Individual project

Developing of technical, economic and environmental impact analysis of a marine renewable energy system

MODULE: Analysis of Marine Renewable Energy Systems

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1. Introduction

The goal of this project is to develop a technical, economic and environmental impact analysis of a marine renewable energy system. For a given technology, it is asked to evaluate the system, the site characteristics, the annual energy production, performs an economic analysis and a simple environmental impact study.

In a past I was working on offshore vessels as mechanical engineer. Among different projects, I was working on Seismic Acquisition in South African offshore waters, next to Durban. There is a rather developed offshore infrastructure, and ocean energy resource has a great potential where two oceans meat. Taking it into account I got an idea to choose this location for the project. I contacted forecasting agencies, port authorities, meteorological stations, Coastal and Port Engineering, but after some conversation I finally got the required data for the project form Transnet National Ports Authority (TNPA) in South Africa.

I chose wave energy resource for this project, because it corresponds to my professional interest. After graduation I want to work in this challenging but very interesting field. The received data are needed to be filtered, analysed together with another factor such as bathymetry, navigation routes, MPAs, fishing and other stakeholders in order to eliminate any potential conflicts, to assess properly the resource and to find the corresponding technological concept, to choose the right anchor, etc. In the next step will be performed a resource assessment, which will allow to choose a specific device. With this device, a farm layout will be designed and a simple economic analysis will be performed. The goal is to show if this project can be economically feasible or not.

2. Stakeholders

2.1. Energy Atlas of South Africa

At present, electricity generation capacity is dominated by the state-owned utility Eskom, which holds 91% of the country's effective/nominal generation capacity. Remaining generation capacity is held by municipalities (1.77%) as well as Independent Power Producers (IPPs) that sell power to Eskom (7.21%). South Africa recently successfully commissioned renewable energy power plants that have contributed to a decrease in load shedding. Renewable energy generation has gained traction with 2,145 MW of available capacity. Solar and wind are responsible for 34.34% and 28.60%, respectively. Coal (13.56%), gas (17.33%), and others inclusive of cogeneration, landfill gas (5.87%), and hydro (0.29%) are relatively less relevant. South Africa's Integrated Resource Plan 2010, targeted an increase in capacity to 89 GW from current 47 GW by 2030. The scenario that requires investment in 56,539 MW of new capacity envisions a shift away from coal-based power (see in table 1):

Table 1 - South Africa Integrated Resource Plan increase power generation

Technology	Total MW 2030	Generation mix %	Capacity additions (MW)
Coal	41,071	45.90%	16,383
Gas (OCGT and CCGT)	9,700	10.80%	7,300
Hydro (incl. pumped storage	7,671	8.6	3,991
Nuclear	11,400	12.7	9,600
Wind	9,200	10.3	9,200
Solar (PV and CSP)	9,600	10.7	9,600
Other	890	1	465
Total	**89,532**		**56,539**

2.2. Harbour Durban – Infrastructure and facilities

The Port of Durban is the busiest container terminal in Africa and the second busiest in the southern hemisphere following Melbourne, Australia. The Ports Authority alone employs 6,200 people at the Durban Port. This figure is expected to rise to over 9,000 by 2018/19 as the R300 billion Capex plans for expansion begin to yield benefit. The Ports Authority estimates that over 30,000 are also employed indirectly. In addition to the container terminal, the port has a ship building and ship-repair facility, a yacht facility, a rail marshalling service, a sport facility, a Navy outpost on Salisbury Island, a protected mangrove, and a Port Academy that trains future employees. To the north of Durban in KwaZulu-Natal, Richard's Bay is the busiest port in South Africa by tonnage and is one of the top two coal handling ports in the world. Richard's Bay focuses on bulk cargo handling while the Durban Port focuses on general cargo. It has also been earmarked for expansion projects with R3.7-billion had been set aside for mobile and quayside equipment, as well as weighbridges. Safety-critical, environmental and legal compliance projects would also be carried out. From a commercial point of view, this port is also looking at developing opportunities in oil and gas, ship/rig repair and maritime vessel building [1]. The developed infrastructure can be also used for offshore renewable energy farms: construction, operation and decommissioning.

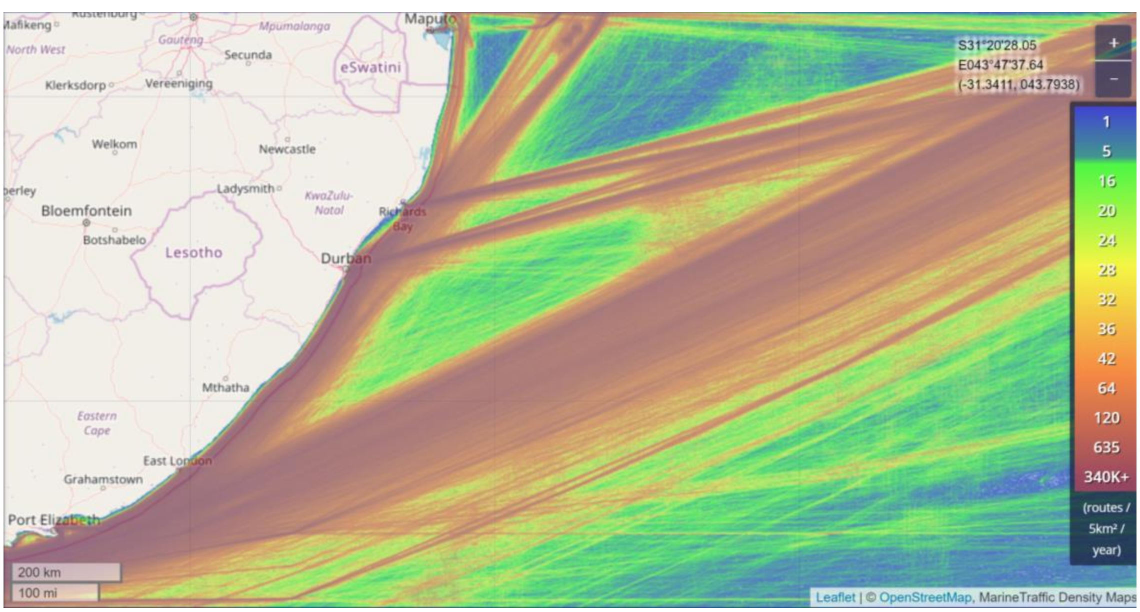


Figure 1 – Marine Navigational routes

Tables 2-4 represent the Durban port facilities, that are important for renewable energy offshore industry. The development of this port is mainly due to commercialization of the port of Durban, buster point for merchant ships and oil&gas industry.

Table 2 - Durban's port business activity

Business activity	
Ships agencies	Agency services
Ship Chandlers	Equipment supply
Underwater diving services	Pumping solutions
Crew change	Thordon bearings
Ship agency port agent	Logistics and transportation
Port agency and port operation	Vessel operations
Laser alignment	Under water inspection

Table 3 - Industry

Industry	
Diving and Underwater services	Ship Services/Suppliers
Ship Chandlers and Port Agents	Ship Repairs
Ship Owners/Managers/Operators	Ship Builders/ Engineering
Marine equipment suppliers	Brokerage
Logistics/Transport/Freight	Surveyors
Crewing Services	Education/Research/Consultancy

Table 4 - Biggest companies at Durban, South Africa

Main companies at port of Durban	
Tidal Shipping Ltd - Port agent	Nautilus Shipbroking - Brokerage
VIP Marine Services&Tours - Logistics/Transport/Freight	Oceanic Seagull Maritime - Ship owners/Manaers/Operators
Hydro Marine Surveying Ltd - Surveyors	SAIAB - Education/Research/Consultancy
Chandling International Ltd - Ship Chandler/Supplier	National Ship Chandlers Natal - Ship Service/Suppliers/Ship building
Durban Seafarer Recruitment - Crewing Service	Axxess Shipping Crew Changes - Crewing Service

3. Environmental Impact Assessment

Most South African MPA's are attached to a National Park or Nature Reserve and that Management Authority then also manages the attached MPA with funding from the SA Government channelled through its Department of Environmental Affairs (DEA) giving the Management Authorities the mandate to manage the day to day running of the MPA and its staff [2].

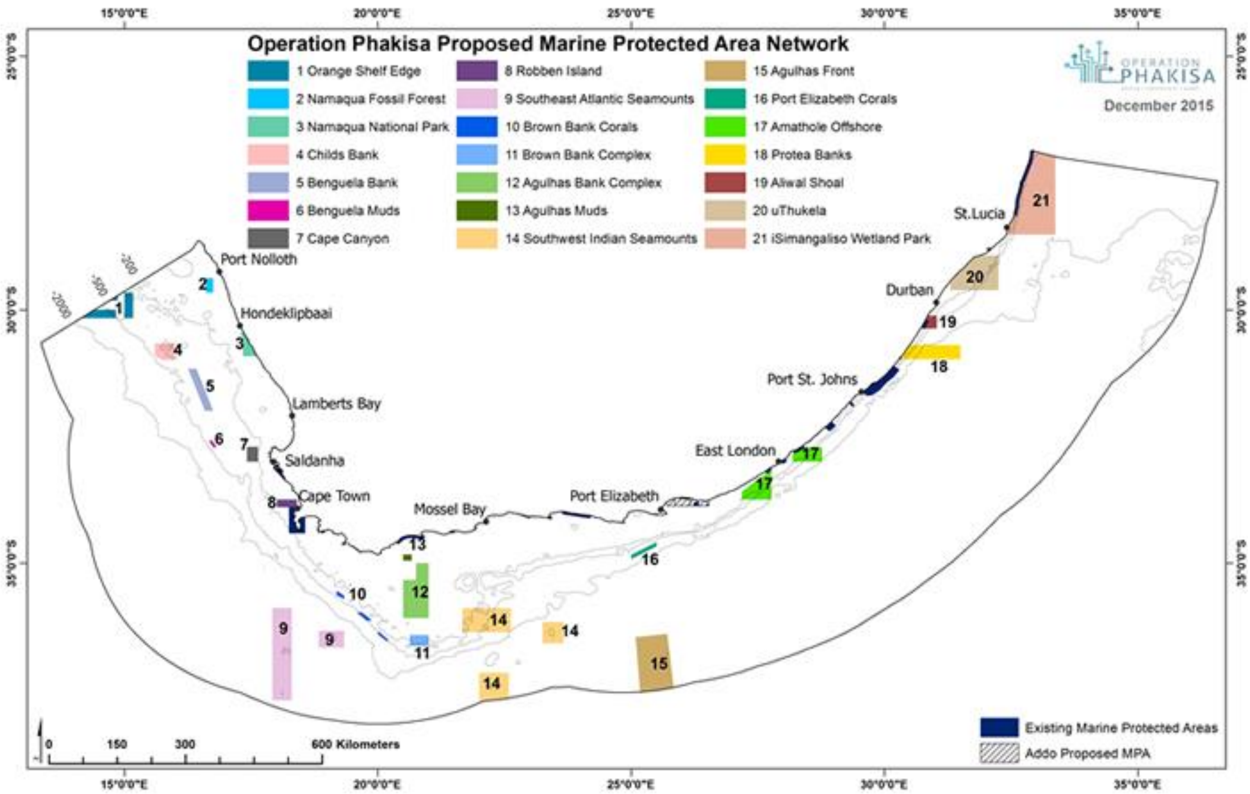


Figure 2 - Network of 22 new proposed Marine Protected Areas in 2016

Figure 3 - Different MPAs in South Africa

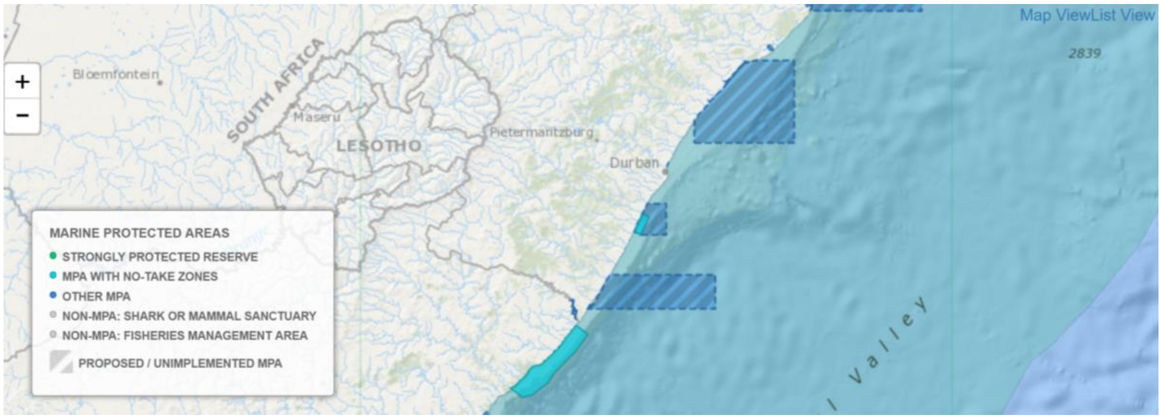


Figure 4 - MPAs around Durban

On figure 4 are shown MPA with no-take zones (blue colour) and proposed (but not implemented) MPAs (blue-grey dashes). Even if there are no Marine Protected Areas (MPAs) within the proposed Exploration Area, promotion of environmental justice and equitable access to environmental resources; avoidance, minimisation and remediation of ecosystem disturbance and biodiversity loss; waste must be avoided or reduced, reused and recycled; participation of Interested and Affected Parties must be promoted and their views taken into account as far as possible; specific attention must be given to sensitive, vulnerable and highly dynamic ecosystems; lifecycle responsibility must be ensured.

This chapter provides more information on MPAs in the vicinity as well as proposed protected areas. Major settlements closest to the Exploration Area include Port St Johns, Port Edward, Ramsgate, Durban and Richards Bay as well as other human activities in these offshore waters.

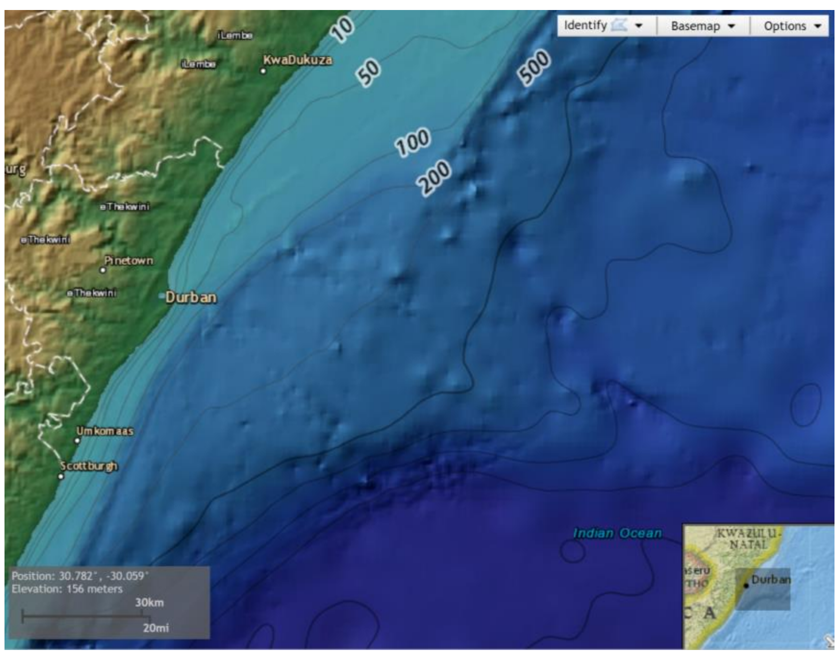


Table 5 -Seabed geology and water depth

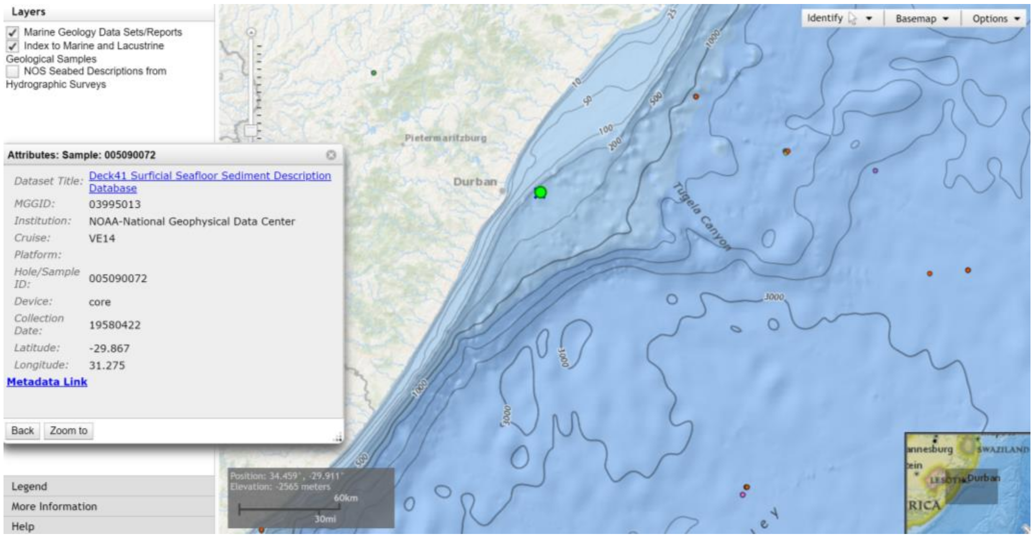


Figure 5 - Seafloor sediment description near port of Durban

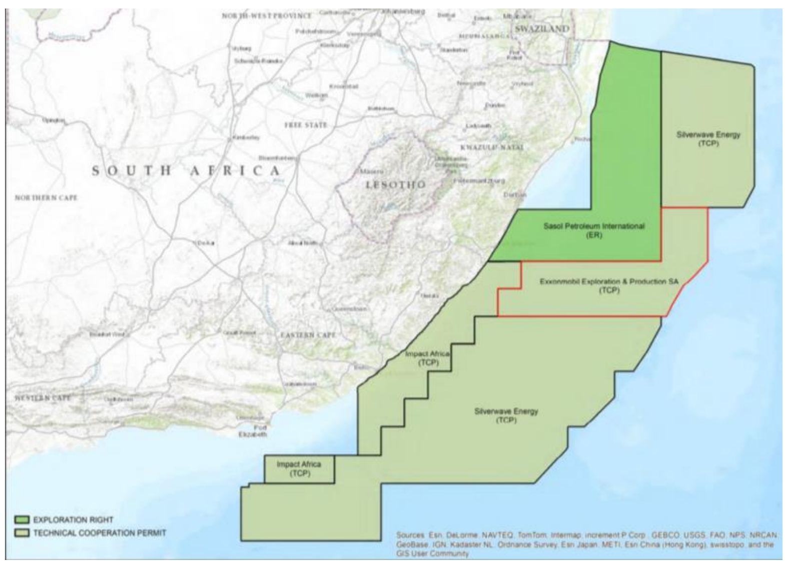


Figure 6 - Locality Map Showing the Delineation of Neighbouring Projects

On figure 6 is shown activities from oil and gas industry. It is clear, that they use a wide surface of the offshore waters. They form an essential basis of hydrocarbon exploration campaigns and allow the petroleum industry to gain an understanding of potential sources of oil and gas. All navigational activities have to take into account presence of oil rigs, supply vessels, seismic vessels, drill ships etc.

Interactions between proposed project activities and environmental or social receptors were initially identified and areas where interactions are not expected to occur were not assessed further. Areas where potential interactions exist were further evaluated and those where potential for impact does not exist or the impact is insignificant are briefly discussed and scoped out of the detailed assessment.

Potential Impacts on Bird Breeding Colonies

Although 46 species of seabird occur commonly on the East Coast, only three species breed regularly along the coast (grey-headed gull, Caspian tern and swift tern).

Potential Impacts on Benthic Fauna

Acoustic emmissions and the resulting pressure changes could potentially interact with benthic fauna in the Exploration Area. The benthic fauna of the outer shelf, continental slope and beyond into the abyss are very poorly known, largely due to limited opportunities for sampling. To date very few areas of the continental slope off the East Coast have been biologically surveyed. Due to the lack of information on benthic macrofaunal communities beyond the shelf break, no description can be provided for the Exploration Area. However, with little sea floor topography and hard substrate, such areas are likely to offer minimal habitat diversity or niches for animals to occupy. Detritus-feeding crustaceans, holothurians and echinoderms tend to be the dominant epi-benthic organisms of such habitats.

Potential Impact on Cetaceans

In 2003, the German Federal Environmental Agency (UBA) placed restrictions on the use of multi-beam systems in Antarctic waters, with the argument that marine mammals could theoretically be ensonified by the fan-shaped sonar beam, potentially resulting in a temporary threshold shift (TTS) or permanent threshold shift (PTS), and leading to disorientation.

Potential Impact on Marine Fauna

Minor interactions between marine fauna and the support vessels are possible.

3.1. General Topography

The seabed is mostly represented by a fossilised sand dune lying roughly parallel to the coast, about 5 km from the shore. It comprises a narrow northern part. The mean depth of the crown area is 12.5 m. The southern wider area includes several protrusions that reach from a depth of some 30 m to around 15 m (e.g. Howard's Castle, Landers Reef). In the crown area, many dive sites, e.g. Raggie Cave and Chunnel have a large amount of uneven topography with small caves, ledges and swim throughs rich in sea life, both fish-wise as well as in invertebrates, e.g. octopus [4].

3.2. Climate

Durban region has subtropical climate which mean monthly air temperatures ranging from 17.0°C (Jul) to 23.9°C (Feb). The sea temperatures tend to be somewhat warmer, due to the warm, tropical, southward-flowing Mozambique sea current, resulting in a balmy 21-26°C throughout the year. Mean monthly weather statistics:

Table 6 - Yearly air and water temperature near Durban

Yearly air and water temperature, °C													
Param.	Month	January	February	March	April	May	June	July	August	September	October	November	December
Air temperature	Min	21.1	21.1	20.3	17.4	13.8	10.6	10.5	12.5	15.3	16.8	18.3	20
	Max	27.8	28	27.7	26.1	24.5	23	22.6	22.8	23.3	24	25.2	26.9
	Mean	24.45	24.55	24	21.75	19.15	16.8	16.55	17.65	19.3	20.4	21.75	23.45
Sea water temperature	Min	24.6	25.2	25.4	23.6	22	21.4	20.2	19.6	20.6	21.1	21.7	22.4
	Max	27.7	27.6	27.3	27.7	24.9	23.7	23.4	22.4	22.8	24.3	24.3	26.1
	Mean	26.15	26.4	26.35	25.65	23.45	22.55	21.8	21	21.7	22.7	23	24.25

4. Wave Resource Assessment

The real data for my project I kindly received from Transnet National Ports Authority (TNPA) and The Council for Scientific and Industrial Research, commonly known as the CSIR, is a world-class African research and development organisation established through an Act of Parliament in 1945 [5]. They kindly send me the data measured in coastal waters near Durban, South Africa for the period from 23/08/2007 to 30/04/2018, so I was able to analyse more than 10 years wave data. After studying the row data, I observed some faulty measurements, so careful filtering was performed. The most interesting parameters are: significant wave height (average height of highest 1/3 of all waves), peak period, extreme wave height, wave direction. Figure 7 shows global map of wave resource (average wave power density). It can be seen that next to the South African coast the power density is in the range of 25-45 kW/m. It can be considered economically feasible for some technologies. Detailed resource assessment is required.

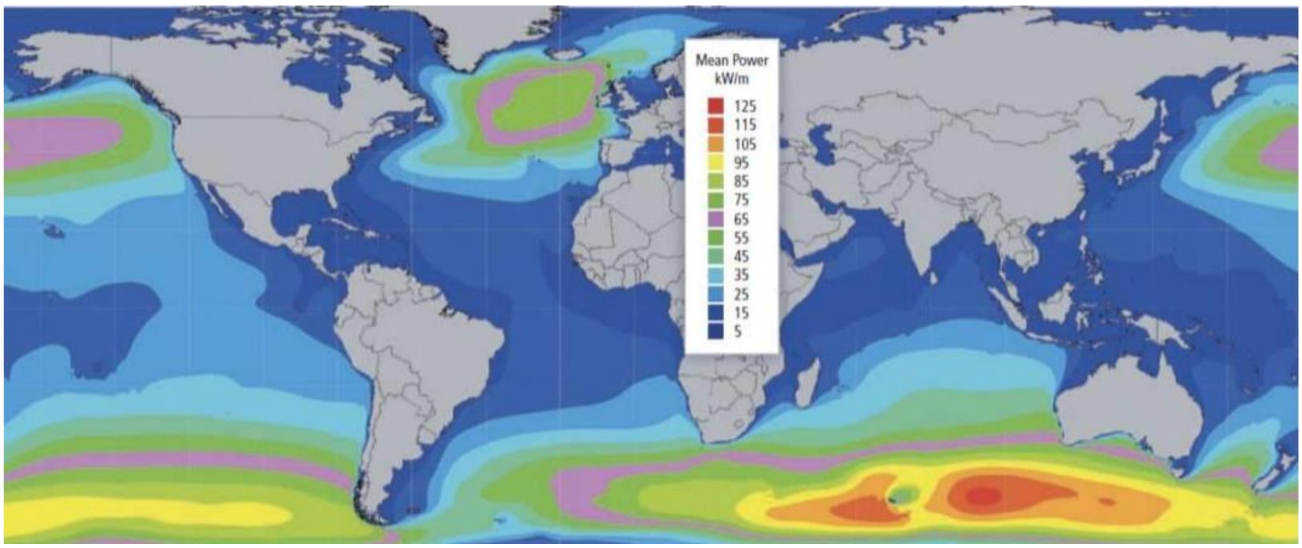


Figure 7 - Global map of mean wave resource, power per meter wave front [kW/m]

4.1. Pierson-Moskowitz Spectrum

Based on the data, the wave quality was assessed using Pierson-Moskowitz Spectrum. The excel sheet called "PM frequency spectrum" can be found in the attached excel file and in Appendix. In order to implement this simple method, some assumptions are taken into consideration. It is assumed that if the wind blew steadily for a long time over a large area, the waves would come into equilibrium with the wind. This is the concept of a fully developed sea (a sea produced by winds blowing steadily over hundreds of miles for several days). Here, a long time is roughly ten-thousand wave periods, and a "large area" is roughly five-thousand wave-lengths on a side. The spectra for the particular location is shown on the figure 8.

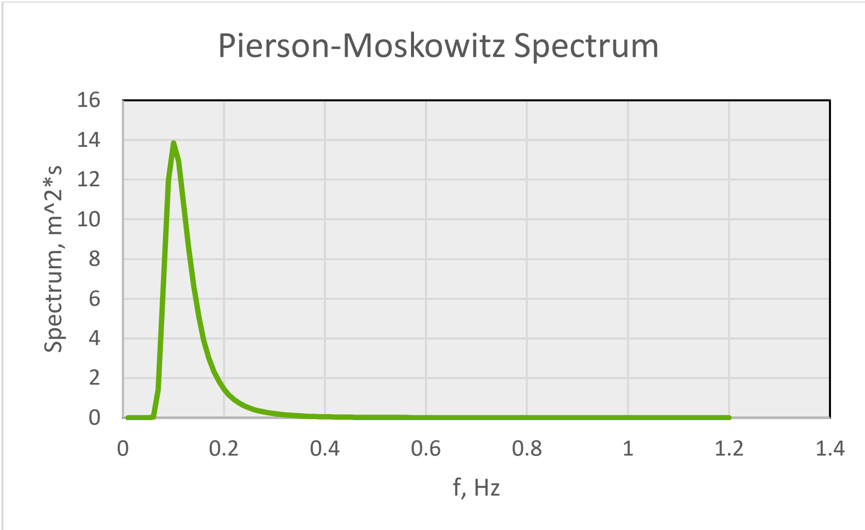


Figure 8 - Pierson-Moskowitz Spectrum

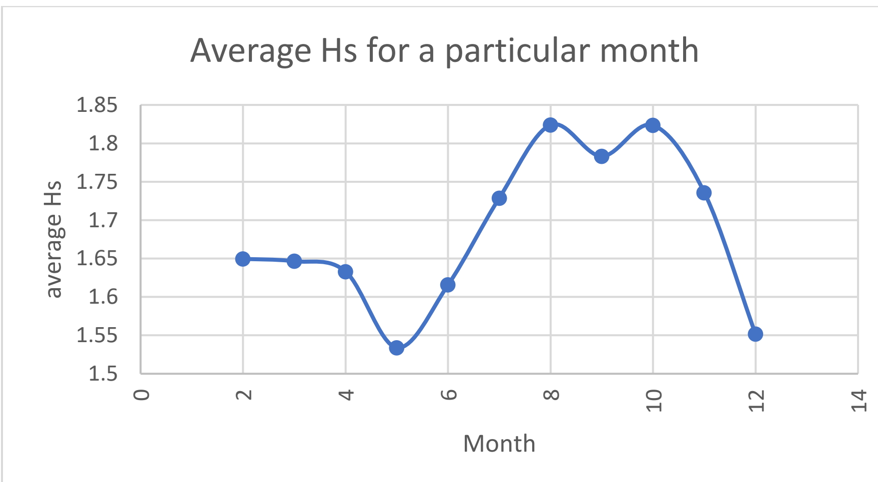


Figure 9 - Average yearly variation of Hs

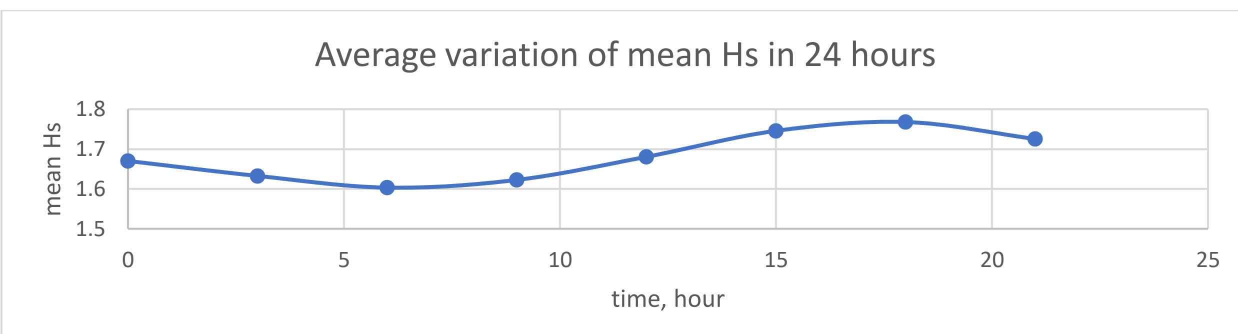


Figure 10 - Average daily variation of Hs

On figures 9 and 10 the average yearly and daily variation of significant wave height are shown respectively. As South Africa is located in the Southern Hemisphere, the maximum wave weight is observed in Autumn and the lowest is Spring. The highest daily wave height is in the afternoon. This can be explained by the temperature effect. During the day time, air becomes hot, and thus the wind speed increases. Wave height is a direct effect of the wind speed.

4.2. Wave direction

Based on available data, the wave direction rose is shown below:

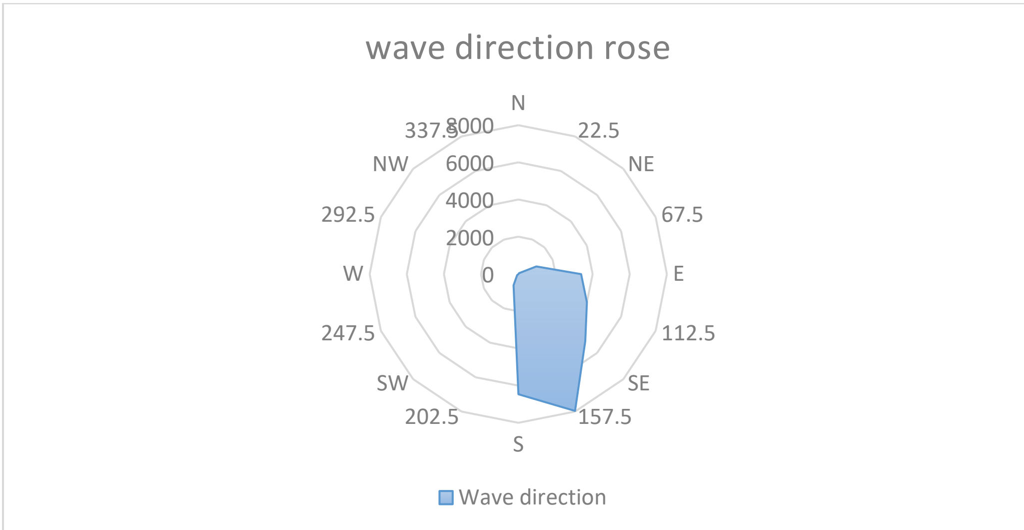


Figure 11 - Wave rose

It can be concluded that the main direction if the incoming waves throughout the year are from the southern direction, which is quite predictable based on geographic location.

Despite very attractive features of the energy resource, there are significant challenges that have so far prevented wave energy from becoming a mainstream energy source. As of today, there is still no solution to harvest energy from ocean waves that has been proven commercial viable. Technical challenges inherently associated with ocean waves may be the root cause explaining the relatively slow progress of wave power compared to wind power over the last 30 years:

1. Slow wave motion requiring high machinery force to absorb substantial amounts of power

2. Reciprocating motion requiring a mechanism able to absorb energy in multiple directions

3. Harsh ocean environment requiring structures to withstand extreme loads in storms

4. Highly fluctuating instantaneous power levels, 20:1 typical in a given sea state.

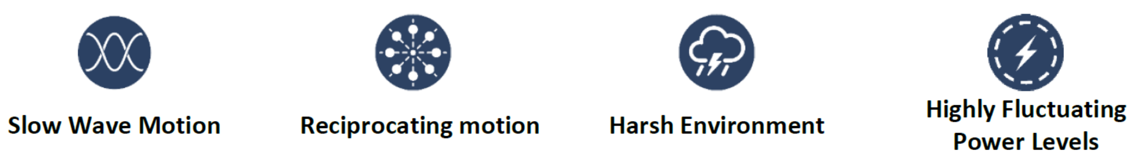


Figure 12 - Key technical challenges in wave energy

4.3. Power Matrix, Annual Energy Yield Calculation

The performance of a project is evaluated using WEC average Annual Energy Production (AEP). The AEP is the yearly theoretical average electrical energy yielded of a single WEC over its lifetime. The AEP is derived from the average available wave resource at a target deployment location and the WEC performance.

The average available wave resource of a deployment location is usually presented in, and referred to as, a scatter diagram. The scatter diagram provides a joint probability table of significant wave heights and characteristic periods. It is based on real wave measurements on site or on hind cast, a statistical calculation determining probable past conditions. The WEC performance is usually presented in, and referred to as, a power matrix. A power matrix presents the power production of the device for each combination of significant wave height and characteristic period.

The following steps were performed:

1. Calculate energy period: $T_e = 0.86 \cdot T_p$
2. Chose wave height and energy period classes: classes were chosen with the width of 0.5 m and 2 s correspondingly
3. Calculate number of occurrences: use Excel built-in function COUNTIFS. Using this function, calculate the number of occurrence of each sea state. Few examples are shown below:

Ex.1: COUNTIFS($C$4:$C$28785,">=0.5",$C$4:$C$28785,"<1",$B$4:$B$28785,"<2")
Ex.2: COUNTIFS($C$4:$C$28785,">=0.5",$C$4:$C$28785,"<1",$B$4:$B$28785,">=2",$B$4:$B$28785,"<4")
Ex.3: COUNTIFS($C$4:$C$28785,">=0.5",$C$4:$C$28785,"<1",$B$4:$B$28785,">24")

The matrix of sea states is obtained and is shown on the figure 13.

number of occurance													
Hs\Te	<2	<4	<6	<8	<10	<12	<14	<16	<18	<20	<22	<24	sum
0.5	0	3	88	283	341	306	49	5	0	0	0	0	1075
1	3	78	1357	2926	2653	2434	841	127	6	3	0	0	10428
1.5	0	64	2239	2930	2529	2021	940	148	2	0	0	0	10873
2	0	5	938	1392	975	820	426	61	5	0	0	0	4622
2.5	0	0	111	395	302	309	136	30	1	0	0	0	1284
3	0	0	6	56	86	129	46	17	0	0	0	0	340
3.5	0	0	0	6	32	37	15	6	0	0	0	0	96
4	0	0	0	0	21	17	5	1	0	0	0	0	44
4.5	0	0	0	0	3	7	4	0	0	0	0	0	14
5	3	0	0	0	4	0	0	0	0	0	0	0	7
5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
sum	6	150	4739	7988	6946	6080	2462	395	14	3	0	0	**28783**

Figure 13 - Sea state matrix, number of occurrences

From that matrix, we obtain the probability matrix. Each state is divided by the total number of the occurrences = 28783 and multiplied b 100 %.

probability													
Hs\Te	<2	<4	<6	<8	<10	<12	<14	<16	<18	<20	<22	<24	sum
0.5	0	0.010423	0.305736	0.983219	1.184727	1.063128	0.170239	0.017371	0	0	0	0	3.734843
1	0.010423	0.270993	4.714588	10.16572	9.217246	8.456381	2.921864	0.441233	0.020846	0.010423	0	0	36.22972
1.5	0	0.222353	7.778897	10.17962	8.786436	7.021506	3.265817	0.514192	0.006949	0	0	0	37.77577
2	0	0.017371	3.258868	4.836188	3.387416	2.848904	1.48004	0.211931	0.017371	0	0	0	16.05809
2.5	0	0	0.385644	1.372338	1.04923	1.07355	0.472501	0.104228	0.003474	0	0	0	4.460967
3	0	0	0.020846	0.194559	0.298787	0.448181	0.159817	0.059063	0	0	0	0	1.181253
3.5	0	0	0	0.020846	0.111177	0.128548	0.052114	0.020846	0	0	0	0	0.33353
4	0	0	0	0	0.07296	0.059063	0.017371	0.003474	0	0	0	0	0.152868
4.5	0	0	0	0	0.010423	0.02432	0.013897	0	0	0	0	0	0.04864
5	0.010423	0	0	0	0.013897	0	0	0	0	0	0	0	0.02432
5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
sum	0.020846	0.521141	16.46458	27.75249	24.1323	21.12358	8.55366	1.372338	0.04864	0.010423	0	0	**100**

Figure 14 - Probability Matrix

Based on significant wave height and energy period classes, the power density matrix is calculated for each sea state using the formula:

$$P_{dens} = 0.49 \cdot {H_s}^2 \cdot T_e \quad (1)$$

The power density matrix is shown on figure 8:

power matrix, kW/m													
	1	3	5	7	9	11	13	15	17	19	21	23	25
Hs\Te	<2	<4	<6	<8	<10	<12	<14	<16	<18	<20	<22	<24	sum
0.5	0.1225	0.3675	0.6125	0.8575	1.1025	1.3475	1.5925	1.8375	2.0825	2.3275	2.5725	2.8175	17.64
1	0.49	1.47	2.45	3.43	4.41	5.39	6.37	7.35	8.33	9.31	10.29	11.27	70.56
1.5	1.1025	3.3075	5.5125	7.7175	9.9225	12.1275	14.3325	16.5375	18.7425	20.9475	23.1525	25.3575	158.76
2	1.96	5.88	9.8	13.72	17.64	21.56	25.48	29.4	33.32	37.24	41.16	45.08	282.24
2.5	3.0625	9.1875	15.3125	21.4375	27.5625	33.6875	39.8125	45.9375	52.0625	58.1875	64.3125	70.4375	441
3	4.41	13.23	22.05	30.87	39.69	48.51	57.33	66.15	74.97	83.79	92.61	101.43	635.04
3.5	6.0025	18.0075	30.0125	42.0175	54.0225	66.0275	78.0325	90.0375	102.0425	114.0475	126.0525	138.0575	864.36
4	7.84	23.52	39.2	54.88	70.56	86.24	101.92	117.6	133.28	148.96	164.64	180.32	1128.96
4.5	9.9225	29.7675	49.6125	69.4575	89.3025	109.1475	128.9925	148.8375	168.6825	188.5275	208.3725	228.2175	1428.84
5	12.25	36.75	61.25	85.75	110.25	134.75	159.25	183.75	208.25	232.75	257.25	281.75	1764
5.5	14.8225	44.4675	74.1125	103.7575	133.4025	163.0475	192.6925	222.3375	251.9825	281.6275	311.2725	340.9175	2134.44
6	17.64	52.92	88.2	123.48	158.76	194.04	229.32	264.6	299.88	335.16	370.44	405.72	2540.16
sum	79.625	238.875	398.125	557.375	716.625	875.875	1035.125	1194.375	1353.625	1512.875	1672.125	1831.375	**11466**

Figure 15 - Power density matrix

energy density, kWh/m													
Hs\Te	<2	<4	<6	<8	<10	<12	<14	<16	<18	<20	<22	<24	sum
0.5	0	0.335542	16.40427	73.85648	114.4198	125.4926	23.7489	2.796182	0	0	0	0	357.0538
1	0.447389	34.89635	1011.845	3054.474	3560.77	3992.798	1630.435	284.0921	15.21123	8.500393	0	0	13593.47
1.5	0	64.42403	3756.391	6881.963	7637.267	7459.43	4100.321	744.9028	11.40842	0	0	0	30656.11
2	0	8.947782	2797.673	5812.479	5234.452	5380.599	3303.521	545.8147	50.7041	0	0	0	23134.19
2.5	0	0	517.2936	2577.148	2533.341	3168.074	1647.883	419.4273	15.84503	0	0	0	10879.01
3	0	0	40.26502	526.1296	1038.837	1904.535	802.616	342.2526	0	0	0	0	4654.636
3.5	0	0	0	76.72723	526.1296	743.5234	356.2336	164.4155	0	0	0	0	1867.029
4	0	0	0	0	450.9682	446.196	155.0949	35.79113	0	0	0	0	1088.05
4.5	0	0	0	0	81.53666	232.5305	157.0336	0	0	0	0	0	471.1007
5	11.18473	0	0	0	134.2167	0	0	0	0	0	0	0	145.4015
5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
sum	11.63212	108.6037	8139.872	19002.78	21311.94	23453.18	12176.89	2539.492	93.16878	8.500393	0	0	**86846.05**

Figure 16 - Energy density matrix

On figure 16 the energy density matrix is shown. It was computed by multiplying power density matrix by probability matrix and by 8760 h (total number of hours per year).

$$E_{dens} = P_{dens} \cdot s(w) \cdot 8760 \qquad (2)$$

The total annual energy density yield is computed and is equal to 86846 kWh = 86,8 MWh.

5. Chose WEC and rated power of the device

Wave energy cannot be transformed directly to the electricity. Different transformation steps are in between. On figure 17 different conversion stages are shown.

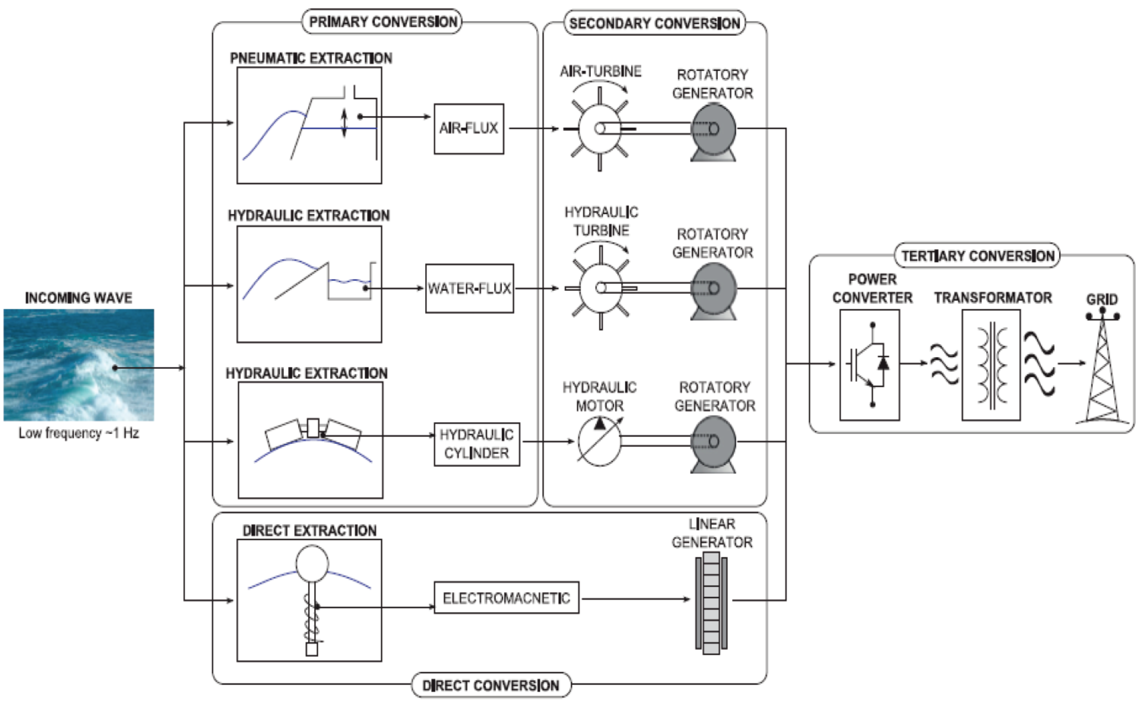


Figure 17 - Energy Conversion Stages

Incoming waves are firstly converted in primary conversion: pneumatic extraction, hydraulic extraction, direct extraction. Different couplings are used: air flux, water flux, hydraulic cylinder, electromagnetic. By means of secondary conversion (air turbine, hydro turbine, hydraulic motor, linear generator), electric energy can be generated.

In the conceptual design, we determined design specifications based on site resource characteristics borrowed from successful commercial technologies and by applying engineering judgment, economic considerations, and simple hand calculations [6]. Wave resource assessment leads to choose of wave energy converter. In combination with bathymetry, distance to shore, the pre-commercial stage of different types of devices, I chose CorPower wave energy converter. The wave energy converter (WEC) developed by CorPower Ocean is point absorber and intended to be deployed in an array. The prototype of the device is around 9 m is diameter.

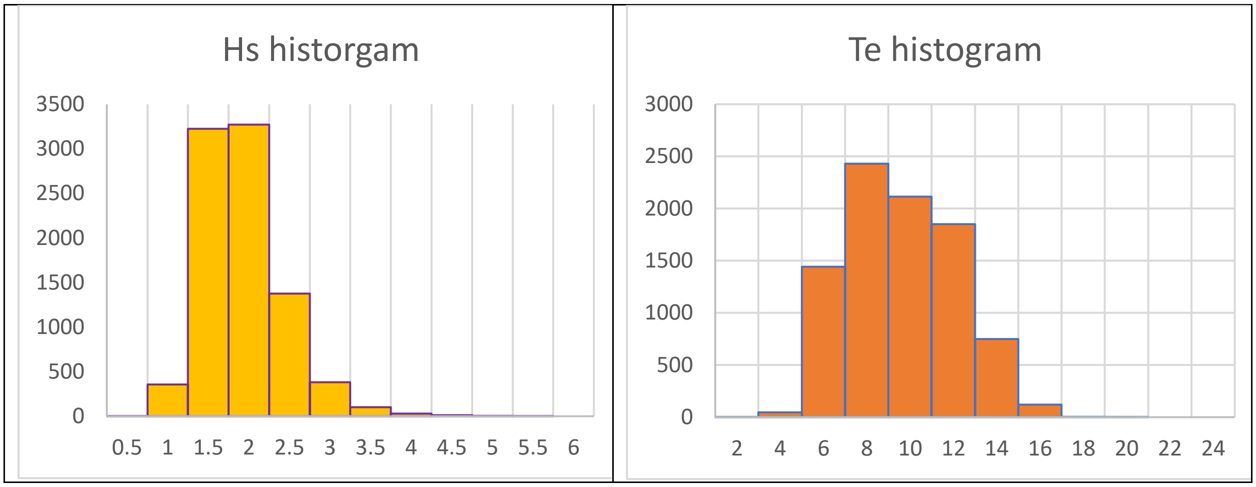


Figure 18 - Histogram: (left) significant wave height; (right) energy period

Histograms of wave height and energy period were plotted from the real data. Based on these histograms, shown on figure 18, we can see that the most probable Hs is between 1.25 and 2.75 m and energy period is between 7 and 13 seconds. Different scenarios were analysed.

Table 7 - Choice of the rated power

Power density	Rated power	AEP 1 device	Number of devices	AEP of 20 MW array	Array power	CF	length of the device
kW/m	kW	kWh	#	MWh	kW	NaN	m
5.555555556	50	42530	400	17012	20000	0.873904	9
11.11111111	100	64065	200	12813	20000	0.658202	9
16.66666667	150	73749	133.3333	9833.2	20000	0.50513	9
22.22222222	200	78891	100	7889.1	20000	0.405262	9
27.77777778	250	81540	80	6523.2	20000	0.335096	9
33.33333333	300	83189	66.66667	5545.933	20000	0.284894	9
38.88888889	350	84234	57.14286	4813.371	20000	0.247262	9

As we know, the CorPower buoy is 9 m large. The Power of the device can be computed by multiplying energy density by the capture width. We also know that the nominal rated power of the prototype can be in range of 100 – 300 (kW). For different rated power, I calculated annual energy yield and capacity factor. Placed in an array the different WECs will interact hydrodynamically and the combined power output is altered. Keeping the average power high is essential for the economic income, at the same time a low peak power is beneficial as it decreases the system cost [7]. To be reasonable, I decided to make a WEC array of total power 20 MW (20 000 kW). On figure 19 I plotted different rated power versus AEP.

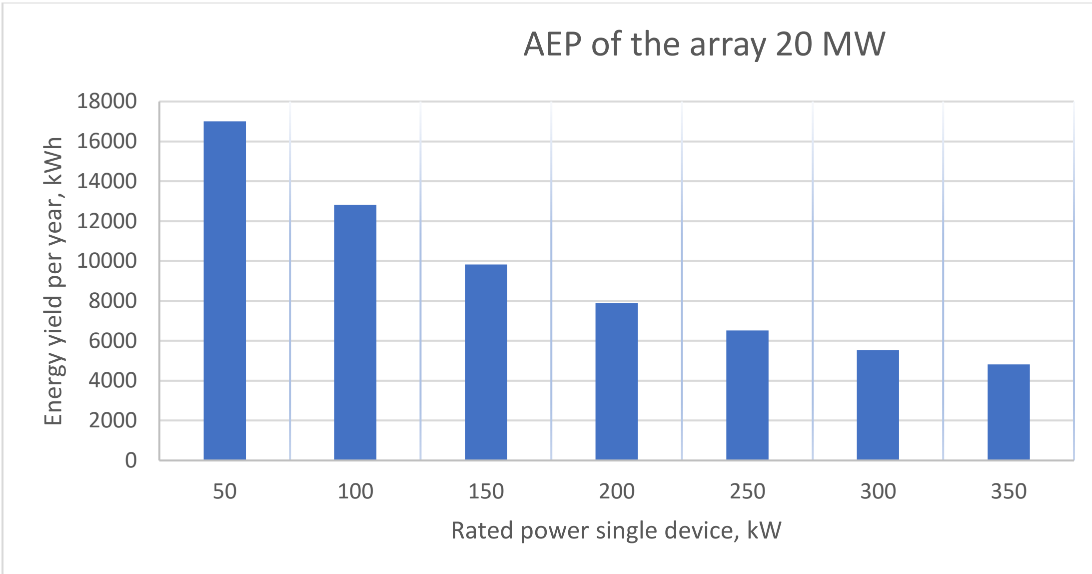


Figure 19 - Annual energy yield versus rated power

From multiple simulations, I chose rated power to be 250 kW.

power matrix, kW/m													
1	3	5	7	9	11	13	15	17	19	21	23	25	
Hs\Te	<2	<4	<6	<8	<10	<12	<14	<16	<18	<20	<22	<24	sum
0.5	0.1225	0.3675	0.6125	0.8575	1.1025	1.3475	1.5925	1.8375	2.0825	2.3275	2.5725	2.8175	17.64
1	0.49	1.47	2.45	3.43	4.41	5.39	6.37	7.35	8.33	9.31	10.29	11.27	70.56
1.5	1.1025	3.3075	5.5125	7.7175	9.9225	12.1275	14.3325	16.5375	18.7425	20.9475	23.1525	25.3575	158.76
2	1.96	5.88	9.8	13.72	17.64	21.56	25.48	27.7	27.7	27.7	27.7	27.7	234.54
2.5	3.0625	9.1875	15.3125	21.4375	27.5625	27.7	27.7	27.7	27.7	27.7	27.7	27.7	270.4625
3	4.41	13.23	22.05	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	288.99
3.5	6.0025	18.0075	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	301.01
4	7.84	23.52	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	308.36
4.5	9.9225	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	314.6225
5	12.25	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	316.95
5.5	14.8225	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	319.5225
6	17.64	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	322.34
sum	79.625	185.77	221.9375	241.0625	254.5375	262.025	269.375	275.025	278.455	281.885	285.315	288.745	**2923.758**

Prated = 250 kW													
energy density, kWh/m													
Hs\Te	<2	<4	<6	<8	<10	<12	<14	<16	<18	<20	<22	<24	sum
0.5	0	0.335542	16.40427	73.85648	114.4198	125.4926	23.7489	2.796182	0	0	0	0	357.0538
1	0.447389	34.89635	1011.845	3054.474	3560.77	3992.798	1630.435	284.0921	15.21123	8.500393	0	0	13593.47
1.5	0	64.42403	3756.391	6881.963	7637.267	7459.43	4100.321	744.9028	11.40842	0	0	0	30656.11
2	0	8.947782	2797.673	5812.479	5234.452	5380.599	3303.521	514.254	42.15196	0	0	0	23094.08
2.5	0	0	517.2936	2577.148	2533.341	2604.991	1146.533	252.9118	8.430393	0	0	0	9640.649
3	0	0	40.26502	472.102	725.0138	1087.521	387.7981	143.3167	0	0	0	0	2856.016
3.5	0	0	0	50.58236	269.7726	311.9245	126.4559	50.58236	0	0	0	0	809.3177
4	0	0	0	0	177.0383	143.3167	42.15196	8.430393	0	0	0	0	370.9373
4.5	0	0	0	0	25.29118	59.01275	33.72157	0	0	0	0	0	118.0255
5	11.18473	0	0	0	33.72157	0	0	0	0	0	0	0	44.9063
5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
sum	11.63212	108.6037	8139.872	18922.6	20311.09	21165.09	10794.69	2001.286	77.20201	8.500393	0	0	**81540.56**

Figure 20 - Energy yield when chosen power density is 27.7 kW/m

In table 8 the main characteristics of the ocean renewable farm in the South African offshore waters are shown. Based on the wave energy resource assessment the rated power of the point absorber was chosen 250 kW. It corresponds to the precommercial prototype of the Swedish Company CorPower Ocean [8].

Table 8 –Ocean Renewable Energy Farm characteristics

Single WEC	
WEC width	9 m
Power density	27.7 kW/m
Prated	250 kW
AEP	81540 kWh
CF	0.34
ORE FARM	
Power of the array	20 MW
Number of WECs	80

In table 8 the most important characteristics of the 20 MW array are shown. As the rated power of a single device is 250 kW, the total number of the devices is 80 (yet without considering losses). Capacity factor is equal to 34 % that can be considerable in wave energy technology.

5.1. CorPower WEC technology

The aim is to have a light buoy that is held at its equilibrium position by a pre-tensioned gas spring. This gives the opportunity for the buoy to move fast, upwards due to the hydrostatic forces and back down into the water due to the gas-spring, with low inertia. Using the phase control by latching the aim is to make the buoy able to use a wide range of waves for power absorption. The phase control enables management of the buoy in a way that in every cycle it moves up and down at the time the wave gives the most force and keeps it steady in a locked position between. This gives the possibility for the buoy to move closer to a higher response frequency (closer to the natural period) resulting in larger heave amplification [9].

5.1.1. Power Take Off Unit (PTO)

The CPO buoy obtains the forces from the waves. In addition, it also obtains force from the PTO itself, through a wire. The wire force can be written as a sum of forces acting on the buoy from the PTO unit.

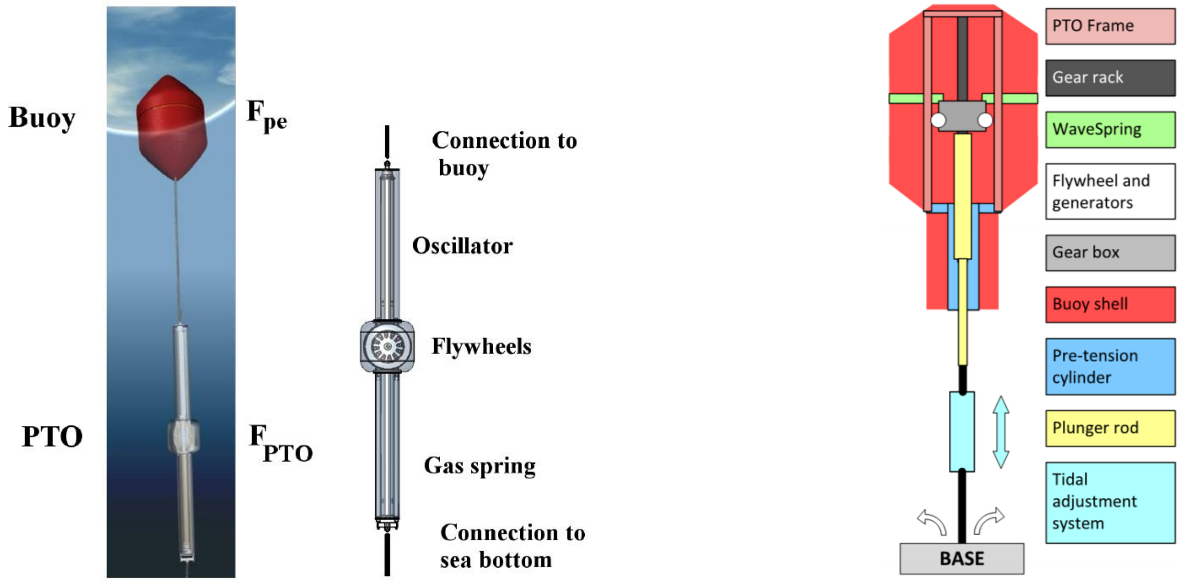


Figure 21 - General schema of the CorPower device

5.1.2. Transmission forces

As the buoy moves in a heaving motion, the oscillator follows the buoy's motions. Transmission forces are forces that are acting when the oscillator is in motion, moving up or down. The oscillators linear motion is transmitted to the flywheels, through a rack pinion system. The energy in the rotational speed of the flywheels is gradually transmitted to generators and subsequently converted to electricity.

5.1.3. Gas Force

A gas force due to a certain pretension, caused by a pressure difference between the upper and the lower reservoir, positioned above and below the oscillator, pulls the buoy down. At equilibrium position this force is equal to the hydrostatic force from the buoy at equilibrium position.

5.1.4. Friction forces

The system is affected by friction forces. In the PTO unit it these forces are around the oscillator and flywheels. These frictions can both be static and dynamic.

5.1.5. Operational principle

Placed in an array the different WECs will interact hydrodynamically and the combined power output is altered. Keeping the average power high is essential for the economic income, at the same time a low peak power is beneficial as it decreases the system cost [7]. Essentially it absorbs energy from the wave by heaving a buoy up and down at a specific point. The heave defines the vertical movement of the buoy. Using phase control makes the buoy be in resonance with the wave and this can be seen in figure 6. The main concept is that a rack is attached to the sea bed with a cable so the rack can be seen as "stationary". A gas spring pre-tensions the buoy to keep it at the surface of the ocean. A novel phase control technology called WaveSpring widens the buoy's response bandwidth, and thereby also increases the power capture. When the buoy heaves up with the wave, a gearbox then (seen to the right in figure 21) moves through the rack. The gearbox has two outputs, one on each side, that are attached to two flywheels. Flywheels have the ability to be accelerated fast and store energy that can be withdrawn slowly. Each flywheel is attached to a generator (coloured red) that converts the rotation to electricity. Only one flywheel is engaged to the gearbox at a time, that is, one is engaged when the buoy moves up and the other when the buoy moves down. Thus, by using flywheels the energy from the WEC can slowly be converted to electricity giving a steady energy output.

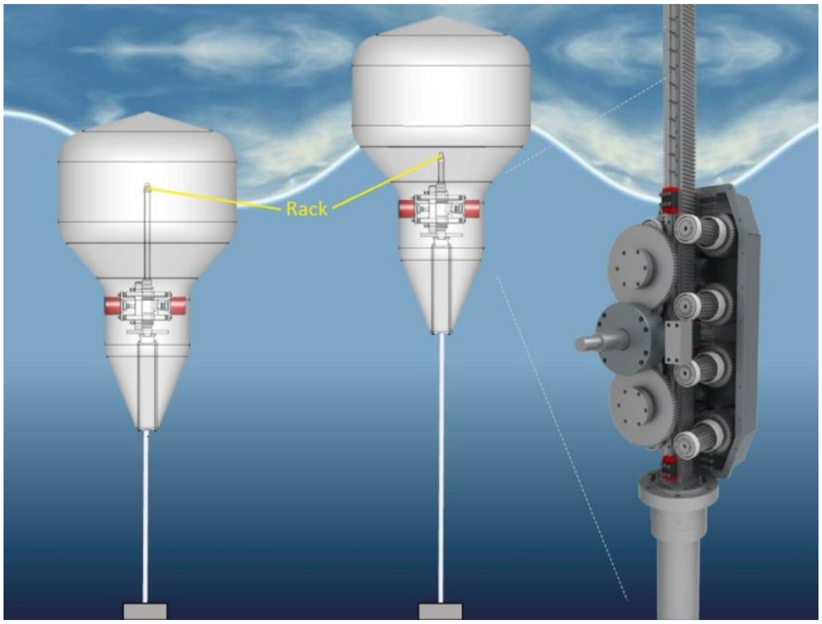


Figure 22 - The movement of the wave energy converter with the incoming wave

When the buoy heaves up and down the motion is translated trough the gearbox that accelerates the flywheels that transfer energy to the generators. The mechanical part of the WEC is called the Power Take Off or PTO [10].

The depth of the chosen location varies from 25 to 50 meters. On the figure 4 it is seen that this area was proposed to be Marine Protected Area called uThukela in 2016, however it is not approved. It should be noted, that renewable energy farm will be much smaller than uThukela. In case if that region will be approved to be MPA, it can be mitigated or shifted a little to the south.

The proposed array can be placed in offshore waters between Durban and Richards Bay. Distance to shore is 10 km. Distance to the closest port which can be used for maintenance and operation as well as for commissioning the project is around 30 km.

5.2. CorPower WEC Array 20 MW

Initially estimated the offshore zone marked with a yellow rectangular on figure 23 is chosen for a wave energy array of the total power 20 MW.

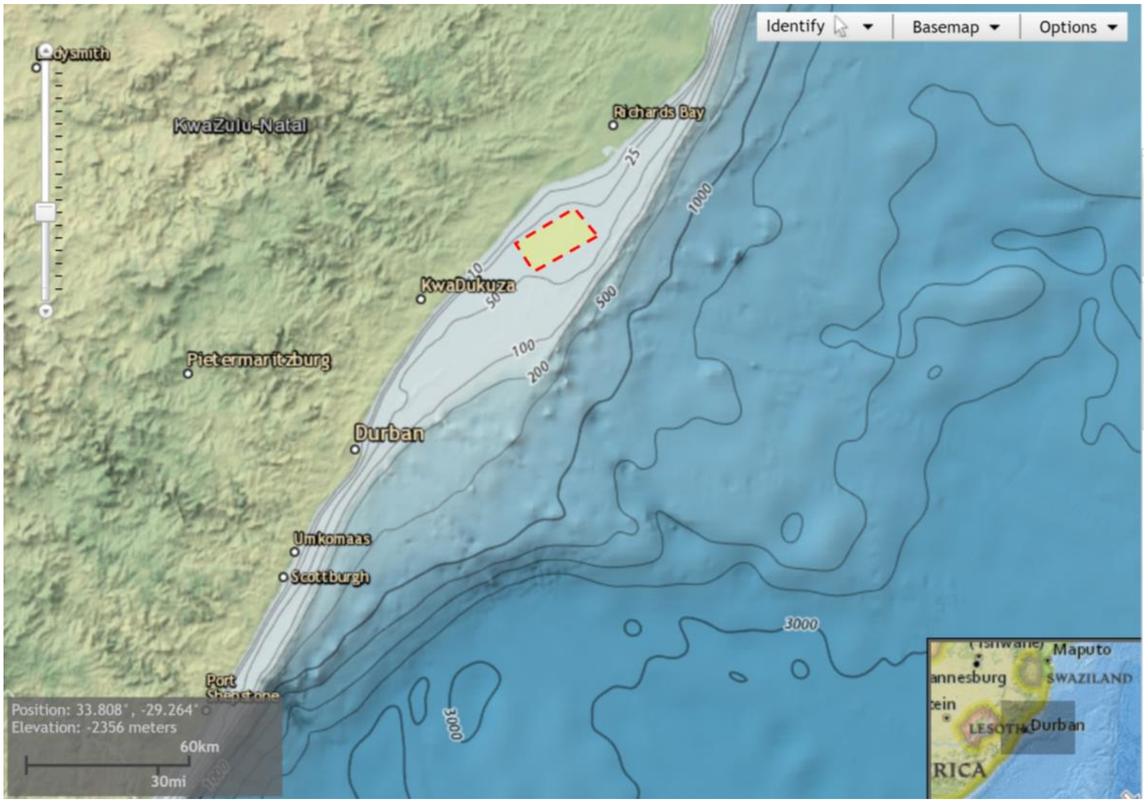


Figure 23 – Location of the CorPower WEC Array 20 MW

5.3. Design of WEC array layout

When designing WEC array, an analysing of the average value and the peak-to-average value of the electric power output should be done. The purpose of the design is to reduce power losses due to interaction of the WECs, power smoothening. Some WECs could experience greater forces than they would in isolation and therefore be at a greater risk of fatigue [7].

Semi-analytical techniques [11]:

- Point absorber method
  - Device dimensions much smaller than wavelength
  - Wave scattering is neglected
  - Only heaving converters
- Plane wave approximation
  - Scattering and radiation are approximated by plane waves
  - Low accuracy for low-frequency waves
  - Only heaving devices
- Multiple scattering methods
  - Few assumptions
  - Total wave field represented by the superposition of the incident wave potential and various orders of propagating and evanescent modes
- Direct matrix method
  - Similar to multiple scattering method

There are several more developed methods to design array layout: boundary-element method, non-linear potential flow methods, spectral wave methods.

When designing the array, the quantification of the park effect is introduced. This is called q-factor.

$$q(w) = \frac{\bar{P}_{array}(w)}{N\bar{P}_{individual}(w)} \tag{3}$$

, where w is $\overline{P}_{array}(w)$ is a total (average) power extracted from the array, $\overline{P}_{individual}(w)$ is Power (average) extracted from an isolated device, N is number of devices in the array. If q(w) < 1, the park effect is disadvantageous, if q(w) > 1, this effect is advantageous. This effect mainly depends on farm layout. Initially the effect of regular waves must be studied for a small number of WEC devices. One of very simple and effective method is known as Parabolic Intersection: Child and Venugopal (2010). With this method the arrays are constructed intuitively, using the results from isolated devices, capable of controlling the minimum distance to avoid collision in practical applications [11]. Another applicable method is Genetic Algorithm. This is an optimization method inspired on the theory of evolution. It uses a set of solutions that develops towards an optimum, it is adequate for large search spaces and multiple local maxima, it is adequate when the function behaviour is unknown, and it is based in random operations.

In frame of this project, I consider a Genetic Algorithm, developed by Elisabet Jansson in her thesis [7]. The GA is used for both a rectangular pattern and a semi-circular pattern, shown in figure II below, in regular waves. The results show that it is possible to achieve significant power smoothening in an array without decreasing the average power too much. The best array configurations found using the GA are shown in figure 24, together with the wave field around the arrays in a regular wave of 9s period and 3m wave height. The wave field shows how the GA makes use of the separation distances between the rows of the array for power smoothening. The rows clearly sample the incident wave at positions with different phases, with close to ¾ of the wave length between the front row and the back row.

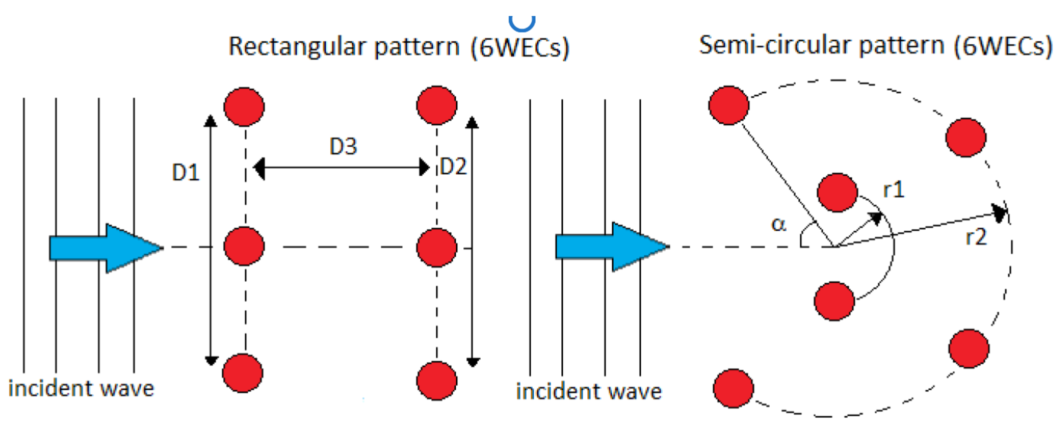


Figure 24 - The rectangular and semi-circular patterns used for the genetic algorithm WEC array optimization

The algorithm is allowed to vary the distanced D1, D2 and D3 of the rectangular pattern and the distances r1, r2 and angle α of the semi-circular pattern [7].

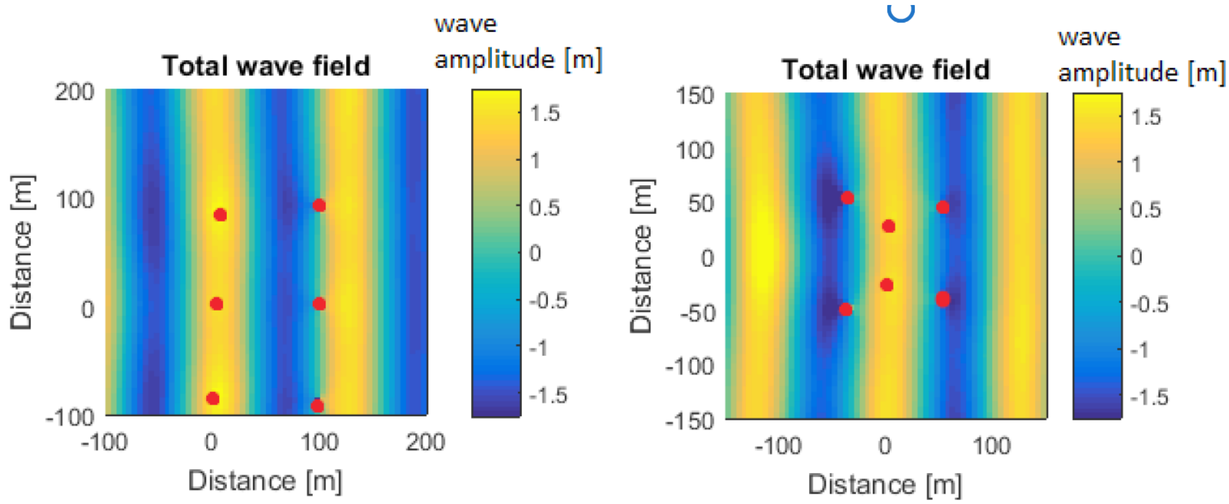


Figure 25 - The wave field around the array configurations found with the genetic algorithm, shown as a snapshot of the surface.

The incident wave is a regular wave with 9s period and 3m wave height (amplitude of 1.5m). The size of the rectangular and the semi-circular arrays are shown as well as how the arrays alter the wave field [7]. Evaluating the array configurations in multi-directional irregular waves indicate that the power smoothening effect is pronounced even under realistic conditions while the effect on the average power is limited. The best results were obtained for the rectangular pattern, in a multi-directional irregular sea state of 9s peak period and 3m significant wave height, where the peak-to-average value of the 6 WEC array was decreased down to 50% of the peak-to-average value for the single WEC unit. Even though the alteration of average power is seen to be small for the 6 WEC arrays here it should not be taken for granted that the same holds for a larger array. Previous studies on WEC arrays have shown that wake effects increase in importance with the number of rows. It is not clear which pattern is most beneficial, the rectangular pattern performs slightly better but the semi-circular pattern is more compact reducing the electric cable length. The distribution of surge separation distances appears to be more important for power smoothening than the pattern itself.

q-factor

Based on the results in the above-mentioned thesis report, in multi-directional irregular waves, the best performance was achieved in the rectangular array configuration, considering reduction of the peak power at the cost of small reduction in the q-factor. Therefore, for simplification of the design, also due to study purpose only, the rectangular array 8x10 was chosen, that is shown on the figure below. For this project, based on the results of simulation in thesis report [7], the q-factor was chosen to be equal 1.

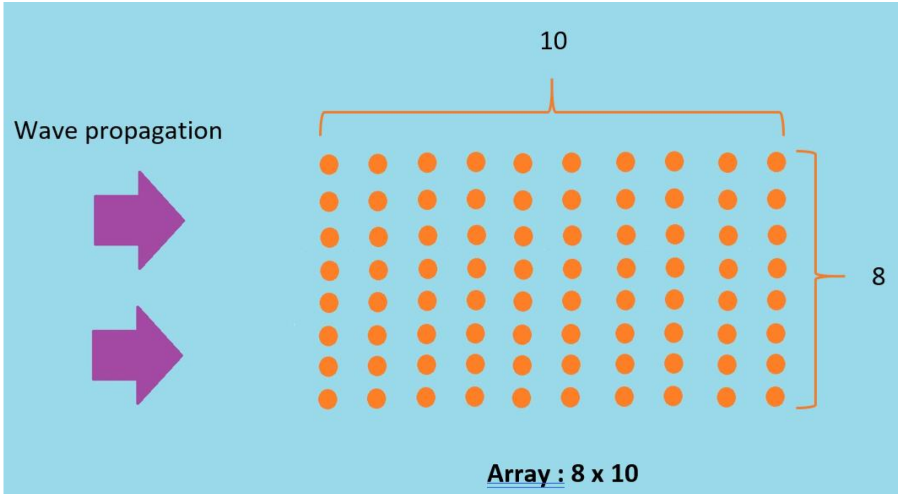


Figure 26 - CorPower WEC rectangular array layout: 80 devices

However, after running the Genetic Algorithm, it was observed that the actual shape of the array is trapezoidal (see figure 27).

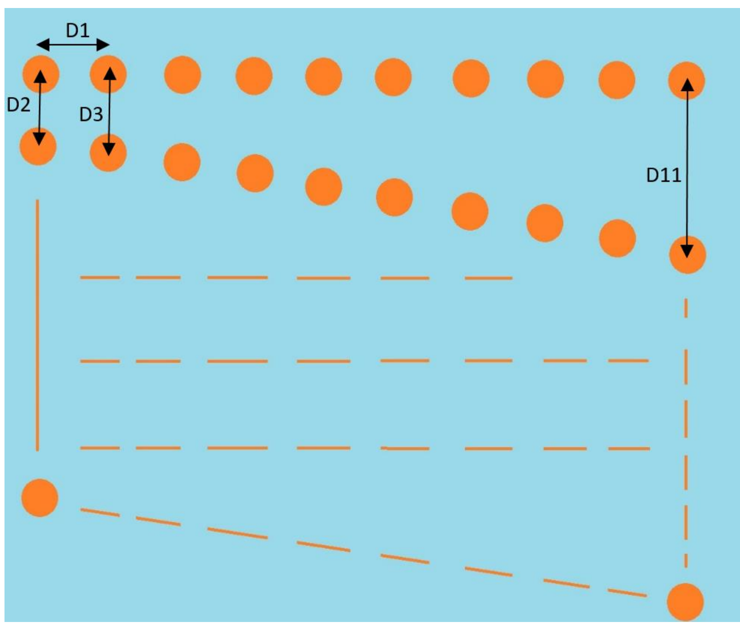


Figure 27 - Size and shape of the WEC array

On figure 27 the final design of the wave energy converter array is shown based on the results in [7]. D1 is the constant distance between the rows, D1 = 94.7 m. D2 is the distance between two WEC in the first row, D2 = 76.3 m. The distance between two devices in the second row: D3 = 82.6 m. Each following row is bigger than previous by the ratio:

$$\frac{D3}{D2} = \frac{82,6}{76,3} = 1,0825 \qquad (4)$$

Multiplying each precedent distance between two devices in the row by this ratio 1.0825, the distance between two neighbouring devices in the next row can be calculated.

Graphically, the array looks like on the picture below on figure 28. Here, the array has power 10 MW and the layout is different, but it is nice to present it for visualization.

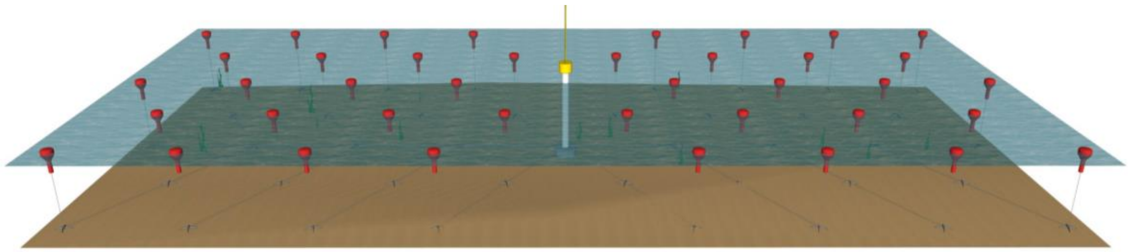


Figure 28 - 10 MW WECs array

Table 9 - Distances between the devices in the array

D1, m	D2, m	D3, m	D4, m	D5, m	D6, m	D7, m	D8, m	D9, m	D10, m	D11, m
94,7	76,3	82,6	89,4	96,78	104,7	113,4	122,7	132,9	143,8	155,7

Table 10 - number of the devices in the array

Total number of devices	80
Number of columns	8
Number of rows	10

This 8 x 10 layout was designed in such way in order to mitigate several reasons: the highest probability of the wave direction, the distance to shore and power grid, bathymetry, facilitating navigation near Durban port, potential interaction with marine habitats. The total power of the array with the correction factor should give 20 MW.

Based on the data in tables 4 and 5, the total area of the array is calculated. The area of the trapezoid is calculated by formula:

$$S = \frac{a+b}{2} \cdot h \tag{5}$$

, where a is the distance of the first row of 8 devices: a = 76.3*7 = 534 (m), b is the last row of 8 devices: b = 155.7*7 = 1089 (m), h is the height of the trapezoid: h = 94.7*9 = 852 (m).

Therefore, the total area of the farm is 691398 m^2 = 0.691 km^2. If taking into account safety margin to the array layout, in total 1 km^2 can be dedicated for this project.

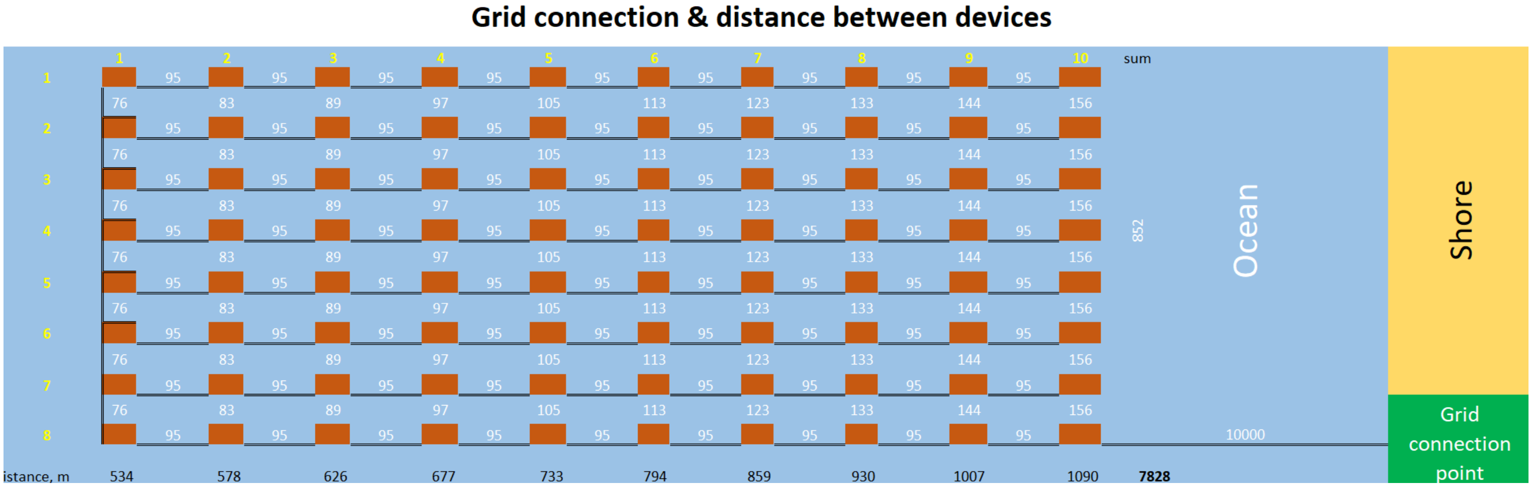


Figure 29 - Farm layout & distances between the devices and to the grid

Red rectangular represent schematically WEC devices in the farm on figure 29. Numbers between devices in white colour stand for distances [m]. Grey line represents interconnection of the devices. Therefore, the total length of the cables to the grid is calculated. The results are shown in table below:

Table 11 - Total length of the cables & power losses

	Total length of the cables	
horizontal	8	km
vertical	0.852	km
to the grid	10	km
	Power losses	
Total distance	18.852	km
Power losses per km	28.25581	kW/km
Power losses in the electrical cables	532.6785	kW

Horizontal length of the cables is equal to the sum of distances of 10 rows. Vertical distance takes into account only the sum of distances between devices in a single column due to farm layout configuration. The total length of the cables is equal 18.852 km. The power loss in cable per km is 28.25 kW/km. Therefore, the total electrical power losses in the cables are equal to 18.852 x 28.25 = 532 kW.

6. Moorings

The two major requirements for a WEC mooring are to withstand the environmental and other loadings involved in keeping the device on station, and to be sufficiently cost effective so that the overall economics of the device remain viable [12].

Each device has only one mooring line. The WEC is connected to the seabed using a taut mooring line. Based on the average depth, the mooring line can be assumed 25 m long.

7. Electrical grid layout

The wave farm concept is based on combining hundreds to thousands of units in arrays, with a common grid export cable that connects the offshore wave farm to existing on-land grid [8].

7.1. Sizing AC cables for Offshore Grids

The current carrying capacity of a cable is dependent upon the type of construction, characteristic of the materials used and also on the operating conditions. The current carrying capacity of the cable must be larger than the loading of the cable under: normal operation conditions, short circuit conditions. This will ensure that no part of the cable will attain a temperature higher than the maximum allowable temperature of the cable [13]. For this project, aluminium is chosen for the cable. The diameter of the cable is 150 mm^2. Rated voltage is 20 kV, I_{max} = 250 A. The calculations of power losses are shown in the attached Excel file and Appendix. Calculated Power losses of the WEC farm is 28.25 kW/km.

8. LCOE calculation

For WEC projects to be successful their performance need to be compared against other offshore renewable energy technology alternatives. WES have identified a number of target outcome metrics against which WECs should be compared to determine their economic performance.

LCOE is defined as a total capital, operational, and maintenance costs associated with the generation, discounted to present day value, divided by the electricity generated to the grid throughout the technology's operational life. A general formula for LCOE is shown below:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{\{Investment_t + O\&M_t + Fuel_t + Carbon_t + Decomissioning_t\}}{(1+r)^t}}{\sum_{t=1}^{n} \frac{WEC\ Production_t}{(1+r)^t}} \tag{6}$$

When considering WEC devices, LCOE can be calculated using the formula 7:

$$LCOE = \frac{CAPEX + \sum_{t=1}^{n} \frac{OPEX_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{WEC\ Production_t}{(1+r)^t}} \tag{7}$$

, where LCOE is the levelized cost of electricity, CAPEX is the capital expenditures, OPEX is the operational expenditures, WEC production (or Annual Energy Yield) is the annual electricity production, n is the lifespan of the system, r is the discount rate.

LCOE is one of the main parameters used in the techno-economic study. Some assumptions are taken in consideration [14]:

- the device is in survival mode in sea states where Hs > 10 m,
- there is no interaction effects among the devices (q factor is equal to 1),
- CAPEX is scaled based on the following equation:

$$CAPEX_2 = CAPEX_1 \times Scale^{Scale\ parameter} \tag{8}$$

, where $CAPEX_1$ corresponds to the CAPEX of 25 kW device, Scale parameter corresponds to the CAPEX Scale parameter

- First OPEX calculation approach: percentage of CAPEX. It is assumed, that initial OPEX is 8% of CAPEX
- Second OPEX calculation approach: based on the real cost of the repair actions through the life-cycle of the device. Cost of the vessel are based on the consultations with a vessel company in Orkney, Scotland, however for this project, I assume that the price remains the same, meaning that the cost of vessel in Durban is equal to the cost of the vessel in Orkney. It is also assumed that the same type of vessel is used for repair action, independently of the rating of the device.
- The level of availability is assumed to be 95 % based on [15].
- It is assumed that the wave energy farm is designed for a 20-year life-cycle.
- A discount rate of 8% has been chosen following [16]
- A feed in tariff of 375 Euro/MWh has been selected. This tariff corresponds to the United Kingdom for wave and tidal projects. I used this information, because this country is the leader in wave energy technology and I cannot find a relevant information in South Africa.
- It is assumed that this will be the first 20 MW farm developed and so the selection of interest rate, availability, and OPEX has been made with this mind.
- A learning rate is applied to CAPEX due to bulk production. Thus, a factor of 0.82 is selected as suggested as an optimistic scenario in [16]. For OPEX, a learning rate of 0.92 is applied (normally OPEX shows slower learning than CAPEX).

8.1. Cost estimation of different modules of the CorPower Ocean WEC

Based on the available information on the internet and libraries, I estimated the costs of the main parts/blocks of the wave energy converter. This information can be not really realistic, but for studying purpose it was assumed to use these values. The assumed costs for the different modules of the WEC are shown in table 12.

Table 12 - Cost estimation of the WEC modules

	WEC CAPEX estimation	
	Module	Budget per module, €
Estimation	Pre-tension system	125000
	WaveSpring	20000
	GearBox	40000
	Fly-wheels	12000
	Interface,packaging, routing	7000
	Control sys[hardware]	35000
	Control sys[software]	5000
	Power conversion system	7000
	Power export system	9000
	Cooling	4000
	Lubrication	5000
	Air supply	5000
	Humid&bilge sys	2000
	Hull	80000
	Emulator	1000
	Test rigs	20000
	Consumables	8000
	Sys assemby	8000
	Tidal system	12000
	Mooring	110000
	Foundation&Anchor	30000
	total	**545000**

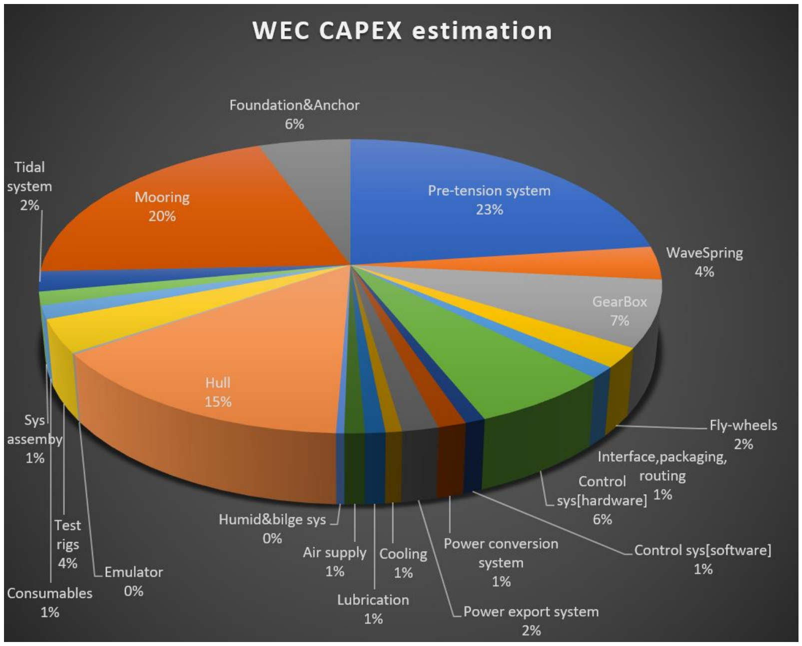


Figure 30 - WEC CAPEX estimation

The most expensive modules of a single device are the pre-tension system, moorings, hull, gearbox, foundation with anchor and control equipment. Figure 30 represents the data from table 12. The total budget of the single device is in total : 545000 €. The rated power of the device is 250 kW. SO, the rpice per kW can be calculated by:

$$\frac{545000\ €}{250\ kW} = 2180\ €/kW \tag{9}$$

Table 13 - Main technical and economic parameters of the device

CorPower Ocean AB	
CAPEX [€/kW]	2180
OPEX [% capex]	8%
Decomm [% Capex]	5%
Size [MW]	20
Financial parameters	
Lifetime [y]	20
Interest rate [%]	8.00%
Electricity generation	
capacity factor	34%
availability	95%
Generation [kWh/y]	56589600
Degradation [%/year]	1%
Feed in tariff [€/kWh]	0.375

In table 13, the main parameters of the devices are set. Decommissioning is due after the last operational year. In the next step, LCOE of the 20 MW WEC array is to be calculated.

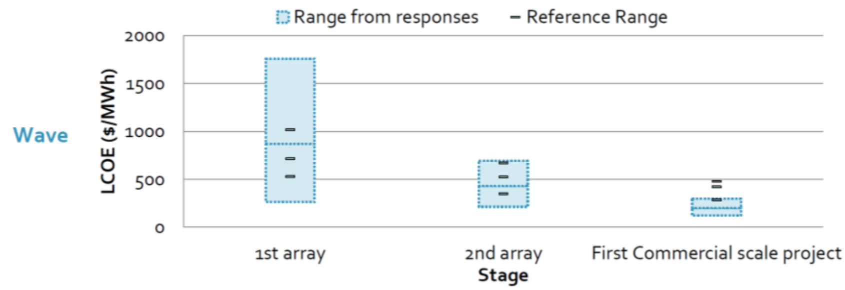


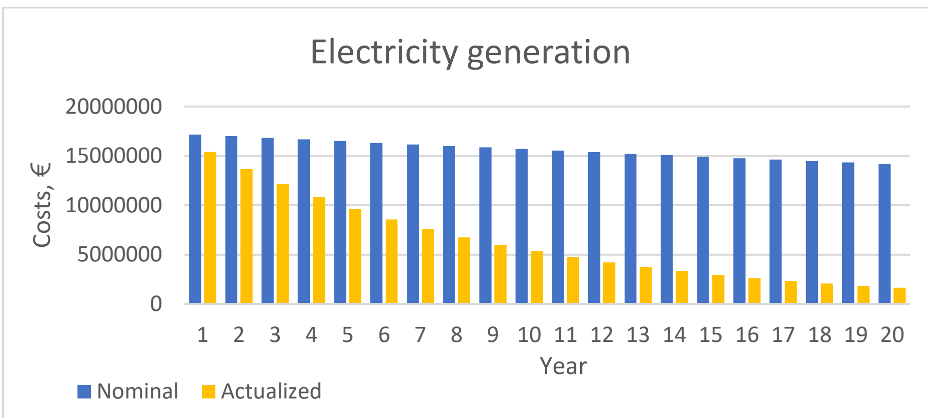
Figure 31 - Estimation of the LCOE of the CorPower Ocean array

Based on the studies from CorPower Ocean AB, the first commercial scale project will bring LCOE to the approximate value of 300$/MWh. Taking this into account, my own calculations will be compared to this estimation.

In the attached Excel file you can find LCOE calculation (sheet "LCOE calculation").

Table 14 - LCOE calculation result

Parameter	Actualized costs [€]	Actualized generation [kWh]	LCOE [€/kWh]	LCOE [€/MWh]
Value	77334989.65	125392620.6	0.61674275	616.7427498



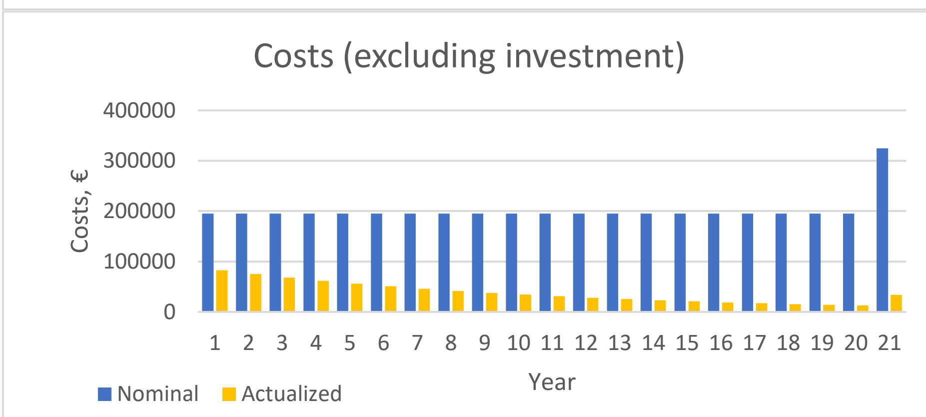


Figure 32 – (up): electricity generation; (bottom): costs (excluding investment)

Table 14 shows the final calculations of the LCOE of the CorPower 20 MW array. The result is 0.616 €/kW or 616 €/MW. This result is not really satisfactory, as it corresponds to the 2nd stage of the pre-commercial full-scale test of the array, but it is not commercial yet. In addition, this result can be compared to the official electricity prices in different countries (see figure 33) [17].

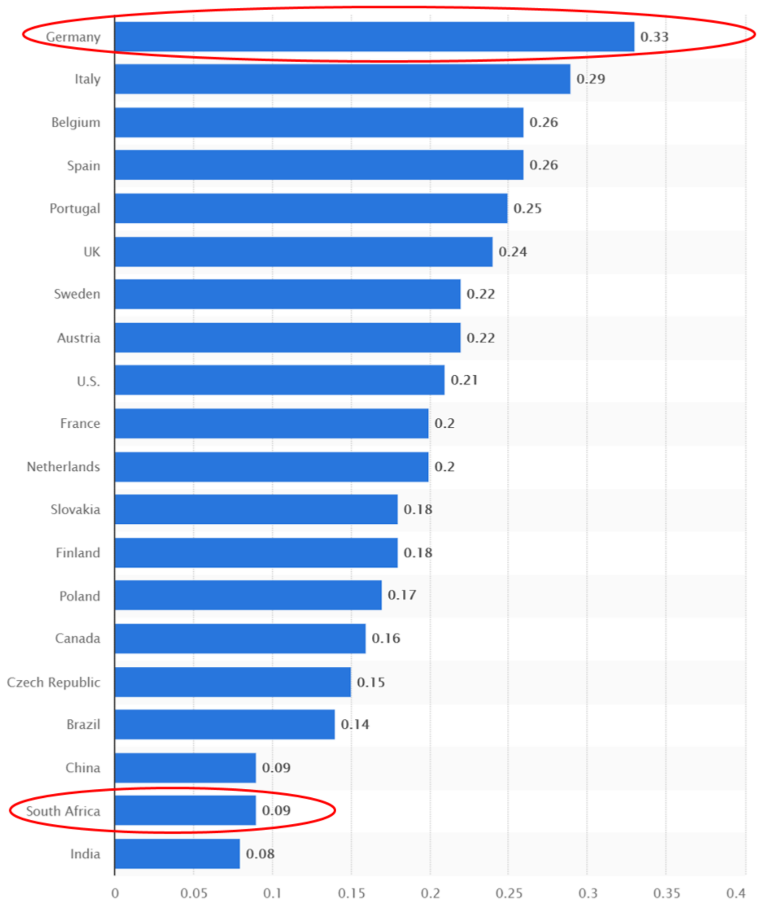


Figure 33 - Electricity prices in U.S. dollars per kilowatt hour

The local electricity price is South Africa was 0.09$ ≈ 0.08€/kWh. This price is much smaller than CorPower Ocean offshore farm can deliver to the grid (0.616 €/kWh).

The project is not yet feasible, even in the area with developed offshore infrastructure, neglected weather windows, very roughly estimated prices of the modules, infrastructure facilities, simplification of the array layout, rough assumption of the loads, extreme conditions, etc. For the feasible project, this technology needs to develop more mature and robust device, cheaper components, more developed infrastructure of the ports, electric grid, logistics. In present, feed in tariff should be modified, larger farms should be built, learning and experience from other farms is required for this technology become mature and commercial. So, it can be concluded, that today this project gives a pessimistic scenario.

9. Conclusion

In this project I analysed the current energetic situation in South Africa, the facilities of the port of Durban, interaction with marine navigational routes, I made an overview of the marine protected (potential) areas. Then I built a scatter diagram and power density matrix. It allowed me to define rated power of the device. I came up to a conclusion that the wave resource in a particular area, depth, seabed geology and other factors allow to install a prototype of CorPower Ocean start-up from Sweden, which has its rated power 250 kW. When designing a farm layout, q-factor was assumed to be equal 1 for simplicity, otherwise this project could be more complicated. A brief explanation how to compute q-factor was explained. I decided to design a WEC farm with a total power of 20 MW. For such farm, 80 devices are needed. A simple rectangular layout 8 x 10 was proposed. Electrical grid connection was analysed, aluminium 3-phase cable was chosen and Power losses were calculated. One single device can produce up to 733.86 MWh/year. The annual energy yield for the farm is 17169 MWh/year. After taking into account power losses, including losses in electrical cables connecting to the grid, availability factor, degradation of the farm each year, the LCOE was computed: 0.616 €/kWh, which is expensive and not competitive with other electrical producers not only in South Africa, but also in rich and developed countries. It can be concluded, that this project is not commercial and it is not a surprise. As of today, there is still no solution to harvest energy from ocean waves that has been proven commercial viable. This new field is very challenging from many prospects of view, however there is a strong believe, that in future it will be a success.

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