans adopted by the competent authority or in bioregional plans; (ff) Core areas in biosphere reserves; (gg) Areas within 10 kilometres from national parks or world heritage sites or 5 kilometres from any other protected area identified in terms of NEMPAA or from the core area of a biosphere reserve; (hh) Areas seawards of the development setback line or within 1 kilometre from the high-water mark of the sea if no such development setback line is determined. [Corrected by "Correction Notice 2" of 10 December 2010, GN No. R. 1159]	Head of the Provincial Environmental Department or delegated Minister as stated in Table G- 2.	Basic Assessment
3/26	Phased activities for all activities listed in this Schedule and as it applies to a specific geographical area, which commenced on or after the effective date of this Schedule, where any phase of the activity may be below a threshold but where a combination of the phases, including expansions or extensions, will exceed a specified threshold. All the areas as identified for the specific activities are listed in this schedule.	Head of the Provincial Environmental Department or delegated Minister as stated in Table G- 2.	Basic Assessment

Table G- 2: List of Competent Authorities

Listing Notice	Competent Authority
Listing Notice 1 (GN R 544)	The competent authority in respect of the activities listed in this part of the schedule is the environmental authority in the province in which the activity is to be undertaken unless it is an application for an activity contemplated in section 24C(2) of the Act, in which case the competent authority is the Minister or an organ of state with delegated powers in terms of section 42(1) of the Act, as amended.
Listing Notice 2 (GN R 545)	The competent authority in respect of the activities listed in this part of the schedule is the environmental authority in the province in which the activity is to be undertaken, unless— (a) it is an application for an activity contemplated in section 24C(2) of the Act, in which case the competent authority is the Minister or an organ of state with delegated powers in terms of section 42(1) of the Act, as amended; or (b) the activity is to be conducted in or on a mining area or is to transform the area where the activity is to be conducted into a mining area in which case the competent authority is the Minister of Minerals and Energy. The exception mentioned in (b) above does not apply to the following activities contained in this Notice: 1; 2; 5; 8; 9; 10; 12; 13; 14; 17; 24; and 25.
Listing Notice 3 (GN R 546)	The competent authority in respect of the activities listed in this part of the schedule is the environmental authority in the province in which the activity is to be undertaken unless it is an application for an activity contemplated in section 24C(2) of the Act, in which case the competent authority is the Minister or an organ of state with power to act under delegated authority in terms of section 42(1) of the Act. [Corrected by "Correction Notice 2" of 10 December 2010, GN No. R. 1159] (With regard to a WEC development this may be the Minister of the National Department of Environmental Affairs, the Minister of Transport or Minister or the Department of Minerals and Resources or all three)
24C Procedure for identifying competent authority	

(1) When listing or specifying activities in terms of section 24 (2) the Minister, or an MEC with the concurrence of the Minister, must identify the competent authority responsible for granting environmental authorisations in respect of those activities.
(2) The Minister must be identified as the competent authority in terms of subsection (1) if the activity-
(a) has implications for international environmental commitments or relations;
(b) will take place within an area protected by means of an international environmental instrument, other than-
(i) any area falling within the sea-shore or within 150 meters
seawards from the high-water mark, whichever is the greater;
(ii) a conservancy;
(iii) a protected natural environment;
(iv) a proclaimed private nature reserve;
(v) a natural heritage site;
(vi) the buffer zone or transitional area of a biosphere reserve; or
(vii) the buffer zone or transitional area of a world heritage site;
(c) a development footprint that falls within the boundaries of more than one province or traverses international boundaries;
(d) is undertaken, or is to be undertaken, by
(i) a national department;
(ii) a provincial department responsible for environmental affairs or any other organ of state performing a regulatory function and reporting to the MEC; or
(iii) a statutory body, excluding any municipality, performing an exclusive competence of the national sphere of government; or
(e) will take place within a national proclaimed protected area or other conservation area under control of a national authority.

Appendix H. Summaries of Expert Meeting Transcripts

No.	Correspondence	Subject:	Type:	Date:	PG
1-	Dr Roberts (DEA)	Permitting	Meeting	15/06/2012	8-183
2-	Dr Boyd (DEA)	Environmental Impacts	Meeting	18/06/2012	8-184
3-	Prof Retief (PRDW)	History, implementation, Environment	Meeting	27/06/2012	8-186
4-	Dr Sink (SANBI)	Implementation	Email, Phone	4/07/2012	8-191
5-	Mr Harris & Mr Pederson (PRDW)	Costing	Meeting	29/06/2012	8-192
6-	Dr Findlay (UCT)	Whales and Dolphins	Meeting	16 /07/2012	8-194
7-	Ms Redell (Dawson, Edwards & Associates)	Law	Meeting	10/08/2012	8-197
8-	Dr Cliff (KZN Sharksboard)	Sharks	Questionnaire	06/09/2012	8-199
9-	Dr Ralston (Birdlife SA)	Marine Birds	Questionnaire	31/10/2012	8-203
10-	Dr Sinclair (TennetT)	Implementation, cabling, foundations	Skype	22/11/2012	8-204

1- Dr Michael J. Roberts (Personal communication)

15th June 2012
Program Leader: Observational & Operational Oceanography
Head of Research Group: Physical & Applied Oceanography
Oceans and Coasts: Department of Environment Affairs Private Bag X2, Roggebaai, 8012 Cape Town, South Africa

The thesis idea was introduced to Dr Roberts and a description of the project was given to him. Then in open discussion Dr Roberts proceeded to discuss some of the considerations involved in the thesis. Contacts were also suggested for further reference. He suggested a meet with DEA, Oceans and Coasts – Ashley Naaido to determine all the ocean policy involved. I was suggested that a major goal of the thesis would be to show the theoretical blueprint of the policy process via flow diagram. Then secondly comment on how well it works in practice and where the stumbling blocks maybe. As an example investigate how long it took for fish farmers to overcome policy (Saldanha oysters and trout farms on the west coast).
Departments to possibly include in the search for relevant policy:

- Defence department (North of Saldhana is a firing range)
- South African Maritime Safety Association (SAMSA). Contact Georgina with regard to the conflict with shipping routes and safety at sea.
- DAFF with regard to infringing on trawling grounds.
- SANBI-Kerry Sink
- MARPOL
- Dept. Public enterprises
- Coastal pollution act.

Contact list provided by Dr Roberts:

Dr Alan Boyd – Director of Biodiversity Department of Environmental Affairs (DEA).

2- Dr Alan Boyd (Personal communication)

18th June 2012
Director: Biodiversity and Coastal Research
Oceans and Coasts offices, Cape Town City.
Department of Environment Affairs
Cape Town, South Africa

The meeting aim was to gain the overarching concerns of Dr Alan Boyd about the possible implementation of the SWEC. The meeting began with me introducing myself and explaining the aim and reasoning behind my thesis as well at what I was hoping to gain out of our meeting together. After explaining the layout of the devices I am looking to implement, Dr Alan Boyd voiced his concerns and opinions about the device implementation. He then described the possible impacts of the devices and pointed out where his major concerns lay and who the relevant contacts were in order gain expert insight around specific concerns.

His concerns in a number of areas were considered. These concerns were focussed in the area of environmental impacts, where marine animals, sediment transportation and sea birds were raised as possible concerns. It was said that the electromagnetic field from subsea cables could either attract of repel sharks. I was provided with relevant contacts that I should talk to with specific concerns. Ocean policy problems were discussed regarding the over lapping jurisdictions and boarders of different marine and coastal policies. Legal issues were discussed. It was suggested that the EIA regulations under the National Environmental Management Act (NEMA) no. 62 of 2008 may be all encompassing. Contact Neil Malan for who is responsible onshore (Maybe cape nature). EIA may trigger other permit requirements during the EIA process.

Other concerns were raised. Including the need for a demonstration plant to test impacts at certain sites before a full plant should be installed. The suggestion was 3 years' worth of monitoring and testing needs to be carried out to prove feasibility of device. Look to marine aquaculture as a joint development and example of possible policy to consider (Silverstroom marine aquaculture development). Mining concessions could also involve some of the policy required to be considered. Marine Protected Areas would need special permissions and that the selected site it would be unlikely that development would be allowed within the protected area of "16 Mile Beach". Would need to consult with Department of Agriculture, Forestry and Fisheries (DAFF).

Issues discussed and suggested contacts were as follows:

- Electromagnetic interference with sharks from subsea cables – Geremy Cliff or Sheldon Dudley from the KWazulu natal sharks board.
- Legal issues and Ocean Policy – Ashley Naaido, Neil Malan (onshore-offshore dynamic) and Nicolet de Kock (legal).

Contact list provided by Dr Alan Boyd:

Policy:

- Nicolette de Kock - DEA Legal Team (Advocate) – (082 904 4834) ndeKock@environment.gov.za
- Niel Malan - DEA Senior Advisor - Integrated Coastal Management (082 5149807) - dmalan@environment.gov.za
- Ashley Naidoo - DEA Director Oceans Conservation - (082 7847131) anaidoo@environment.gov.za
- Environmental impacts:
- Rob Crawford – Department of Environmental Affairs, leading seabird scientist (021 402 3140) - crawford@environment.gov.za
- Geremy Cliff - shark scientist manager - KZN Sharks Board (083 777 9839) (cliff@shark.co.za)
- Sheldon Dudley – KZN Sharks board (031 566 0413)
- Ken Findlay - whale expert - UCT (082 570 8212)- private - kenfin@mweb.co.za
- Kerry Sink - Marine Biodiversity expert/planner SANBI (082 831 0536) - k.sink@sanbi.org.za

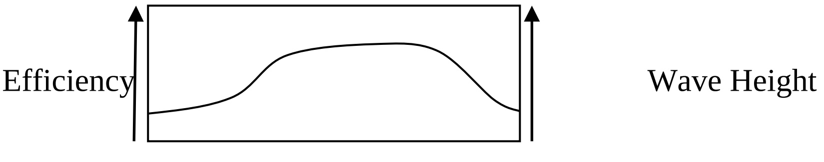
3- Professor Deon Retief (Personal communication)

27th June 2012
Director (Retired): Prestedge, Retief, Dresner and Wijnberg (PRDW) (PTY) Ltd, Coastal Engineers, Co-developer of the Stellenbosch Wave Energy Converter.
Home of Professor Retief, Somerset West.

The interview began with me describing what the goal of my thesis and asking for a background of the wave energy device. Conversion was led by a number of pre-formulated questions.

Wave energy studies have been completed in the past however it was report by Prof Retief that many of them tend to focus on the meso-scale systems or stretches of coastline. This is problematic as the variability in the ocean waves is so high at that scale that predication is limited. Thus he believes Geustyn, (1983) who has a more generalized wave assessment on a broader scale across the country, which is better as it allows for determination of long term cycles. Cycles such as the 11 year and 21 year wave cycles (which tie in with sunspot cycles). More localized studies have too much variability and spatial variability locally is high. Geustyn, (1983) used indicators such as the % of calm in his study which is very relevant for wave energy devices.

In the 1970's De Beers and Anglo were mine the west coast for diamonds. In 1973 the oil crisis began drastically raising the price of oil, making operations expensive due to them being far off grid. Anglo and De beers began considering off grid electricity on the Northern West coast to power the mining of sand s for diamonds. Since large wave resources were available in this area they considered the possibility of wave power. Considering wave energy to power operations lead to the idea of the Stellenbosch Wave Energy Convertor. The mandate set out by the designers was as follows. The device is to be Simple, rugged and survivable. Not complex with moving parts. The device needed to be physically modelled in 3D hence had to be simple due to lack of technical skills. SWEC needs to be practical and survivable. SWEC's philosophy was 30% efficiency. This was beneficial for a number of reasons. The design of the SWEC means that as the seas get bigger the waves over top the device. 30% efficiency also means that not so much energy is taken out the wave so as to affect coastal processes. Hence kelp is still able to survive and sand transport isn't largely affected. Also as the seas get larger the efficiency tappers off. Most other devices the power output increases exponentially meaning large variability in power output which has to be controlled at another point as the electricity grid is sensitive to certain frequencies and levels of power. However with the efficiency tapering off in high seas the SWEC is able to deliver a far more stable power output which is easier to deal with and prevents spikes of output entering the grid. The SWEC effectively smooths the efficiency as wave height increases. Thus it is good for base load power.



The original budget is estimated at around R120million for the first unit to be produced. There was roughly a 5 year development plan. It was cost equivalent to nuclear power of the same period. But alternate energy is very expensive as it need back up for when the resource is unreliable and backup takes its place. The cost of this backup in the form of diesel generators, and the recovery of the oil price to a lower level killed the project.

The original site was selected for its straight sandy beaches which made deployment in the soft sand much easier. Also the beach was almost at right angles to wave direction. Now the northern section of the site is a Marine Protected area. Retief said theoretically they may not like the idea of developing in a marine protected area, but practically it shouldn’t be an issue.

The design of the SWEC was also tuned to the average wave period on the west coast (12s). The angle of the V was optimized for this site. The device was physically modelled in terms of sediment build up and sand transport. In front of the device there was no sediment build up. The back wash was powerful enough to clear the sediment. Behind the device there was sediment build up but it was not significant due to water movement.

Implementation: determining the rights on the site may be difficult as the owner of the land will have to be determined. Would the sub sea bed be owned of leases? Putting expensive equipment on government owned land difficult. In breaking water you could never own the site. Lease rights will have to be determined especially as the device will be in public space. For example breakwaters the land isn’t owner, and has to have lease rights for the device to be located in public space. This creates a problem with the insurers as there is not full ownership. Also liability issues as there is not certain ownership in incidences of fishing boat accidents. Look to the maritime act for clarity on responsibility. Floating wave energy converters such as the Pelamis would have additional issues as the question arises of who would be responsible if the device come loose and wrecked (may have to be registered as a vessel). This is also a drawback of the floating devices. Also unlimited liability is a concern, as if the device wrecks on a beach with a hotel on the beach. The Hotel could then sue for damages. There could also be responsibility for sediment erosion on the beaches. Would the device owners be responsible or the land owners?

Also there are a few secondary environmental impacts. The SWEC device can act as an artificial reef offering protection to marine fish and plant species. Sediment movement needs to be defined and monitored. Navigation lights are required to prevent collision with vessels and this may have a visual impact. The device will have a tower protruding from the sea with a helicopter pad and navigation light, which could have visual impacts, but the device would be located 2-3km offshore meaning that the above sea level parts of the device may not even be visible from shore. There will be 3 navigation lights on all three points of the V device. The device may have noise impacts but being located so far from shore it is unlikely that the noise from the device would be heard at all. Also the noise would be limited as the system is a closed loop system and is air tight meaning there would not be air rushing in or out of the device creating noise. There would be an array of subsea cables that may affect the electromagnetic sensors of marine animals such as sharks and fish (to be questioned further). Cables would be oriented in a configuration to limit shore crossings, so that only every fifth device would have a subsea cable crossing the shore to land. A full array of devices (154 V shaped converters) would require 30 subsea cable crossings roughly one per every 1.25km. However a demonstration plant would only have one cable. 30 cables would only be required for a full scale power plant.

Work to test effects on sharks is ongoing. But it is likely that the electromagnetic interference would repel sharks. (There are already submarine cables between the Knysna heads and potentially one linking Robben Island to Cape Town.

Construction and costing information can be obtained from Kenneth Pederson of PRDW.

The site will have to be prepared by driving piles using a jack up platform. It floats to the site and anchors at a number of points. The sections of the wave energy converter are then floated in on the device and attached to pull down cables which pull the sections of the device accurately onto the top of the piles. Flexible rubber tubes join the sections together via a subway joint. The equipment to perform this task is very expensive. Mobilization of the pile rig platform and to make the casting bed for the device will cost in the region of R60 million. However, this figure is lowered with repetition of the process.

The Pelamis would be a lot cheaper to mobilize as it can simply be towed out to sea, anchored anywhere and it will begin to operate. The disadvantages however are the flexible joints and flexible power cables. This means higher maintenance costs. Also since there are differing periods of waves in southern Africa (12s and big storms 13-14s) to Europe (7-8s) the movement will be more strenuous on the motion of the devices. In addition on the Southern and eastern coastlines prevailing winds have a different direction often perpendicular of the flow to the prevailing wave direction, which would result in the device being sideswiped meaning it would be forced to be at an angle to the prevailing wave direction reducing efficiency and increasing stress on the device. This is not as much of an issue in the northern hemisphere as many of the wind and wave directions coincide. Multiple period wave models would be required to determine a more realistic depiction of the performance on devices in practice, as currently all the wave models use average wave conditions.

The meeting was concluded with the option of further advice and suggestion of contacting:

Muller Coetze, the Technical Director of ERM SA – (083 325 8732) (021 702 9100) – (muller.coetzee@erm.com)

Professor Jan Glazewski – Professor of maritime law at UCT – (0216503075) Jan.Glazewski@uct.ac.za

Email: Professor Deon Retief
14th July 2012

deon@nutwood.co.za

Jonathan Frick:

> "Dear Prof Retief
>
> I just have a follow up question from our last discussion. You said that the SWEC only takes 30% of the wave energy from the waves in order to protect the coastal processes. I was wondering how this figure came about? Was there an environmental study which suggested at 30% no alteration would occur to the coastal processes, or was this simply just the maximum efficiency possible, and implicitly it was beneficial for the coastal processes?
>
> Thank you for your time.
>
> Regards
>
> Jonathan"

Prof Deon Retief:

> "Dear Jonathan,
>
> I suppose there are two main coastal processes which might be affected by a change in incident energy: visible biological activity such as kelp propagation which needs a threshold energy level for its survival and secondly sediment transport which responds to average energy levels for typical representative transport rates and extreme storm events which often dictate the shape and form of coastal features such as estuarine sand bars, embayment shape etc.
>
> I have no idea what the minimum requirements are for healthy biological functions. When we designed the wave excitation for the kelp tank in the Two Oceans Aquarium, the marine biologists led us to believe that as long as there was continuous water motion in the tank the kelp would be fine. You could enquire at the Aquarium regarding possible up-dates on the subject. Sediment transport can to day be accurately quantified both at a macro level and at the local specific level of individual units. As I mentioned to you the localised impact of individual units on the shore line would be negligible, however the macro effect of a large array would have to be quantified, especially at low level, average wave height conditions when a 30% reduction in littoral energy could slow down average rates of sediment transport through the converter zone. The only variable in this case would be the spacing between units. I am not worried about extreme events as the reduced efficiency of the SWEC under these conditions would further minimise the impact.
>
> Our two dimensional tests indicated that we would encounter a reduction of conversion efficiency with increase in wave height, which pleased us as this would attenuate the generated power curve. The precise efficiency only became apparent after we had completed the three dimensional tests. Further tests were aimed at

increasing efficiency within the constraints of the system and the final curves were then accepted as a given. As previously stated the only remaining variable on the environmental front would be the spacing of units.

Once a specific site has been chosen the detailed design phase would include detailed sediment modelling to quantify the impact of the array on the specific ambient transport dynamics of the site. Where a coast line has a series of rocky outcrops the intervening sandy stretches often remain in their individual states of dynamic equilibrium, which means that although each section of beach might move locally under varying wave conditions there might be very little net transport between beaches, around the rocky headlands. In this case the macro impact of the SWEC would be minimal. Each site would therefore have to be studied individually.

Hope this helps a bit. The second half of your question therefore applies --“maximum efficiency possible and implicitly beneficial for the coastal processes.”

Regards

Deon Retief”

4- Dr Kerry Sink (Telephonic interview)

4th July 2012
Marine Program Manager, South African National Biodiversity Institute
Centre for Biodiversity Conservation, Rhodes Avenue, Kirstenbosch
Private Bag X7, Claremont, 7735.
www.sanbi.org

The phone call began with an introduction of my thesis and the device concerned. I continued to ask for Dr Sink's thoughts. She suggested that the NEMA EIA regulations be considered. Subsea cables should be investigated for their impact on wild life, with the subsea cables from the telecommunications industry being an example to use. Cables should be grouped as much as possible. The device may have impacts on the penguin population which inhabits the West Coast of South Africa. Further contact to follow in September 2012.

5- Rhydar Harris and Kennith Pederson (Personal communication)

29th June 2012

Rhydar Harris, MSc (Eng), Engineer
Kenneth Pederson, Senior Engineer
Prestedge Retief Dresner Wijnberg (Pty) Ltd (PRDW)| Consulting Port and Coastal Engineers
5th Floor, Safmarine Quay, Clock Tower Precinct, Victoria and Alfred Waterfront, Cape Town, South Africa
www.prdw.com

The meeting began with an introduction of my thesis and the concept behind it. As well as a description of the costing I will be doing as part of my thesis. A number of opinion and points were made by the team at PRDW regarding costing and implementation.

Costing of marine engineering is extremely difficult. Determining the prices of component such as concrete of a device that has never been constructed is also very complex and difficult to do. Costing of the turbine and subsea cables is also very difficult as it is highly specialized. Also would need other specialized costs such as for the construction of helicopter decks and standing platforms and rails on the device.

Impacts of not having a demonstration device lead to uncertainty as to how maintenance will affect the costing of the device. Pelamis and oyster are likely to have much higher maintenance costs as they endure much greater forces given their location on relation to the shore and sea surface. SWEC has higher local benefits, employment, skills, simple, wave period, and survivability.

Pelamis has the benefit of being tested in real sea conditions so it is more likely that the O&M coasts and fabrication and construction costs will be known and more easily estimated. It has also proven its feasibility in the ocean. SA is not interested in investing in a technology that has not been tested in the ocean. So SWEC at a disadvantage as no ocean trials have been taken up. It also only draws 30% of the power form the waves which is often thought of as a disadvantage in comparison to other devices but this is not considered in terms of the environmental benefits for the coastline of South Africa. SWEC also has part of its design and costing rooted in civil engineering while the other part is rooted in mechanical engineering. Thus producing estimates taking in all the factors from many different specialists is difficult.

Connection to high voltage cables and suitability to sites based on access to high voltage cables also becomes an important factor in costing estimates. For costing for the oyster and the Pelamis would need to consider if they would alter their device design to be suited to the longer period waves experience on the South African coast. Thus extra cost to calculate the redesigning would also need to be considered. The Pelamis would need to be made longer and designed for increased loads and maintenance costs. SA may need a dedicated wave testing site which could drive up the cost substantially.

Seriously note the costing troubles and why it may not be possible for certain devices. And why there are troubles. SA has different period waves therefore costing difficult for foreign devices.

Generic costing such as are port facilities available for specialized equipment? If not may have to construct from Cape Town harbour instead of Langebaan which increases the cost. Specialized equipment also drives up the price, as you need jack up rigs for construction and deployment. These will have to be imported. Also need specialized maintenance vessels. This raises the costs significantly!

A benefit of the WEC's but a complexity of estimating their costing is that individual units begin producing power when the first unit is constructed. So the costs are already being paid back from the period when the first device has been implemented and the second device is being constructed.

Meeting was concluded with a follow up information to be provided.

Note:

- Look at wave star they have information on their website.
- Oyster website, costing and implementation plan for South Africa.
- EMEC for costing info.

6- **Ken Finlay, (Personal communication)**

16th July 2012.
Academic Director, Mammal Research Institute Whale Unit / Marine mammalogist.
Department of Zoology & Entomology, University of Cape Town
Whale centre, Natural History Museum.

After an introduction of the Wave energy technologies investigate, the aims of my thesis were presented. A general discussing commenced regarding the potential impacts of a full array of WEC devices on whales and marine mammals on the West Coast of South Africa.

Dr Findlay began by suggesting there are two main species of baleen whales, and those are Right Whales and Humpback whales. Right Whales historically occur from False Bay and extend eastwards; between August and December each year where the females seek out large sheltered bays as protected areas for calves. And that was the thinking until recently where satellite tagging which showed that a number of animals, specifically the Right Whale move around Cape Point and up the West Coast, in shore that would constitute the particular area you are studying on the West Coast. Also humpback whales which migrate from arctic waters in summer where they feed to tropical coastal waters of Mozambique, Angola and Gabon. They utilize the coastal waters, inshore to migrate up to the tropical areas and that is via the shelf along the South African Coastline and through the site being investigated for deployment. At the same time the Right Whale's feeding grounds are off the West Coast, aligned with that is the Humpback feeding ground. It was thought that the Humpback was resting on the West Coast just feeding before they migrated back to the Antarctic , but it looks as though a component of that population actually stays along the West coast (with the epicentre at St Helena Bay) and doesn't migrate south. This is due to the productivity of the west coast upwelling system and the whales staying to feed. Although St Helena bay is the epicentre of the whales feeding there is use of the whole coast from Cape Point up to South of Namibia.

In terms of the dolphin species the endemic dolphins is the Heaviside's only occurring on the west coast of Africa between cape point and Southern Angola. Population numbers aren't well known, but it is unlikely to be endangered but it is endemic using coastal continental waters. Thus there are animals that utilize this area as critical habitat, that the animals particularly require for feeding or breeding purposes, in which a development such as the WEC may have population consequences. Particularly with large baleen whales it has to be born in context that Right Whales were reduced in numbers through whaling from 20 000 in southern Africa down to less than 100. They were protected in 1935 and numbers are now in the region of 5500. They are faring well and are increasing at 7% a year but compared to their carrying capacity of 20 000 they are nowhere near recovered and are still listed by the International Union for the Conservation of Nature (IUCN). Humpbacks are a different story, in the southern hemisphere numbers whittled away due to huge catches of over 200 000 in the last century in the southern ocean leaving populations highly decimated. Alternately the Humpbacks are increasing at about 10% per year and a faring much better than the Right whales.

However the population of whales utilizing this feeding area on the west coast of South Africa maybe unique in that they don't mix with the other whales in the Southern ocean, and the genetics suggests this as well. Consequently there would be a concern with such a large development (40km array of WEC devices) directly in the area where a unique species of whales are feeding. In addition Right whales during breeding season remain in water depths of around 5 meters trying to conserve as much energy as possible. In this season generally they are not using the west coast for feeding and they are energy stressed and stick to shallow, sandy bays to conserve energy. (This is similar ocean terrain to that required for the development of the SWEC). The development of a 40km array of WEC's would act as maize to the animals that are already energy stressed. The placement of such a development within that area would raise a number of concerns. Firstly the physical presence of the devices is concerning. As they have a fairly wide birth which would act as an obstruction and for an animal to move from the inside to the outside of the device creates a maize for energy stressed animals to navigate through. The issue there is one of entrapment. The "v" shape of the device also raises concern with regard to entrapment. The configuration of the device (v shape) focuses energy toward the apex and there should be investigation into whether the force of the waves being focused may trap marine mammals especially dolphins within the "V". Also would the height of the device provide a barrier to passing animals i.e. can the animals swim over the device? Is there enough head for an animal to clear the device? The reduction of the wave energy by the device (particularly the terminator devices) may actually provide a protective lagoon for energy stressed whales to rest. Smaller dolphins feed on reef fish and the WEC acting as artificial reef may provide more habitat for reef fish, thus increasing their numbers and possibly increasing the food resource available for small dolphins.

In addition cabling could be an issue as the animals love to scratch and any exposed cabling would be vulnerable to scratching from extremely large heavy animals and would need to be able to take the forces. This has been documented in the crayfish industry where animals cause damage to cables and equipment. This maybe a concern for the Pelamis device as it will require mooring and it may need to be strong enough to take the forces of the whales scratching.

The second concern is with regard to the percussive noise and pressure noise from the device such as waves crashing against the device and air rushing through pipes. Also any mechanical noise that the device may produce. With this concern the Oyster would be a major concern in terms of noise pollution and mechanical noise. In addition any percussive noise during construction would be a concern such as pile driving, dredging or from blasting. Would need a specialist noise study.

Since the structures are so large the currents created by the device may be fairly server. As such eddies and currents created may affect the plankton dynamics, possibly entrapping plankton prey in the currents and thus altering the plankton's feeding behaviour.

Boat traffic would also be an issue with regard to the device construction and operation in terms of mitigation measures as to how animals should be approached or not approached etc.

A three phased approach would be required to consider impacts. The first being construction, second operation and third being decommissioning.

Construction: Pile driving will have a huge noise consideration particularly on marine animals. The repetitive, percussive hammering can be extremely damaging and is well documented.

Operation: Subsea cables are not expected to impact on whales and marine mammals and there is no evidence that they would. However one of the hypothesized reasons for mass beaching is geomagnetic anomaly. Certain areas with geomagnetic anomaly maybe the cause for such beaching due to the switch of magnetic field in those areas. This suggests to Dr Findlay that there may be a component of magnetism within migration but he is doubtful of whether a localized magnetic field will impact a whales navigational abilities.

Decommissioning if done explosively need to be timed carefully and should be done in a time of year when the whales are not near the site.

7- Christine Reddell, (Personal communication)

10th August 2012
Dawson, Edwards and Associates Maritime and Commercial Attorneys
"De Hoop," 2 Vriende Street, Gardens Cape Town

The meeting began with a brief description of the SWEC device and its operating principle and associated infrastructure. Then I described my thesis aims, goals and gaps. Legal advice on the permitting and agencies involved were then discussed informally along the following structure.

WAVE ENERGY GENERATOR – LEGAL ISSUES TO CONSIDER:

- Consider 3 relevant stages of the project:
    - Initial stages – getting approval to undertake the project in the desired location.
    - Laying the cables to transport the generated energy to shore.
    - Decommissioning of project.

1. Initial stages

- Will the project be considered a "listed activity" in terms of the NEMA EIA Regs (2010)?
    - It is likely that the project will fall into a number of listed activities (see the "Example of Basic Assessment" document – particularly page 11). Some of the listed activities require a full EIA, and some require only a basic assessment (this depends on which listing notice the activity falls under – Activities in Listing Notice 1 require basic assessment; Activities in Listing Notice 2 require full scoping and environmental impact reporting; Activities in Listing Notice 3 require basic assessment). The required contents of a basic assessment report are contained in regulation 22 of the EIA regulations. The required contents for a scoping report and environmental impact assessment report are contained in regulations 28 and 31 of the EIA regulations).
- The White Paper on Energy Policy (1998), the White Paper on Renewable Energy (2003) and the Energy Efficiency Strategy of 2005 will count in the project's favour (have included copies for you to have a look at).
- The National Environmental Management: Integrated Coastal Management Act of 2008 will have an impact on this project. In terms of this Act, coastal land and coastal waters cannot be privately owned. These waters and land must be utilised for the benefit of all South Africans. The State acts as custodian under the "public trust" doctrine. Minister has the authority to grant leases and coastal concessions. The coastal lease must be awarded for a fixed period of not more than 20 years and must

provide for payment by the lessee. Consider the Act carefully. (In particular, see section 65, section 66, and section 68).

- Consider the implications of a Marine Protected Area (MPA) – probably unlikely that these activities would be allowed in such an area. In terms of section 43(2) of the Marine Living Resources Act, no fishing or destruction of any other fauna or flora is allowed within an MPA. Permission for such activities seems to be limited to activities required for the proper management of the MPA (see section 43(3)).

2. The actual installation and pipelines (see "Class Notes on Offshore Installations")

- Look at – Marine Traffic Act, Marine Pollution Act, Maritime Zones Act. See definition on installation in the Marine Traffic Act – it would include a pipeline of this nature.
- Marine Pollution Act – would this be considered as the transfer of a harmful substance?? If it does fall within the scope of the Act, then one would have to report the discharge of any harmful substance to SAMSA. One would also need a pollution safety certificate from SAMSA.
- Minister can designate safety areas around these pipelines (Marine Traffic Act). This is to protect ships navigating in this area.

3. The decommissioning of this installation (see "Class Notes on Decommissioning")

- Look at Dumping at Sea Control Act. Dumping includes the abandonment of any platform or other structure at sea. So – obligation to plan for the decommissioning costs of the project (can be very costly).
- See my "Class Notes on Decommissioning" – however, the first couple of sections deal more with mining activities. See the discussion of the National Environmental Management: Integrated Coastal Management Act (page 5/58). If you're not going to completely remove the structure after the project, then you would need to obtain a dumping permit from the Minister of Environmental Affairs. You would need to comply with certain principles (since the abandonment of structures is not desirable environmentally).

8- Dr Geremy Cliff, (Questionnaire)

6th September 2012
Head of Research, KwaZulu-Natal Sharks Board

Questionnaire:

(Please answer any questions you would like to offer an opinion on and leave out any question you don't feel comfortable offering an opinion on)

1. What is your initial impression of wave energy converters?

Seems like an excellent way to produce clean energy. Apart from the aesthetics, there would be very little if any noise or chemical pollution. It is a renewable and sustainable source, reducing dependence on fossil fuels or nuclear power. I assume that cost is an issue for any power generating system. Is hydro-electric more cost effective than this wave converter?

2. What would your major concerns with implementing a wave energy converter?

Can the device stand up to the rigours of ocean winds, swells and currents? I am sure that it probably could, but there are the exceptional/extreme weather events, similar to 1-in-50 year or 1-in- 100 year floods.

Fishing vessels snagging the seabed cable running from the device to the shore.

Ships in very poor seaworthy condition hitting the device while rounding the Cape, although ships should be travelling in water deeper than 15-20 m.

Biofouling and trying to minimise it

3. What would be your concern with such a development on the west coast between Langebaan and Grotto Bay?

I am not at all familiar with that section of coastline, but regardless of where it is located, the issues of aesthetics and appearance come to mind. Because the device is 1.5 km offshore I am sure the air turbine tower would not constitute an eyesore to people on land. The advantages far outweigh the disadvantages.

I presume the area does not have much near shore reef, which would interfere with the operations.

4. What would you expect the environmental impacts to be of a Wave energy converter to be?

I don't foresee any of significant magnitude, possibly some minor intrusion during construction phase. If piling is necessary in the construction, it could create significant noise to disturb marine mammals. If the converter requires regular attendance and monitoring, then the physical presence of boats and people would constitute an intrusion. Running the cable through the surf, up the beach and to the power station would also represent an intrusion which must be minimised. .

5. What Impacts would you expect on marine animals?
   a. Sharks?

Sharks might bite the electrical cables, because they are very sensitive to electric fields and as a result may find the field attractive.

i. Electromagnetic interference issues?

See comments above.

Sharks may use the earth's electro-magnetic field to navigate large distances. The device could provide some interference, but I suspect that it will only be for sharks in the immediate area and therefore would be of minimal concern.

b. Other Fish?

Fish would use the device as a FAD (fish aggregating device) which might result in increased interest from fishermen. I assume that there would be a large no-go zone around the device which would prevent fisherman from accessing the fish attracted by the device.

c. Sea birds?

I am not sure. The tower would be a good roosting/guano platforms, but there must be effective marine scarecrows.

The gannets might be tempted to dive onto anything small, bright and shiny that resembles a fish/food.

d. Marine Mammals?

Seals would be attracted to any fish using the device as a FAD. I presume whales will pass the area and might rub themselves on the structure. Need to ensure that there are no ropes or cables (other than those on the seabed) which could snag the whales.

6. What other animals may be affected by electromagnetic interference?

Inverts in the sediment – unlikely to be affected?

7. What would you think the impact would be on marine flora?

Minimal, biofouling of the converter by both seaweeds and inverts may be problem.

8. How would reduction of wave action impact on the coast line and coastal processes? (SWEC estimated to only reduce the wave energy by 30%)
    a. Sand transportation?

I think the affect would be minimal, provided the energy reduction remains at 1/3, but difficult to comment without knowing anything about the coastline.

    b. If the wave energy was reduced by a greater amount would there be further impacts?

Hard to say, I would be guided by any other such studies elsewhere in the world.

9. What would the impact be on fisheries?

Very small reduction in fishing area available, too small to have any negative effects, assuming that it is not a favourite lobster fishing ground.

10. What should be considered during implementation?

Good publicity campaign to ensure everyone is kept informed.

11. Which permitting agencies or departments need to be involved?

Mineral and Energy Affairs, Environmental Affairs (Oceans and Coasts), SAN Parks, Science and Technology, Agriculture, Forestry and Fisheries.

Try and get any environmental (eg WESSA) agencies or other civil society groups involved and informed

Opinions:

Sounds really exciting. I hope the funds are available to at least construct a demonstration plant. I have not fully investigated the disadvantages of nuclear generated power, but there appears to be huge opposition to it, presumably largely with the risks of contamination during operation and the disposal of radio-active waste. The wave energy converter does not have any of the problems associated with nuclear power plants.

So often a wide range of such initiatives are supported by society. They range from low cost housing, construction of prisons, cell phones towers to power stations. The rider though is NOT IN MY BACKYARD. Hopefully it won't be the same with this project.

Opinions:

Other Devices: Please offer an opinion if you have any concerns regarding the operation of other devices. The three devices describes below are all internationally established technologies.

Pelamis: Moored to the sea bed via cables and floats on the surface. Rolling swell causes flexing motion and drives hydraulic pistons located in the joins to generate electricity.

Surprisingly small, unless it is a prototype. Very clean; I believe that the anti-fouling paints commonly used up till now have been banned. Presumably because it is moving, birds don't use it as a roost.

Wave Dragon: Floating device on the sea surface. Focuses waves up a ramp to a retention pool. Water is then dropped out the pool through turbines back into the ocean.

No concern

Oyster: The oyster consists of a wave plate moored to the sea bed. The plate rocks back and forth in the surge of the waves. The rocking plate drives a piston which pumps water to drive a turbine and produce electricity.

No concerns

9- Dr Samantha Ralston (Questionnaire)

20th November 2012
Birds and Renewable Energy Manager at BirdLife South Africa.

Marine Birds

I have had a look at your questionnaire and have consulted my colleagues for their input so the views expressed below are not mine alone. I have not answered your questionnaire directly as many of the questions are beyond the scope of my expertise and /or would require a detailed assessment.

While we don't note any obvious fatal flaws, I would like to see such specialist assessments before I was satisfied that the environmental impacts, including but not limited to birds, will be minimal. These should include a faunal study, and avifaunal study and assessments of the potential impacts on marine ecology and marine processes (e.g. sand movement).

I imagine that direct impacts on birds would mostly be related to disturbance and noise during construction and maintenance. It is not clear if there will also be noise during operation. Noise may also interfere with fish navigation. The west coast is an important area for sardine and anchovy. The anchovy are thought to migrate down the west coast from about March to September. If any noise from the wave generator disrupts this migration that would have serious implications for seabirds around Cape Town, as well for fisheries.

The proposed site itself, it is very near Dassen Island which is the largest penguin colony in the Western Cape and home to many other seabird species. I would therefore urge caution if any negative impacts on birds or their prey is anticipated.

Another unknown is if and how electromagnetic fields could affect fish and birds (especially penguins). I'm not sure if any work has been done on that.

The facility may also have indirect impacts on birdlife through changing the local habitat and coastal processes. These impacts could be positive or negative depending on what the changes are. A specialist would need to have a look at that.

Would inshore trawl fishery be affected? The impacts of this would also need to be considered.

Onshore impacts on birds would largely relate to the transmission lines (e.g. habitat loss, disturbance and collisions with lines). This is unlikely to be a fatal flaw, but the impacts should be assessed and mitigated (e.g. though the use of bird diverters and appropriate environmental management and avoidance of sensitive areas).

I've attached a paper that may be of interest Frid et al,

If you haven't already I would suggest you also contact CapeNature, DEA and DAFF for their input.

10- Dr David Sinclair (Skype meeting)

20th February 2013
Offshore Installation Manager Tennet Offshore GmbH - HVDC/AC installations. Survey & technical lead in EPC contracts.

Questions:
(Below are guiding questions, as I would like to keep the meeting as open and as informative as possible)

1. What would your major concerns with implementing a wave energy converter?

For a device such as this which has a large foundation footprint - sediment mobility, especially cumulative effects on array layouts.
Viability of foundation design as bottom currents from storm events will result in scour around foundation.
For any device which is taking energy from a system the issue would be on how this will affect coastal processes.

2. What should be considered during implementation?

Fully functioning scale model or smaller version which is shown to be commercially viable and that is able to be maintained and operate during a period covering winter storms – for example MCT scale model built in Strandforg Lough, NI.

- Grid connection
- Foundation design
- Intra-array cabling
- Export cabling

3. What challenges are faced operating in a marine environment?

High energy environment, which is an essential factor for site selection. This creates limited window for surveys and even smaller for construction and maintenance.
Possibilities for repairs due to extreme events.
For SA there is likely to be a skills shortage, SA has a very limited offshore industry focused on a few O&G platforms. Take for example UK & Denmark which have a large O&G industry and this has formed the skills base for offshore renewables. Compare this to Germany which essentially has no offshore O&G industry and much of the labour and specialist skills have been imported.
Access to resources – specialist vessels or jack-ups required for construction / maintenance are in short supply and are used in competing offshore engineering projects around the world.

4. What are the safety implications for construction and operation vessel and crew while operating at sea?

   Access to and from site – requirement for safe refuge in case of storm which prevents transfer by crew boat or helicopter.

5. What threats does decommissioning carry?

   Cables – negligible

   Foundations – disturbance of seabed that has since returned to equilibrium since construction. Decommissioning may not necessarily require removal, as this could have a greater impact than in leaving the foundations in situ, see for example decommissioning plans for UK Round 2 sites some of which consider leaving gravity base foundations on site.

6. What are the major criteria in site selection?

   Grid connection point – no device is worth developing if generated power cannot be integrated into transmission grid

   Energy environment – resource efficiency

   These two are pass / fail criteria before a site can be considered further. Thereafter a consideration of

   Marine habitats – fauna and flora, is developing this site creating more environmental impacts.

   Coastal processes – changes in sediment transport

7. What would be your concern with such a development on the west coast between Langebaan and Grotto Bay?

   Feature represents a significant navigational hazard – increased risk of vessel collisions, especially near approach to working harbour like Saldhana.

8. What would you expect the environmental impacts to be of a Wave energy converter to be?

   a. Physical

   Effecting the wave energy and swell that reaches the shore will impact upon coastal processes and this could be difficult to model and quantify

   b. On marine life

With a design like this that has a large footprint on the seabed environmental impact on marine flora and fauna will be significant. This is a fixed structure, not floating, so impacts on sediment mobility and a change in the seabed surfaces for organic growth – that does not mean that a significant impact is necessarily a bad impact.

- Benefits also result from creation of renewable energy areas
- Increase in hard substrate can act as artificial reef promoting biodiversity

- Presence of cable creates a no-fishing zone so area acts as a fishing nursery ground.

Impacts of cable installation likely to be minimal as cable is long but area of impact is very narrow.

9. What animals may be affected by electromagnetic interference?

This would require an HVAC export cable, impact on elasmobranchs needs to be considered, for example refer to "*The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon Elasmobranch Fishes*" (http://www.offshorewindenergy.org/reports/report_004.pdf)

No induced magnetic field which is a problem for HVDC cables- as this brings in navigational issues.

10. What would you think the impact would be on marine flora?

Change in habitat with increased areas of hard and loss of sandy substrate.

Changes in sediment spatial distribution and also in grain size

11. How would reduction of wave action impact on the coast line and coastal processes? (SWEC estimated to only reduce the wave energy by 30%)
    a. Sand transportation?

    b. If the wave energy was reduced by a greater amount would there be further impacts?

Difficult to answer as this would require comprehensive modelling of coastal processes as a whole. There may not be a linear relationship between impacts on wave energy and coastal processes, but rather a tipping point reached whereby a further slight decrease in energy has a significant impact.

12. Which permitting agencies or departments need to be involved?

SANBI – baseline, and impacts on, biodiversity

NSRI and shipping – assess navigational hazards

Commercial and subsistence fishing representatives – these would likely strongly object to anything that closes off an area for fishing activities.

SA Navy – maritime security

Cape Nature / SAN Parks

Provincial Government on possible outcomes of changes in coastal processes.

--- END ---

Implementation Plan for the Stellenbosch Wave Energy Converter on the South-West Coast of South Africa

By

Jonathan Frick

Comments

Most of the deficiencies identified in the first review have been addressed. However, there are a few observations on the responses:

1. **Response #1**: As three focus areas addressed in this thesis are fragmented by discipline, the results we[re] detailed at the end of each chapter. Drawing three varying topics into one chapter may create more confusion in the findings of the thesis.
   Comment: Findings from different disciplines need to be coherent in supporting the research hypothesis.
2. **Response #3**: The structure of the thesis has been revisited and amendments to the specified methods sections have been addressed.
   Comment: A section on methodology has been included in the introductory chapter. Nevertheless, collation of all sections on methods into a single chapter was suggested to improve the structure of the thesis.
3. **Response #6**: 'Ethical considerations were addressed via an application to the board of Ethics.
   Comment: Questions 2.4 and 2.5 of Addendum 2 of the application form to the Ethics Committee are as follows:
   2.4 Will any confidential data be collected or will identifiable records of individuals be kept?
   2.5 In reporting on this research is there any possibility that you will not be able to keep the identities of the individuals involved anonymous?
   The answer to both questions was 'No'. However, the revised thesis still contains identifiable records of individuals, and the individuals are known.

August 27, 2014

Dear Professor Bennett, Examiners and Board of Examiners.

I write to you as a means of formal response to the **second round of** comments received on Friday the 1st of August 2014. I will respond to the examiners comments as numbered in the received comments namely; #1, #3 and #6.

Response #1:

I agree that drawing three sections into one chapter has the potential to be confusing. However as the three chapters are segmented throughout the thesis to avoid confusion it is important to have a dedicated space namely Chapter 6: Results and Conclusions where the chapters can be integrated. This is however done under three separate sub sections 6.1; 6.2 and 6.3 and discussed together below. The chapter discussed the sections separately but attempts to draw interlinks between the varying scopes of work to determine a coherent outcome. Even within the conclusions the separate sections are given their own subheading before conclusions are presented.

Response #3:

The methods although not structured in their own chapter are all contained within a single section where they are explained in detail under section 1.7 and structured according to the methods used.

Response #6:

No confidential data has be collected, kept or published. No personal data or records were collected from the interviewee and the only content shared was the expert's professional opinion on some of the outcomes of the wave energy converter device (hence the response to question 2.4 was 'No' - "2.4 will any confidential data be collected or will identifiable records of individuals be kept?").

All interviewees are industry experts and thus the value in the interview comes from each of the interviewees being recognized as an industry expert. However it is possible that an interview could remain anonymous if they opted to do so. Furthermore the interviewees were given the option to remain anonymous, and all information was presented as an opinion and not represented as researched fact. It was possible to keep interviewees anonymous if they had opted to do so (hence the response to the question was ‘No’ to question “2.5 in reporting the on this research is there any possibility that you will not be able to keep the identities of the individuals involved anonymous?”).

Warm regards,

Jonathan Frick

Jonathan Frick

Second Letter of Response to Examiners Comments

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Warm regards,

Jonathan Frick

Implementation Plan for the Stellenbosch Wave Energy Converter in South Africa

Jonathan Frick, University of Cape Town

Abstract— Lack of experience in wave energy conversion locally leads to uncertainty in the implementation process for the Stellenbosch Wave Energy Converter (SWEC), which is the cause of many developmental hindrances in terms of determining cost estimates, the potential site specific environmental impacts and the required permits. Cost estimates based on assumptions of capacity factor, inflation extrapolated component costs, show that with significant learning rates and reduced risk the SWEC may become cost competitive with current prices of traditional renewables. A full array of SWEC devices carries significant threat to coastal process, marine flora and fauna, ecosystem dynamics and functioning. Mitigation is required to be incorporated into the design and layout of the plant particularly to conserve wave energy to drive coastal processes. A considerable number of permits and permissions are required for the Development of the SWEC, with the National Environmental Management Act forming the base for the majority of permitting procedures. Complexity is added through the coastal leasing policy relying on two different Acts, and policy reform is required to encourage the uptake of wave energy conversion technologies in South Africa as current energy policy acts as a barrier to adoption. Expected environmental impacts are ranked, required permits are listed resulting in the formulation of a simple implementation plan.

Index Terms— environmental impact, energy policy, implementation plan, levelised cost of electricity, permitting, wave energy converter.

1 Introduction

South Africa has a a unique opportunity to deploy the Stellenbosch Wave Energy Converter (SWEC) locally developed at the University of Stellenbosch, tailored to the wave climate conditions and seabed environment of the south west coast of South Africa (Van Niekerk, 2009). The SWEC was intiailly designed during the oil crisis in the 1970's (van Niekerk, 2009). After the technology was designed and patented, the research and development (R&D) was discontinued due to the reduction in the oil price and hence rendering the project an unnecessary substitute for oil. Since there is currently a major demand for renewable energy supply and energy security; wave energy technology has come to the surface as a possible source in the renewable energy generation mix (van Niekerk, 2009; Joubert, 2008). The attractive wave energy climate on the south west coast is the environment the SWEC has been designed for and requires no further optimization (van Niekerk, 2009; Retief et al, 1984). Additionally it could offer substantial local benefits to the econmy, environment and energy security as well as developing an emerging industry. However the economic, environmental and political feasibility require further investigation due to the limited local knowledge and experience (van Niekerk et al, 2011; Cameron, 2007).

Limited experience locally in the implementation of wave energy convertor (WEC) devices, such as the SWEC introduces uncertainty around any potential development and the associated deployment costs, environmental impacts and regulatory barriers. The Department of Energy's (DOE) Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) is the key driver of renewable uptake in South Africa but currently wave energy technologies are excluded from the tender process (DOE, 2011). Exclusiion from the REIPPPP is the most significant barrier to the uptake of wave energy in South Africa (Winkler and Marquad, 2009). There are a number of other legislative criteria to meet in order to implement a wave energy converter such as land rights, wayleave rights, environmental authorization, and a host of third party permits, compliance codes and standards to adhere to. To a degree a number of there permissions are included in the existing legislature or developemtn framework but a number of the required consents are not formalized and need to be obtained on a project specific basis.

The development and implementation of such a device is associated with a significant cost that is estimated by way of a levelised cost of electricity (LCOE) calculation to enable comparison of the cost estimate for the SWEC against traditional fuels and other renewable sources. This determination demonstrates the inflated Operation and Maintenace cost center accounting for approximately 50% of the SWEC's LCOE due to the high energy environment in which the SWEC operates. The remainder of the cost of the SWEC is made up of the large capital cost of the device which results from the extensive research and development and production costs. As a result of the setup costs of a new wave energy tehnology the learning rates involved in the production of the SWEC are a significant influencing factor when cost estimates are projected into the future.

Environmental Impact Assessment is a requirement under a multitude of government listed activities in terms of the National Environmental Management Act, 107 of 1988 (NEMA) Environmental Impact Assessment Regulations (DEA, 2010). The Impact Assessment is the process by which the key permit the Environmental Authorisation is received. The process also facilitates the consent from a number of third party bodies

- *Jonathan Frick is currently pursuing a masters degree programme in Energy and Development Studies at the University of Cape Town, South Africa, PH-0216574056. E-mail: Jonathan.Frick@mainstreamrp.com*

through the mandatory public participation process. Although the environmental impacts has been investigated internationally, the depth of research, and specificity to southern Africa and the SWEC device inparticular is limited. Little experience in the wave energy industry in South Africa means there is a gap in the knowledge base in the potential environmanetl impacts that may occur from the implementation of a single SWEC unit or an entire SWEC array. Given the lack in site specific environmental research, cost estimates and policy implications for wave energy converters in South Africa the research paper determined if the Stellenbosch Wave Energy Converter (SWEC) is environmentally, practically and financially feasible for deployment in South Africa. Resultantly an implementation plan was developed for the Stellenbosch Wave Energy Converter planned on for the south west coast of South Africa between Langebaan and Grotto Bay as per Figure 1.

Figure 1: SWEC Project Site Locality

2 Methodology

2.1 Costing of a Converter

The LCOE allows for an economic comparison of energy generation technologies that ordinarily would not be comparable on a like for like basis (IAEA, 1984). This aids in determineing the feasibility of implementation from a financial stand point. A detailed costing of components was compiled in 1984 by Retief et al, which was extrapolated at the rate of inflation until 2003 based on inflation by Pederson, (2006). The cost estimates are further extrapolated to 2013 using a simple LCOE model utilizing the standard LCOE formula along with the assumptions outlined in Table 1. Inputs and extrapolated costs from the simple LCOE were utilized in the the SNAPP detailed LCOE model developed by the University of Cape Town and based on the Integrated Resource Plan 2010 (ERC, 2013). This allowed for a unit cost comparison of the SWEC wave energy converter under varying interest rates, learning rates and capacity factors against establish electricity generation technologies.

Table 1: Basic Wave Data and Economic Assumptions[1]

Mean power available	30 kW/m
Device data (1 Unit)	
Water Depth	~ 15-20m
Distance off shore	~ 1.5km
Design Wave Length	12s
Conversion Efficiency	75%
Mean absorbable Power	30%
Unit Max Rate Design Power	5 MW
Mean Power Generation	2.55 MW
Average Power Generation (Winter; Summer)	2.9 MW; 2.2 MW
Units in an Array	154 Units
Unit arm length	160m
Unit footprint	1.28 ha
Economic Assumptions	
Economic life time of all installations	30 ears
Fixed Operation and Maintenance	2.5% of Capital
Variable Operation and Maintenance	2% of Capital
Rate of Interest (Discount rate)	7.5%; 15%
Average Inflation rate 2003 -2013	6.15%
All Prices include:	
Normal contingencies (depending on component)	
Interest on components during construction	
Offshore installation costs (estimate)	
Exclude:	
Subsea cabling costs ~ € 1 million/km	
Project development, design, specialist equipment costs	
Financing cost for long term projects	
Various taxes (e.g. V.A.T.)	

2.2 Sources of information

Literature was used to determine the known environmental impacts, focusing on negative impacts, of WEC's based on international, practical experience. Focus is given to South African sources whether with sources being largely govern-

[1] Information gathered from (Joubert, 2008; van Niekerk, 2008; Retief, 2007),

ment commissioned studies and reports as well as device developer inputs. Literature was used to establish a baseline for the dynamic environment that is south west coast of South Africa. A combination of interviews with local experts on marine mammals, marine birds, sharks and the SWEC device and a review of available literature in comparable cases of environmental impact from Wave Energy Converters (WEC's) lead to the projection of potential impacts that may arise from the implementation of a SWEC unit or array.

A review of South African Energy Policy is undertaken via literature review to determine relevant and influential policies inorder to establish the required permits and consents. Drawing on implementation plan literature, Li et al, (2008) specifically the importance of analysing government policy, and a Strengths Weaknesses Opportunities Threats (SWOT) model for designing interviews, as recommended by Schmidt and Laycock, (2009) and Elfring and Voelbreda, (2001) an Implementation plan is developed. A framework from Li et al, (2008) is used to direct the development of the simple implementation plan for the SWEC.

Table 2: Levelised Cost of Electricity Wave Energy Technologies (ERC, 2013)

Scenario	Device	LCOE (R/kWh)
Base	Oceanlinx	1.38
Optimistic	SWEC (*i* =8%)	1.29
Conservative	SWEC (*i* =15%)	1.54

3 Levelised Cost of Electricity

Extrapolated costs based on inflation have been estimated up until 2003 by Pederson, these are utilized to extend pricing to 2013 as a full component costing would be an exhaustive process and beyond the scope of the study (Harris and Pederson, 2012). Based on an inflation rate of 10.5% assumed by Pederson, (2006) between 1984 and 2003 the estimated cost of producing the first 5MW SWEC unit rose from R10.77 million to R 80.96 million by 2003. Based on the 6.15% average inflation rate between 2003 and 2013, (StatsSA, 2013) the cost of producing the same unit in 2013 rose to R 172.30 million. These costs based on the 2003 component estimate indicate an increase of almost R 100 million/ 5MW unit based on assumed inflation rates. This shows that the capital cost of the device in today's period would cost more than in 1984 if inflation is discounted. A conservative cost per megawatt installed estimate being close on R35 million/MW is a significant stumbling block for any enegy technology.

A larger portion of the cost is attributed to Operation and Maintenance (O&M) costs that traditional technologies due to the extreme environment, remote location and highly corrosive atmosphere. Previsic, (2004) notes the O&M costs have a considerable effect on the estimated LCOE, as was the result in the simple LCOE for the SWEC as seen in Figure 2. The O&M cost for the SWEC (4.5% of capital per year) was drawn from the Oceanlinx MK1 as the OWC device uses a similar operating principal while costing is estimates for a commercial array off 152 devices meaning the O&M ties in closely with that of the SWEC device (Previsic, 2004).

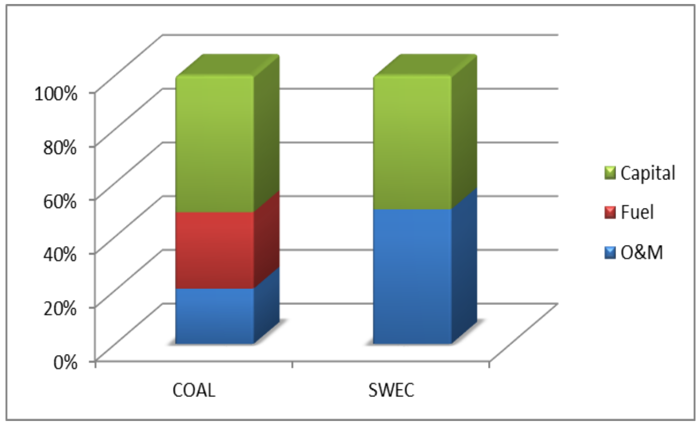
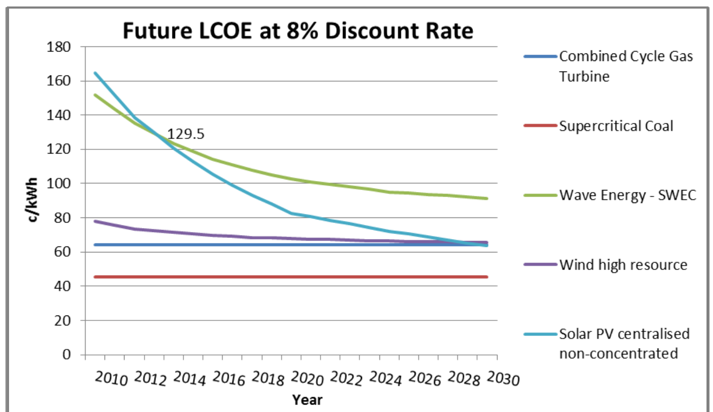


Figure 2: Relative cost centers of Traditional Coal in SA to the SWEC.

A cost comparison between the Oceanlinx MK1 and the SWEC reveal that the LCOE is comparable (Table 2) in the current period with the assumed discount and learning rates the key influential factor on the price range.



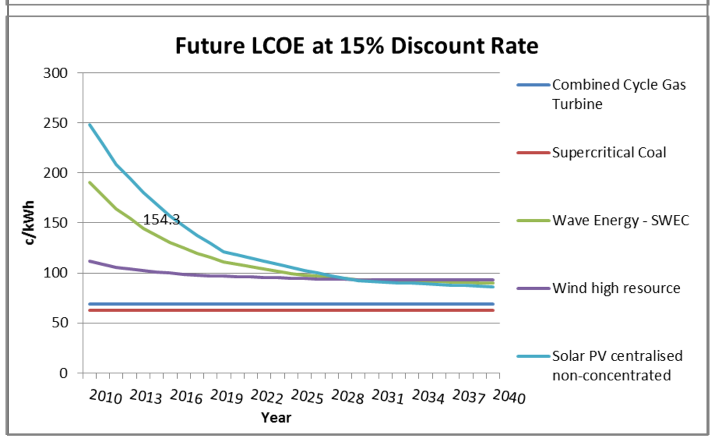


Figure 3: Influence of Learning Rates on the LCOE Comparing the SWEC to existing Technologies at an 8% and 15% Discount Rate Respectively

A more detailed costing is concluded using the SNAPP LCOE model based on the IRP 2010, developed by the ERC, (2013). It allows for a greater number of inputs including learning rates. Although varying learning are quoted from different sources, literature surrounding wave energy seems to indicate trends of above 10% beyond 2020 varying widely between device types (ARUP, 2011; RUK, 2010). Optimistic learning rates of 16.9% rendered larger cost reduction in the future with the pessimistic rates of 13.8% dropping to 11.6% by 2030 is assumed limiting the reduction of the LCOE of wave energy (ARUP, 2011; RenUK, 2010).

When discount rates are raised to 15%, inherently indicating a more risk prone investment climate, and assuming a 51% capacity factor for the SWEC (see Figure 3), the device becomes more cost effective than centralised solar PV at capacity factors of 19% (ERC, 2013). In the short to medium term the SWEC has a lower life time cost than PV due to the relatively high assumed capacity factor and the optimistic efficiency of 75% compared to solar PV's 17% combined with the higher cost of capital (*i*=15%). However the SWEC is still significantly more expensive than wind and traditional technologies and has extensive cost reductions to achieve before being a viable competitor.

Costing of a commercial scale WEC outside of a model is far more complex due to the costing of the turbines, civil works, ducting, helipads, specialised vessels and specialist equipment required by the SWEC (Harris and Pederson, 2012). The largest barrier to detailed design is the lack of detailed technical designs and sourcing of suppliers for device specific components. Although permitting may cost in the region of R10 million a seismic and geo-technical survey in the marine environment may cost in the region of R220 million, when including this to the R10 million per km cost (40km minimum) of subsea cabling, it quickly becomes evident that the cost are likely to be inflated outside of a simple model (Sinclair, 2012). The project costs are likely to outweigh the comparative development and construction cost of an established renewable energy by a factor of ten. Assumptions made in the financial model preclude external factors such as renting, imported specialised marine vessels, weather windows delaying construction, ability of harbours to accommodate casting works and transport vessels, all contributing to the inflated true cost of a WEC development (Harris and Pederson, 2012; Retief, 2012). Such external factors render a SWEC development in the current climate unfeasible.

4 Environmental Impacts

The scope for positive and negative environmental impact during SWEC development is broad with varying degrees of severity and duration. Factors influencing the extent of an impact include many design aspects of a wave energy converter (WEC) such as size, operating principle depth, and distance from shore (Nelson et al, 2008). The affected environment is a nutrient rich environment fed from the Benguela Upwelling System which allows for extensive blooms of plankton, resulting in large shoals of mid-trophic level, foraging fish which dominate the ecosystem but also allow for rich fishing grounds (Cury et al, 2001). Placing 154 units to create an array of SWEC devices increases the severity and complexity of environmental impacts (Finlay, 2012; Retief, 2012).

4.1 Construction and Decommissioning Impacts

Site preparation and rehabilitation activities result in the most persistant construction phase impacts due to the long period of influence over the estimated thirty year life time of the project. SWEC device would be located in the deep to sub photic area and is likely that there will be direct construction impacts on seaweeds, kelp, intertidal invertebrates and fish. Impacts are likely to arise from activities such as dropping of anchors or supports for the SWEC which crush benthic organisms, increase turbidity and clear vegetation. (PIER, 2008). A change in the turbidity of the environment would reduce photosynthesis due to increase suspended solids resulting in lower productivity of photosynthesizing organisms which may have up the chain impacts within the ecosystem (PIER, 2008). The major concern in the case of the SWEC would be vegetation clearing due to the sheer footprint size of the SWEC specified in Table 1. A similar impact is felt during decommissioning as the removal of the device would also have wide spread destruction of the established marine vegetation. According to Lombard et al, (2004) in the study of the three key datasets the near shore coastal habitat at the location of the SWEC development is completely (100%) irreplaceable. As a result subsea cabling infrastructure for the SWEC to deliver power onshore would need to be addressed methodically as it would run directly through inter-tidal vegetation where destruction is not reversible or compesatable. The SWEC is sited on the boarder of the near shore and sub tidal habitat, 0.6 -0.8 replacible, and the proximity to the nearshore environment means it is flagged as highly valuable habitat (Lombart et al, 2004). However there is a distinct lack of spatial deata documenting reef distribution, type, density and size as a result creating significant uncertainty around the potential impact from the placement of a SWEC array (Lombard et al, 2004). If the SWEC location falls further out to sea within the deep trophic area the probabilioty of significant impact decreases significantly as the area is regarded as a sand-bottom, and lacking reef habitat therefore may not be a complex and sensitive environment. A detail locational study of the proposed site would be necessary to avoid significant impact but could be facilitated through the Environmental Impact Assessement process.

Noise impacts are determined as the second significant impact during both construction and decomissioing. The percussive hammering of piling activities, loud, low frequency noise from seismic surveys or mechanical deconstruction of the devices will have wide spread impact as sound carries much larger distances in submarine environments (Finlay, 2012). Avoidance behaviour from marine animals is the most likely outcome which may marginalise the animals feeding behaviour, interrupt communications of dolphins or whales but in extreme cases execisive noise marine birds and fish may also experience injury or mortality (Nowacek et al, 2013; PIER, 2007)

4.2 Operational Impacts

Energy Reduction Impacts

The SWEC creates a hardened subsurface feature located on the seabed. One unit or an array of SWEC units reduce the wave energy on the leeward side of the deivce as numerically shown by (Zettler-Mann, 2010). Waves begin to interact with the seabed when the wavelength equals the depth of the water, typically at depths of approximately 50 m and less is where appreciable impact on bottom current occurs (Segar, 2006; Boud, 2003; Retief, 1979). The placement of the SWEC device in depths of up to 50 m would reduce wave energy and create a wave shadow on the leeward side of the device. The reduction of wave energy is estimated in the region of 30% as per Table 1. A significant energy extraction may impact near shore marine life and coastal processes and even small effects in these systems can have large ecological consequences (Gonzalez-Santamaria, 2013; Segar, 2006; Boud, 2003). Vulnerable costal processes are wave energy reliant such as sediment transportation and ecosystem functioning.

Sediment transportation patetrns are altered as the energy of breaking waves, erodes coastlines and moves sand along the coast to create and sustain beaches (Segar, 2006). Up to fourty eight changes mabe experienced to sediment transport patterns, beach nourishment, and coastal erosion (Gonzalez-Santamaria, 2013).Waves occuring at a perpendicular angles either deposit or recover sediment and suspend it in the retreating water body, while angular, long shore currents recycle sediment, transporting it along the coast in a dominant direction (PIER, 2008). PIER, (2008) empirically proves that the reduction in wave height due to an offshore WEC results in an amplified reduction in long shore currents and hence long shore sediment transport (PIER, 2008; pg. 71). The results of the numerical model of Abanades et al, (2014) shows the reduction in wave energy leads beaches to accrete and the evolution of the beach profile. Increased deposition rates may alter rocky, hard-bottom environments such as kelp forests and allow them to become sand dominated environments (PIER, 2008). Unlike rocky environments, organisms inhabiting soft, sandy habitats survive by living within the sediment. Although organisms survive insulated from hydrodynamic forces within the sediment layer, the layer is inherently dynamic (PIER, 2008). Sediment deposition varies with wave energy, impacting on particle size and shape, resulting in shallower horizontal slopes, and finer sediment in higher energy environments (dissipative beaches) than low energy beaches (reflective beaches) (PIER, 2008). The SWEC development is based on a sandy seabed surface potentially altering sediment transport and consequently shifting the profile of beach habitats is an appreciable concern (Wilkinson and Japp, 2005; Lombard et al, 2004). Increased deposition rates would alter the shape of the beach consequently changing the structure of the community and reducing habitat of beach spawning fish and organisms (PIER, 2008).

Wave energy also maintains certain habitats dynamics such as kelp forests. The reduction in wave energy in sensitive habitats such as the hard bottom kelp forests may lead to the domination of "giant kelp over bull kelp, fleshy algae over coralline algae species" which thrive in marine forests of lower wave energy (PIER, 2008). The reduction in energy would reduce the near bottom orbital currents resulting in sedimentation in areas that would usually not experience sedimentation (PIER, 2008). Consequently the delivery of dissolved and particulate material (food) to benthic (bottom dwelling) organisms would be reduced in the wave shadow but also beyond due to the lower wave energy (PIER, 2008). This carries the threat of altering wave driven benthic (bottom) systems resulting in less productive benthic systems but further detailed study is required. Reduced wave energy, altering flow dynamics of fish larvae and eggs potentially leading to a large scale alteration on the community on which the entire marine predatory system and human fisheries are based (PIER, 2008).

Vertical mixing of stratified layers of water would be hindered behind the SWEC resulting in less mixing. Deeper, cooler waters are not mixed with the warmer, surface waters resulting in warmer sea surface temperatures potentially, fundamentally altering the cold water, near-shore species composition (PIER, 2008). The extent to which reduced wave energy could alter vertical mixing is uncertain the overall impact on the near shore community from both reduced nutrient transport and increased sea surface temperature needs to be addressed in a further fine scale study.

Impedance Impacts

The second tier of environmental impacts during the operational phase are impedance impacts. These occur from the physical obstical of the SWEC device within the deep to sub photic area which restricts the accessibility to the typical sandy bottom habitat and crossings between the intertidal and deep photic habitats. Specific concern is given to marine mamals, the Humpback and Southern Right Whales in particular, which migrate along the south west coast. These species use the area as a nursery but also feeding grounds, traveling nearshore to protect calves during the energy intensive migration (Finlay, 2012). An array of SWEC devices may create a maze effect for energy stressed individuals causing the mamals to expend more energy which may ultimately affect feeding and breeding pattern according to Reynolds and Rommel (2007). Conversely the leeward side of the devices may provide relatively calm seas providing the mamals areas to shelter as calving mothers often occur in water depths of 5 - 20m to protect their young from predators (Finlay, 2012).

Seal lions, and marine birds may be affected by incidental use of SWEC structures as they utilise the above surface sections as roosts or haul-out areas (Hofford, 2011; PIER, 2007). The electromagnetic field of submarine cables may also have orientation and feeding impacts on marine species (PIER, 2007). Such Species are:

- Elasmobranch fishes (Sharks, Rays and Skates),

- Decapods crustaceans (crabs, shrimp and lobster)
- Baleen whales and toothed whales (Southern Right, Humpback and Killer Whales)
- Dolphins (Common and Bottlenose)
- Sea turtles (Loggerhead, Leatherback and Green turtles)

Tricas and Gill, (2011) show that there are a variety of navigational, sensory and feeding impacts with the species listed above the most vulnerable. Given the estimate of 40km of cabling required impacts will need to be considered carefully but much of the potential impact can be mitigated through burying of the cables although the damage to sensitive intertidal habitat would then be significantly increased (Sinclair, 2012).

4.2 Environmental Benefits

Beyond the green house gass emission savings from the renewable energy source, localised environmental benefits exist. Lombard et al, (2004) identifies extractive marine living resource use as the leading threat to the critically endangered environment surrounding the SWEC site. Although counter intuitive that the implementation of the SWEC device may assist in repleshing pressurized fish stocks, it negates the fact that the SWEC site would likely be a no sail and hence a no catch zone.

The hardened SWEC surface provides an area for propagules to settle and seed on, effectively creating an artificial reef. The vast extent of the SWEC array and the artificial reef environment created may provide extensive sheltered breeding grounds for marine fish species potentially assisting in the recovery of the pelagic fish species currently under threat (PIER, 2008). Whether the type of reef environment created is desirable breeding habitat or if it would fundamentally alter the ecosystem dynamics by introduction a 'new environment' to the maritime ecosystem would require further study. Upon this is it recommended that the SWEC development could potential facilitate the extention of the Marine Protected Area of Sixteen Mile Beach to meet the Marine Protected Area of Dassen Island 9.5 km offshore from Yzerfontein. While increasing irreplaceable marine habitats, it would also affer breeding ground for under pressure pelagic fish also allowing the fishery to recovery (Lombard et al, 2004).

5 Permitting and Policy Implications

The 2010 National Environmental Management Act (NEMA) Environmental Impact Assessment (EIA) Regulations, are the core environmental policies with which compliance is mandatory. The regulations publish a list of triggering activities which require different levels of environmental study as amended in the Government Notice (GN) Regulation (R)

- Listing notice 1: 543 (for Basic Assessments)
- Listing notice 2: 544 (for a full Environmental Impact Assessments)
- Listing Notice 3: 546 (Assessments for specific provinces areas)

The SWEC development triggers up to 28 activities across all three notices which will all need to be assessed in terms of the development. Thus a full environmental impact assessment is required which is the most detailed environmental study required by legislation (DEA, 2010).

The EIA can facilitate receipt of consent trhough the mandatory public participation process run as part of the process. However there are a host of formal and no legislated permits or consents required from third parties before permission may be granted in full. A summary of the legislated permits is provided in Table 3 detailing the legislated permits required.

Table 3: Register of Formal Permits Required

Statute:	**Consent:**
National Environmental Management Act, 107 of 1998 (NEMA)	Environmental Authorization for the electricity generation plant, associated activities
NEMA: Integrated Coastal Management Act	20 Year lease with condition to exclusive water use rights from the DEA
NEMA: Integrated Coastal Management Act	Lease for temporary occupation of land with in coastal zone
NERSA Electricity Regulation Act	Electricity Generation Licence
Mineral and Petroleum Resources Development Act, 28 of 2002 ("MPRDA") – Section 53	Consent in terms of section 53 to use land contrary to the objects of the MPRDA
National Environmental Management Biodiversity Act (NEMBA), Provincial Nature Conservation Ordinances, and regulations promulgated under them	Biodiversity Consents: the removal of certain sensitive fauna/flora, permission is required from the Department of Environmental Affairs ("DEA") or the Department of Agriculture, Forestry and Fisheries ("DAFF"). Permit to be applied for during the Environmental Impact Assessment
Sea Birds and Seals Protection Act	Permit for the disturbance of Sea Birds and Seals. To be undertaken during the Environmental Impact Assessment
National Heritage Resources Act, 25 of 1999 ("NHRA") – Section 38	Required notification of the relevant heritage authority. Notification to occur as part of the Environmental Impact Assessment
National Heritage Resources Act, 25 of 1999 ("NHRA")	Heritage Approval and any destruction permits or related permits for an impact on a heritage site or object. If any artefact is discovered notification of the relevant authority is required. Assessed during EIA by the relevant authority.
Civil Aviation Act, 13 of 2009 ("CAA")	Aviation Consents, particularly if there is the intention to have helicopter landing pads on the device platform. To be applied for once device location and designs finalised.
National Building Standards Act, 103 of 1977	Building plan approval required prior to the commencement of construction.
Electronic Communications Act	Section 36 of the Act requires the developer to obtain consent from the relevant Telecoms officials across the varying companies.

The Integrated Coastal Management Act (ICMA) is the latest piece of legislation published to govern the coastal property held in trust by the government for the people. Published in 2008 sections of the ICMA pertaining to coastal leases were not entered into force hence the Sea Shore Act 21 of 1935 still legislates the maritime zones and the consequently coastal lease policy. Publicly owned coastal land requires a lease agreement to be concluded with the state for the exclusive right to that land. In this regard the state's representative's consent is required for a coastal lease and this is legislated to be 'The Minister' (Minister of the Department of Environmental Affairs) (DEA, 2009a).

In certain cases other ministers are given authority if a development would impact on another minister's management portfolio, that minister may be given authority and this could occur in cases where the navigation of vessels is restricted, or where the mineral prospecting and mining rights are compromisedd (DEA, 2009a; DEA, 2009b; RSA, 1997). This is a possibility for the SWEC as the SWEC development is in proximity to gas prospecting rights and heavily utilised shipping routes. Further more the SWEC development would need to comply with setbacks from Marine Protected Areas according to the Marine Living Resources Act No. 18 of 1998 and Maritime Zones Act (No.15 of 1994) unless special permission is obtained from the Minister. A detailed list of Maritmie policy and the coastal zones in which they are applicable as seen in Figure 4. The setbacks required by the MPA's presents a potential opportunity to utilise the no catch zone created by the SWEC to facilitate the extention of the Dassen Island MPA to join the Sixteen Mile beach MPA as recommended by Du Plessis, (2012) and the Dassen Island Nature Reserve as seen in Figure 5. SanParks would need to be approached for consultation regarding the development in such close proximity to marine reserves (Du Plessis, 2012).

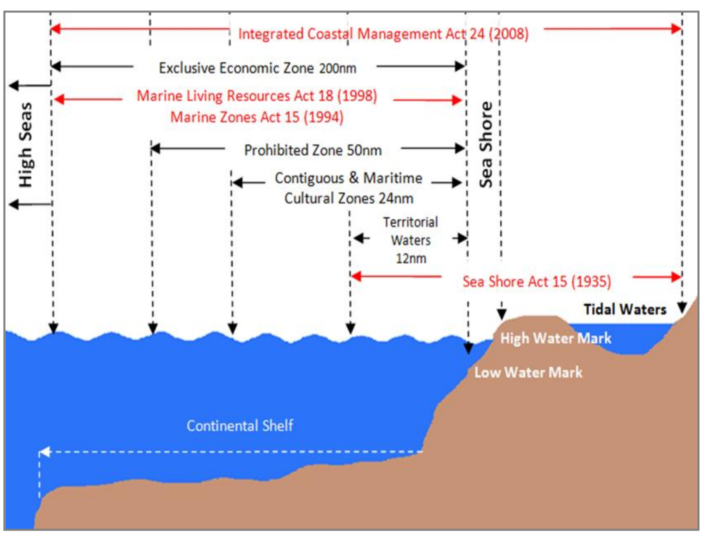


Figure 4: Spatial Influence of Maritime Policy

The department of fisheries as well as local fisheries would need detailed engagement early on as the potential environmental impacts may have significant impacts on local fisheries. Involvemnet and strong public relations will be vital in receiving consent for such an extensive maritime project.

Section 53 of the Mineral and Petroleum Resources Development Amendment Act (no.49 of 2008) precludes the development or any land use on the surface of any land which may "detrimentally affect the mining of mineral resources" (RSA, 2008). An application will be required to sterilise the SWEC site of mineral rights and this is necessary as natural gas prospecting rights are held over off shore sections of the south west coast although the suggested SWEC site does not seem directly affected (PASA, 2012).

Figure 5: Dassen Island – 16 Mile Beach MPA Extension Du Plessis, (2012)

As the south west coast experiences heavy shipping traffic and the SWEC site is in proximity to medium activity shipping lanes the Department of Transport and Transnet would need to be notified and consent gained to prevent obstruction of lanes and avoid wreckage (CSIR, 2008). Additionally the National Defense Force, the Department of Defense and the South African Navy in Particular would need to be contacted to ensure there is no conflict with maritime radar or monitoring systems Inaddtion to consents a number of compliances will need to be met such as the National Building Standards and the South African Maritime Safety Authority Standards.

Legislative Barriers

Energy policy in the form of the Department of Energy's REIPPP programme advicates exclusive demand for renewable energy generation, simultaneously excluding tenders for generation from wave energy technology under the current format of the programme (Winkler and Marquad, 2009; Winkler, 2005). This threatens the overarching objective of generation diversification and will remain if the build plan of the IRP remains the same putting wave energy at a developmental disadvantage. (DoE, 2011). Diversity of the market is stagnated leaving reliance on a limited number of renewable technologies, which may lead to perverse outcomes, ultimately increasing energy risk. Correction of this would require a portion of the renewable energy quota in future rounds to be allocated to fringe technologies such as wave energy or remain unallocated and available for all other renewable technologies to participate.

6 Implementation Plan

According to Li et al, (2008); the developed implementation plan is a pre-implementation plan. As suggested by the Li et al, (2008) the basis of the plan was founded by gathering view points from a number of specialised stakeholders. Viewpoints were gathered with regards to three key scopes; device costing, environmental impacts and government policy. Questionnaires and interviews were utilised as the recommended means of data collection by Li et al, (2008), along with literature review. Questionnaire and interviews were structured according to the SWOT model and facilitated to support the pre-implementation and organising implementation phases of an implementation plan (Li et al, 2008).

Li et al, (2008) defines it as organizing implementation, dealing largely with the early phases of development but does not focus on procurement, fostering collaboration, monitoring results and operation and maintenance. Commercial and financial structres are not investigate but are outlined interms of their chronological order in the implementation process. Figure 7 portrays a simple flow diagram representing the chronological process of development areas involved in the pre-implementation process. It begins with the land acquisition phase and details of the coastal lease policy. A suggested by Kelman, (1984) the implementation plan takes a critical look at policy. Policy requirements leave a complex mesh of environmental approvals, regulatory permissions and additional consents to be obtained during the development process.

A detailed site specific energy measurement and analysis would be the next phase in the process. Beginning the environmental impact study is the next phase with all the required detailed specialist studies forming part of the EIA process. Beyond the environmental impact studies there are a number of regulatory and additional consents required before commercial agreements and ultimately contracting and construction can take place.

There are number of aspects excluded from the implementation plan and these are made up of mixed and softer factors. Socio-economic factors affecting local fishing communities, job creation opportunities, stakeholder buy-in, site specific designs, financial investment, and power purchase agreements are all excluded from the implementation plan as the device is not at a stage where those goals can be achieved. The goal of the prefeasibility plan is to highlight the permitting process and the potential environmental impacts as well as cost barriers that would be required not only for the SWEC but any other wave energy converter entering the market (Mindzberg, 1990).

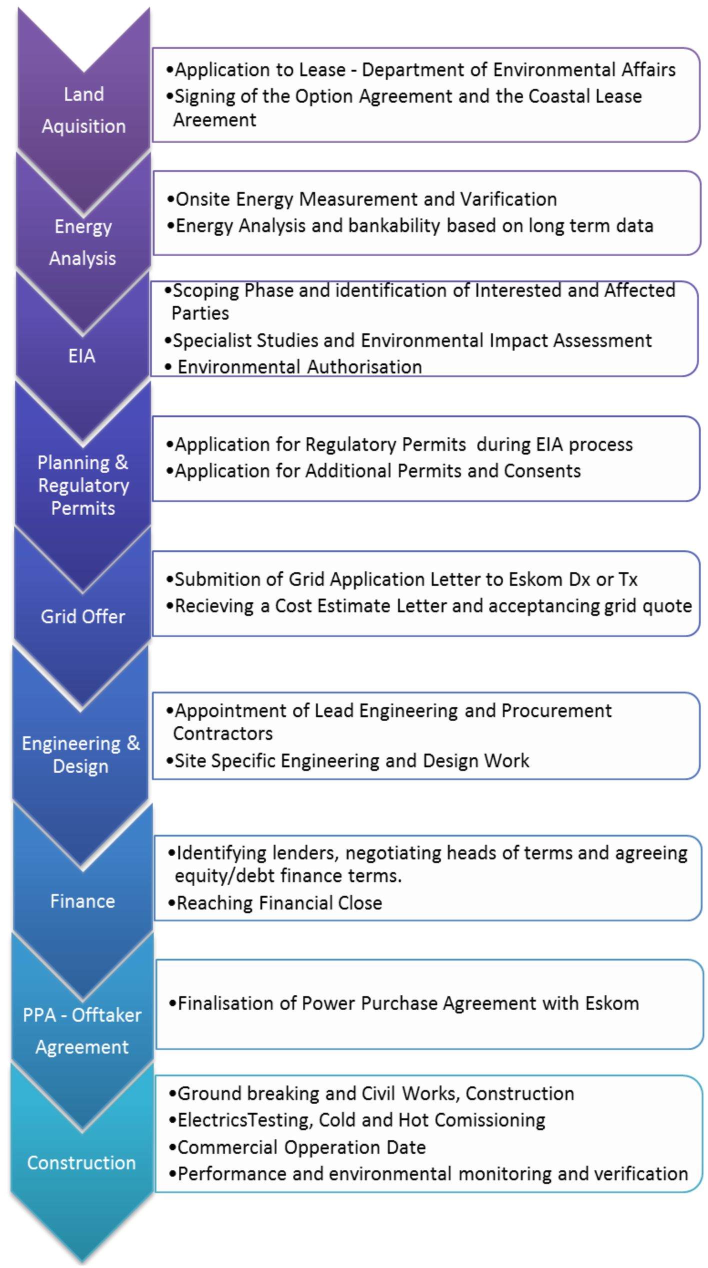


Figure 7: SWEC Development Implementation Plan

The implementation plan detailed in Figure 7 is available to guide the development process and reduce uncertainty to streamline the implementation process. The steps following the pre-implementation process are detailed in Figure 7, but serve as reference to the final two steps of a strategic implementation plan, namely the managing implementation and sustaining performance.

7 RESULTS CONCLUSSIONS

7.1 Financial Pragmatism

The simple LCOE calculation indicates power from the Stellenbosch Wave Energy Converter being priced at 2056c/kWh assuming a capacity factor of 51%, discount rates of 15% and excluding cabling costs. Higher discount rates resulting from more risk associated with lending to a project is the immediate price driver and this is visible from Figure 3. Estimated costs are lower than what is provided in the literature as the Carbon Trust, (2011) estimates WEC prices between R4.80/kwh – 6.60/kwh, although these are influenced by the exchange rate conversions. The inclusion of subsea cabling costs tend to add in the region of 50c/kWh to the LCOE for a WEC and this price is highly variable based on the electrical redundancy requirement and method for cabling used. Never the less it is an influential cost center that should not be excluded from any costing exercise. The SNAPP model displays the influence of learning rates on cost with strong learning rates (15-19%) making the SWEC cost competitive toward 2030. Assuming optimistic learning rates the SWEC is cost competitive to the Oceanlinx MK1 sharing operating principals and design characteristics, but more moderate learning, necessary site specific design requirements, cabling and interest during construction on a larger capital investment would erode the SWEC's competitiveness.

Operations and maintenance costs and capital costs share the overall cost approximately 45% to 55% over the thirty year life time of the SWEC plants operation. The economics of the SWEC would decline if the government continued to only commit to twenty year PPA's as they currently do in the REIPPP programme. Thus the SWEC needs legislative assistance to advance development in the current market. Although the levelsied cost of electricity is limited in accuracy by the reliance on assumptions the cost estimate modell, is useful as a proxy for comparison across technology types.

The displayed capital intensity and in particular inexperience leading to inflated operation and maintenance costs locally result in a levelised cost of electricity that results in the SWEC not being competitive operating outside the REIPPP programme. Consequently, in the current political and economic climate the SWEC is not economically feasible to implement on the south west coast of South Africa.

7.2 Permitting

Nineteen key permits are determined for the permitting process for a wave energy converter as listed in Table 3. Once a coastal lease is secured from the state, the Environmental Impact Assessment process facilitated under the National Environmental Management Act (NEMA) forms the key permit in the development of a wave energy converter. Given the aforementioned proximity to Dassen Island as a marine bird breeding ground a bird specialist report would be required as part of the EIA to assess the impacts. Along with an environmental authorisation the EIA process facilitates comment and required consent from a number of other bodies such as SAHRA, Telecomunications companies, departments representing fisheries, transpost, electricity generation and transmission, natura conservation and mineral rights. Futher consents are identified and applicability is determined on a case by case basis. Ultimately the consents required is project dependant but responsible development requires comment from each of the bodies concerned.

7.3 Environmental constraints

Impact severity aligned with implementation of the SWEC, is highly dependent on whether a full SWEC array is implemented or only a single unit. The degree to which a receptor is impacted tends to increase to a level where moderate impacts become severe when a full array of devices are implemented. The most significant noise impacts occur with short duration during the construction phase, originating from seismis surveys and pile driving. This stage carries the largest threat to animal mortality and injury (Frid et al, 2011).

Southern Right and Hunpback whales stand to be the most sensitive receptors during construction and operation with dynamic breeding, feeding and migratory patterns all under pressure from a SWEC development. A number of large devices would provide a physical barrier to migrating whales and other marine predators active in the productive marine environment located along the west coast (Finlay, 2012). Diving marine birds are also at threat particularly if devices are sites in shallower water environments. Mitigation methods for marine predators and birds would be deeper water siting although this does come with a higher construction and maintenance cost. The proximity of a well-documented bird breeding island, Dassen Island is a distinct concern and should be monitored carefully for disturbance from marine traffic and noise. At a high level the impact is estimated to be moderate with likelihood of occurrence uncertain. Since the SWEC site is likely to be a no catch zone for the purpose of marine safety, it poses negative impact to the fishing industry. However the impact of reducing the fishing grounds for trawling and lobster catching, a dual benefit may be reached by extending the Sixteen Mile Beach marine protected area to include Dassen Island and the extent of the SWEC site as a no catch zone into one large marine reserve.

The operational phase will largely affect the dynamics of ecosystems and coastal process as the SWEC device acts a terminating device lowering the wave energy to the leeward side of the device (Zettler-Mann, 2010). A benefit of the reduction of wave energy may directly benefit coastal settlement by offering protection from storm event by lowering the wave energy before it reaches the shoreline (Abanades et al, 2014). The reduction of energy also critically alters erosion and deposition rates by and estimated 30% (Retief, 2012). This changes the slope of the beach and may fundamentally alter the shoreline habitat. The SWEC array being located in a sandy bottom environment would an artificial reef and potentially attracting no- endemic species. The combination of these factors have the potential to alter the ecosystem dynamics of a critically endangered and sensitive marine environment, resulting in the rating of a SWEC array impact as 'high'. Detailed Site specific results require further indepth specialist study.

8 CONCLUSSIONS

1. The levelised cost of electricity produced by the SWEC is not economical and currently not competitive with comparative wave energy converters at the current power price.

2. A single SWEC unit will have a number of significant, negative environmental impacts, the majority of which can be mitigated. However the development of an entire 154 unit SWEC array comes with considerable uncertainty regarding the long term ecosystem functioning as a consequence of a multitude of direct and cumulative impacts. The balance of the environmental impact without mitigation results in a negative environmental effect.

3. Of the many permits required for the implementation of the SWEC, the majority of the processes are well defined, however the use of outdated or wave energy exclusive policy complicates permitting and acts as a barrier to implementation of wave energy devices. Fisheries, marine protected areas and mineral rights are the three most important permissions to overcome for a WEC development on the west coast.

In combination the economic cost, environmental threat and political challenges represent major barriers to the development of a local economically feasible and environmentally acceptable wave energy industry in South Africa. South African energy policy is tailored to enable only certain established, low cost types of renewable energy to enter the market. Entry of new technologies has been left to the means of the private sector while government focuses on rapid uptake of relatively cheaper technologies to avoid driving up the cost of electricity. This ultimately discourages uptake of the relatively capital intensive and risky technologies such as the SWEC. The SWEC has the ability to become cost competitive in the long run with other renewable technologies due to the relatively high capacity factors experienced in the South African wave climate. Even if cost and policy is addressed, trade-offs between environmental preservation and large scale wave energy output remains a stumbling block. Given the distinct lack of site specific data detailed investigations into site specific and regional scale environmental impacts of the SWEC on coastal processes, marine flora and fauna, are required. It is suggested that long term modelling of the park effect, monitoring on a demonstration unit and assessment of potential cumulative impacts are necessary before a considered decision on full array implementation can be authorised. An amicable solution, such as using the SWEC development to form a large marine reserve, will be required to gain the support and buy-in required to see the deployment of a full SWEC array. A high-level chronological implementation plan for the SWEC detailing the different development areas has been produced to guide the implementation process.

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