

**DESIGN AND DEVELOPMENT OF A SIMPLE WAVE ENERGY
HARVESTING UNIT SUITABLE FOR LOCAL USE**



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CERTIFICATION

This is to certify that this research work on the “Design and Development of a Simple Wave Energy Harvesting Unit Suitable for Local Use” was carried out by Odigie Kingsley (ENG1805261), Othuke Odueme Bright (ENG1805262) and Ehiedu Soblessed Chibueze (ENG1805238) of the Department of Marine Engineering, University of Benin, under the supervision of Engr. Anderson Augherughe

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DEDICATION

This project is heart fully dedicated to Jehovah God Almighty, who has made everything a reality. We also humbly dedicate this report to our families and relatives who stood by us during challenging moments and for their invaluable direction, guidance, support, and prayers all through our study. We honestly cannot fully repay the love you have shown. We are fully assured that your labor of love is not in vain.

Finally, we would like to dedicate this report to our dear classmates and friends too numerous to mention.

ACKNOWLEDGEMENTS

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We deeply acknowledge the tremendous impact from our lecturers who have selflessly helped us during our training as a marine engineering student, the person of **Engr. W. Jaja** our course adviser, **Dr. O. Ighodaro**, **Prof Godfrey.O. Ariavie**, **Dr. A. Orogun**, and others, to name a few.

We would also cease this opportunity to show appreciation to everyone who contributed in the success of the project. To our beloved families; **Mr. and Mrs. Odigie**, **Mr. and Mrs. Odueme** and **Mr. and Mrs. EHIEDU**. We also extend this gratitude to our selfless course mate, Avunu Wisdom, Johnson God's power and John Udo.

ABSTRACT

In recent times, the trend of exploring renewable energy source has become paramount as the emission from fossil fuels use for power generation happens to become a threat to lives and environment. Hence, this project focuses on designing a simple device to harness clean and renewable energy in coastal region that experiences appreciable amount of wave activity. Compare to solar energy, wave energy is less talk of in some continent of the world, most especially Africa, this challenge led us to research and gather information from existing location that already utilized wave energy converters. The study involves analyzing wave data to determine the energy content of the waves and the feasibility of wave energy extraction at the location sited. Based on the wave characteristics, a wave harvesting unit will be developed, considering wave factors such as wave height, wave period and water depth.

Moreover, in the course of this project the potential energy yield of the designed will be estimated based on the wave energy resources available at the site. The findings of this study will contribute to the development of sustainable energy solutions and provide insights into the viability of wave energy as a renewable energy source at the selected location.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

In recent years, a lot of research work are now being focused on energy sources that are environmentally friendly like renewable sources which the Paris agreement pointed to as a possible source for future energy need for mankind. Apart from high cost of convention energy sources like fossil fuel which includes petroleum, coal, gas, these sources are dangerous to the environment leading to climatic changes and environmental pollution because these energy sources produce byproduct which are harmful greenhouse gases. As such much research work has been directed towards renewable energy resources that don't pollute the environment and are continuously replenish by nature, making them in exhaustible. It has been observed that not every location on the planet earth has this renewable energy sources in the same quantity or intensity and sometimes they are not readily available to same amount or degree. This situation makes renewable energy mostly location specific. Therefore, it implies that certain locations are very suitable for certain type of renewable energy. Open spaces often are suitable for wind and solar energy exploitation while some locations are suitable for geothermal energy exploitation.

Ocean coastal areas are also particularly highly suitable for wave and tidal energy exploitation. This is the key area of focus for this project work. Nigeria is not land locked country; Nigeria has a long costal area in the south that border the ocean. Apart from this th ere are lengths of coast lines that experience wave actions that could be tap for local use.

Wave energy is a form of renewable energy that exists in coastal areas and generated due to the rise and fall of water surface. It has been recorded that the global power potential represented by waves that hit all coast worldwide, has been estimated to be in the order of 1TW. J Falnes, (2007). This project work would help those communities lining in the coastal regions that are

inadequately served by the national grid and have wave energy potential that can be to electricity. A case in point is the Gelegele Shore Line where preliminary studies show that there is an appreciable wave action that can be tapped using wave energy conversion and transmission devices. This project work intends to exploit this resource for the benefit of the local community.

1.2 Statement of the Problem

Tapping wave energy requires two components, these are;

1. Availability of an appreciable level of wave activity
2. Wave energy collection device

While the first resource is placed there naturally the second resource is created and put in place by man and that's where the engineering comes in. A suitable wave energy device is not readily available in the market and in many cases these devices are tailored to the wave condition in a particular location. Tailoring or designing a wave energy device entails the study of the available resource. A design that would therefore yield the maximum output will therefore be the focus of the engineer. This project works entails to carry out studies and measurement that will serve as guidance in an effort to design a suitable wave making tapping device to the location named. This is the problem that will be solved during the execution of this project.

1.3 Aim and Objective of the Study

1.3.1 Aim

Design and development of a wave energy tapping device suitable for the mentioned location

1.3.2 Objectives

- To carry out a survey of the location and identify the spot with the highest wave activity
- To collect relevant data related to the wave action for the identified spot in the chosen location

- Compare the data collected with those identify for various locations found in the literature review.
- Identify the wave energy tapping device used for the similar location
- Study the design of wave energy device identified and determines the possible modification required to make it work efficiently at the Gelegele location earlier identified.
- Design a suitable wave energy tapping device based on the information gathered
- To estimate the wave energy yield based on the designed device

1.4 Scope of Work

The scope of this project work is limited to

1. Study of wave energy potentials of the location
2. The design of a suitable wave energy tapping device
3. Estimate the quantity of energy the designed wave energy device would yield

1.5 Significance of the Study

Wave energy is one of the least exploited renewable energy resources in Nigeria, the focus have always being on solar, wind and biomass. Notwithstanding there are popular locations that could easily tapped the wave action around them for energy yield purposes. Wave energy, unlike solar and wind often is available for longer duration virtually all the time with a fairly steady intensity which is an advantage. This project work therefore will be an eye opening for locations with these potentials.

1.6 Methodology

The methodology to be applied in the execution of this project work is expected to be a model for the installation of wave energy tapping device in any costal locations. The followings are the steps outlining the methodology of such studies;

1. Carry out a physical survey of the location suitable for exploitation.
2. Measurement of the average wave height, timing of wave cycles, frequency of wave occurrence, water depth.
3. Design of a suitable wave energy tapping device
4. Find out if the materials for the design are available locally
5. Determine if the engineering facilities are available for fabricating the component designed.
6. Estimate the cost for all the component required

Of course as stated earlier this guidelines listed above to be followed when actual fabrication and installation is to be done

CHAPTER TWO

LITERATURE REVIEW

2.1 WHAT IS WAVE ENERGY

Wave energy pertains to the latent potential and kinetic energy harnessed from the undulating motions occurring on the surface of the ocean. This valuable energy source can be effectively harnessed by specialized devices designed to capture the rhythmic movement of waves, subsequently transforming it into alternative forms of motion that can be harnessed for the generation of electricity or various other energy derivatives. In essence, the utilization of wave energy holds promise as an environmentally sustainable and renewable means of meeting our growing energy needs. (Li et al., 2022). Dincer et.al. (2021) also explain how that wave energy arises from the movement of air over the ocean's surface, a phenomenon propelled by the uneven warming of the Earth's surface driven by solar radiation. As the sun's energy interacts with the planet, creating temperature variations, the resulting winds set the stage for the development of waves, forming a dynamic connection between solar power, atmospheric conditions, and the vast expanse of the sea. Electricity is produced through the harnessing of ocean wave energy, where the magnitude, speed, and duration of a wave directly influence the generated energy. Specialized equipment positioned on the ocean's surface captures the kinetic energy resulting from the rhythmic oscillation of the sea. This captured energy is then utilized to drive a turbine, connected to a generator, facilitating the conversion of kinetic power into electricity. The generated electricity can be efficiently transmitted back to the shore, establishing a sustainable and renewable source of power derived from the dynamic movements of the ocean. Vosough (2011) posited that wave energy involves the transfer of energy through ocean surface waves, with the subsequent harnessing of this energy for practical applications. This may encompass various tasks, such as generating electricity,

desalinating water, and pumping water into reservoirs. The utilization of wave power demonstrates the potential for sustainable and versatile energy sources derived from the dynamic forces of the ocean. In the article, ‘motion of the ocean: Introduction to wave energy’ It was affirmed that wave energy represents a renewable energy form that is derived from the movement of ocean waves, offering a sustainable source of power through the harnessing of wave motion. This innovative approach taps into the rhythmic and constant nature of waves, showcasing a promising avenue for clean and environmentally friendly energy production. (Justenergy, 2024)

Wave energy stands out as a pristine and sustainable power source within the global energy landscape, boasting expansive potential and promising prospects. This form of energy, derived from the rhythmic oscillations on the ocean surface, is acknowledged for its eco-friendly attributes, positioning it as a vital component in the pursuit of clean and renewable energy solutions worldwide. As we navigate the challenges of a rapidly evolving energy landscape, the broad horizons of wave energy become increasingly apparent, heralding a future where its integration could play a pivotal role in addressing the world's growing energy demands while minimizing environmental impact (Li et al., 2022).



Figure 2.1 Pelamis P2-001 wave energy converter of Pelamis Wave energy during testing at the European Marine Energy Centre (EMEC) in Orkney, Scotland, in 2010.

2.2 CAUSES OF WAVES

In the vast expanses of the oceans, a perpetual motion unfolds, manifesting in the rhythmic ebb and flow of waves – from the gentle caress of tide to the formidable surge of a storm. The complexity of oceanography, a field that has fascinated both scientists and beach enthusiasts for centuries, unfolds as we dissect the various elements influencing the creation of ocean waves. Many literatures so far have been written on the many causes of ocean wave.

In December 1942, the Queen Mary navigated a storm in the North Atlantic with nearly 11,400 American soldiers on board, braving swells ranging from 50 to 60 feet. Unexpectedly, it confronted an exceptionally deep trough and was struck broadside by an enormous wave towering at an estimated height of 90 feet. The ship leaned precariously to a 52-degree angle, within a mere 3 degrees of its limit, before gradually returning to an upright position. In the early 1960s, the Union-Castle Line's Edinburgh Castle faced a similar ordeal when it encountered an "ocean hole" while sailing from Durban to Cape Town, resulting in a 45-degree tilt, reaching its limit but managing to recover.

Fortunately, the Edinburgh Castle successfully righted itself. Conversely, in July 1909, the SS Waratah, a 10,000-ton vessel carrying 211 individuals, mysteriously vanished en-route from Durban to Cape Town. Its discovery in 1999 on the seafloor, upright and intact, suggested a rapid sinking, potentially attributed to encountering a colossal wave. In February 1982, massive waves, surpassing 65 feet, relentlessly battered the semi-submersible oil rig Ocean Ranger, leading to its sinking off the coast of Newfoundland, Canada. Another notable incident occurred in December 2008 when a colossal wave struck the Dunbar oil rig in the North Sea. (Marine Executive, 2022)

Many literatures so far have been written on the many causes of ocean waves. According to Interesting Engineering, (2023) in her article, 'what causes waves in the ocean? All you need

to know' Agard Sade stated four major causes of waves, these include wind, earthquakes, underwater landslide and gravity.

2.2.1 Wind

The predominant force shaping ocean waves is wind, constituting the primary catalyst for their formation. When the wind traverses the surface of the ocean, it instigates friction with the water's surface, giving rise to the initial formation of ripples. These modest ripples, stirred by the persistent force of the wind, evolve into larger waves that possess the capability to traverse vast distances across the ocean. In their wake, they leave behind a distinctive trail of white foam, marking the dynamic passage of this natural phenomenon.

In instances of heightened wind intensity, such as during a hurricane, a consequential phenomenon known as a storm surge can emerge. This surge manifests as a sequence of extended waves originating far from the shore. As these waves progress into shallower waters, their vigor intensifies, leading to a remarkable escalation in both size and power. The result is a spectacle of formidable waves, further underscoring the profound impact that varying wind strengths can have on the dynamic character of oceanic waves. (Interesting Engineering, 2023)

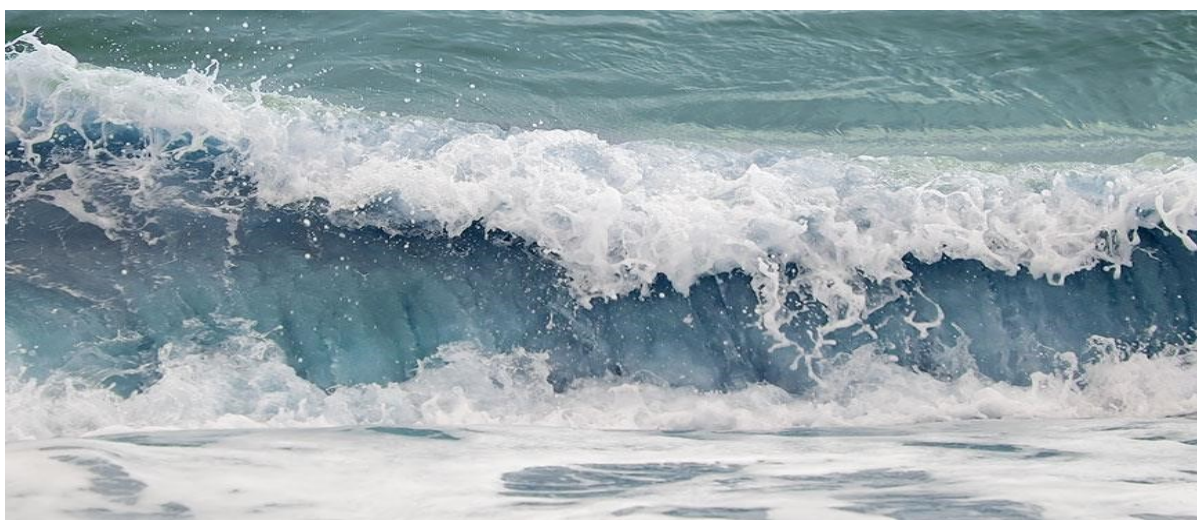


Figure 2.2 NOAA. Why does the ocean have waves? National Ocean Service website, 2023.

2.2.2 Earthquakes

Ocean waves can also be triggered by seismic activity, specifically underwater earthquakes. When an earthquake occurs beneath the ocean's surface, the energy unleashed by the shifting tectonic plates generates seismic waves that traverse through the Earth's crust. This seismic energy has the potential to induce vertical movements in the ocean floor, leading to the substantial displacement of water.

This displacement, in turn, sets in motion a succession of waves emanating from the epicenter of the earthquake. As the waves propagate outward, they carry the signature of the seismic disturbance, creating a visual representation of the powerful forces unleashed beneath the ocean. The interconnected dynamics of tectonic movements and water displacement underscore the profound influence that underwater earthquakes can exert on the generation of ocean waves, contributing to the complex and diverse nature of these natural phenomena (Interesting Engineering, 2023)

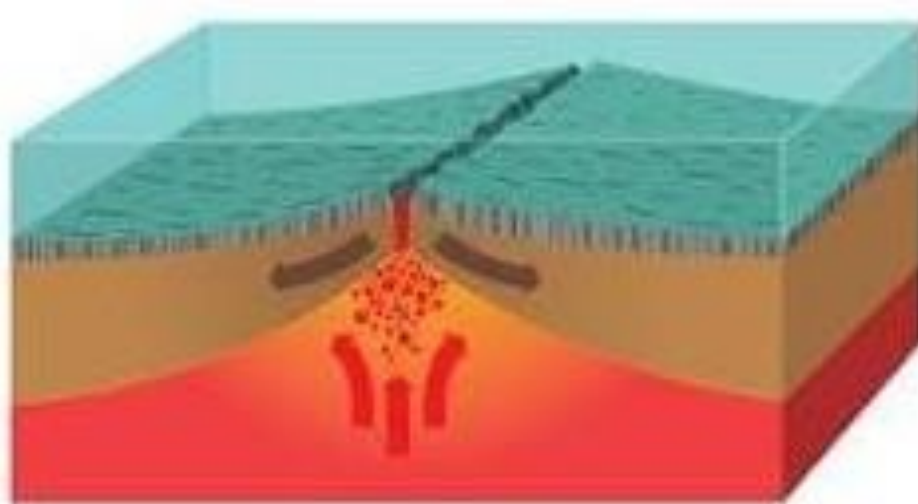


Figure 2.3 Underwater earthquake images, Stock photos, 3D objects, Shutterstock.com.

2.2.3 Landslides

Landslides encompass various forms of ground movement, such as rock falls, slope failures, debris flows, and slumps, and they have the potential to generate ocean waves. The genesis of waves occurs when a landslide displaces water either from above (sub aerial) or below (submarine). Underwater landslides are influenced by factors like tectonic activity, alterations in water depth, and changes in sediment composition.

Under specific circumstances, a landslide has the potential to instigate a tsunami wave, dependent on factors such as the volume of displaced material, its speed, and the depth at which it occurs. A notable instance of this phenomenon unfolded in 1979 along the southern coast of France during the construction of an airport runway in Nice. It is hypothesized that the project's activities triggered a submarine landslide, unleashing destructive tsunami waves into Antibes harbor. The estimated volume of debris that plunged into the ocean during this event was approximately 150 million cubic meters. . (Interesting Engineering, 2023)

According to Maritime executive (2022), while it is generally agreed that wind blowing over a large expanse of ocean produces waves on the ocean surface, seafloor topography and changing climate are also major factors influencing ocean waves

2.3 HARNESSING WAVE ENERGY

In the face of an impending global energy crisis and the rapid depletion of fossil fuel reserves, the imperative for widespread adoption of renewable energy is intensifying across nations worldwide. Beyond the finite nature of Earth's fossil fuel reserves, their escalating withdrawal rates are pushing countries towards an unavoidable energy crunch. The extensive reliance on carbon-based fuels not only exacerbates the depletion issue but also contributes to heightened pollution levels and a surge in greenhouse gas emissions, inflicting nearly irreversible damage upon the planet.

The repercussions of rising global temperatures and climate change are manifesting in diverse, adverse ways, prompting policymakers and international institutions to urgently call for concerted efforts to curtail carbon emissions. The push for achieving 'carbon neutrality' by 2030 has become imperative to avert a potential catastrophe. International entities, such as the United Nations (UN), have been actively addressing these critical issues. The UN's commitment to sustainable development is encapsulated in its 17 Sustainable Development Goals (SDGs), among which SDG 7 stands out with its mission to 'ensure access to affordable, reliable, sustainable, and modern energy for all.' SDG 7 outlines five targets and six indicators, with Target 7.2 specifically aimed at increasing the global percentage of renewable energy. By 2030, the goal is to substantially boost the share of renewable energy in the global energy mix, aligning with a broader commitment to mitigate environmental impact and foster a sustainable energy future. This collective effort underscores the urgency of transitioning towards renewable energy sources and aligns with the broader vision of building a resilient and sustainable global energy landscape (Nandi, 2023).

Highlighting its potential, in 1989, the World Energy Council estimated the global wave energy potential at approximately 2 Terawatts if fully utilized a capacity that could effectively fulfill the electricity needs of the entire world. In conjunction with other renewable resources, wave energy holds significant promise in addressing the world's energy demands and facilitating the attainment of carbon emission targets. The historical background and the substantial interest in wave energy emphasize its pivotal role in the broader context of sustainable and low-carbon energy solutions (Nandi, 2023).

Now, nearly the entirety of wave energy, approximately 95%, resides within the span between the water surface and the upper one-fourth of the wavelength. This abundant energy resource can be harnessed through various methodologies, resulting in a rich assortment of technologies that have been both developed and deployed. Waves, as a dynamic force, encapsulate three fundamental motions, each offering distinct opportunities for extraction:

Surge Motion: This is the horizontal front/back movement within a wave, commonly referred to as the "surge." Technologies employing a "roll rotation" are adept at extracting energy from this specific motion. Sway Motion: Representing the horizontal side-to-side oscillation, known as the "sway," technologies incorporating a "pitch rotation" excel in capturing this aspect of wave energy. Heave Motion: The vertical (up and down) motion, termed the "heave," can be harnessed through technologies utilizing either a "yaw rotation" or a "translation" mechanism.







Categorizing wave energy technologies involves an examination of how these devices capture the surge, heave, or sway motions, either individually or in combination (EMEC, 2014). Notably, point absorbers stand out as devices adept at converting the "heave" motion into a piston-driven up-and-down motion, while terminators and oscillating wave surge converters focus on extracting the "surge" to generate electricity. Attenuators, on the other hand, specialize in converting the "pitch" of the wave into rotational energy to drive a rotor.


2.4 EXISTING WAVE ENERGY PLANTS IN THE WORLD











Figure2.4 Agucadoura Wave Farm in Portugal, enwikipedia.org (2008)

Table 2.1, Existing Wave Energy Plants in The World Chris, C. (2024, January 17). 'List of Wave Power Stations.' Wikipedia.

| Station | Country | Location | Capacity (MW) | Type | Operation | Notes |
|---------------------------------------|--|---|---------------|------------------------------|----------------------------|--|
| Ada Foah Wave Farm |  Ghana | | 0.4 | Point absorber | 2016 | |
| Agucadoura Wave Farm. |  Portugal |  41°25'57"N 08°50'33"W | 2.25 | Surface following attenuator | July 2008 November 2008 | |
| Azura |  United States | | 0.02 | Point absorber | 2015 | |
| BOLT Lifesaver |  United States | | 0.03 | Point absorber | 2016 | |
| CETO |  Australia | Western Australia | | | 2015 | Two submerged buoys anchored to the seabed generate energy through hydraulic pressure. |

| | | | | | | |
|---|--|---|--|----------------------------------|------------------|--------------|
| Gibraltar Wave Farm |  Gibraltar | Gibraltar | .1 | Surface attenuator | 2016` | |
| Islay Limpet |  United Kingdom |  55°41'24"N 06°31'15"W | 0.5 | Oscillating water column | 2000–2012 | |
| Mutriku Breakwater Wave Plant |  Spain |  43°18'26"N 2°23'6"W | 0.3 (296 kW from 16 turbines and 16 OWCs. | Oscillating water column | 2011 | |
| Station | Country | Location | Capacity (MW) | Type | Operation | Notes |
| Ocean RusEnergy |  Russia | Yekaterinburg | N | Smallscale | 2013 | |
| Orkney Wave Power Station |  United Kingdom |  58°56'12"N 02°44'38"W | 2.4 | Oscillating wave surge converter | Proposed | |

| | | | | | | |
|--|---|---|------|----------------------------------|------|--|
| Pico Wave Power Plant |  Portugal | | 0.4 | Oscillating water column | 2010 | |
| Runde Demo Site |  Norway | | 0.1 | Oscillating water column | 2017 | |
| SDE Sea Waves Power Plant |  Israel |  32°05'59"N 34°46'24"E | 0.04 | Oscillating wave surge converter | 2009 | |
| SINN Power wave energy converter |  Greece |  35.352161°N 25.156061°E | 0.02 | Point absorber | 2015 | |
| Sotenas Wave Power Station |  Sweden |  58°22'45"N 11°08'57"E | 3 | Point absorber | 2015 | |

2.4.1 Estimating A Wave Energy Site Potential: Indian Coastline As Case Study

Having known that wave energy can be harnessed, it is good we know the potential of the wave energy that can be generated. The wave energy that is highly concentrated near the ocean

surface is stored in the oceans worldwide. Out of the abundance of energy stored in waves, only a small part of it is used for commercial electricity generation today (Uihlein et al., 2015). An article by (Sannasiraj et al., 2016) deals with the details of possible potential sites along the Indian coastline for establishing systems to convert energy in the ocean waves to electricity. Wave energy was extracted when the turbines are placed on the surface of the ocean. Prior to planning for the installation of wave energy convertor, a detailed investigation was carried out to understand the available location wise wave power potential. The available wave power depends on the wave period and its height, in other words energy. Further, the seasonal variation is also important. One should not be carried away if the wave power potential is high only over a short duration within a year. An ideal site should have consistent power availability over the entire year. Initially before their article, the available wave power was evaluated from the wave characteristics (wave period and height) for different locations along Indian coastline by many authors (NarasimhRao and Sundar, 1982; Ravindran and Koola, (1991) from the ship observed information on the wave characteristics. Kumar et al. analyzed 18 years of altimeter wave data in the Indian Ocean region. Further, Pogarskii et al. (2012) made a detailed statistical analysis of 12-years (1998–2009) wind and wave fields in the Indian Ocean. The wave field was generated using wind-wave numerical modeling using modified source functions. In the study, the data sets collected by the above authors were the basis for the wave power potential estimate and thus obtained is used to identify possible sites for the installation of wave energy conversion plants to generate electricity from waves. In the same article the selection of a wave energy device was carried out with specific focus. The approach aimed to tailor the choice of the wave energy device according to site characteristics and specific environmental and economic context of the region, ensuring optimal performance and alignment with the local conditions.

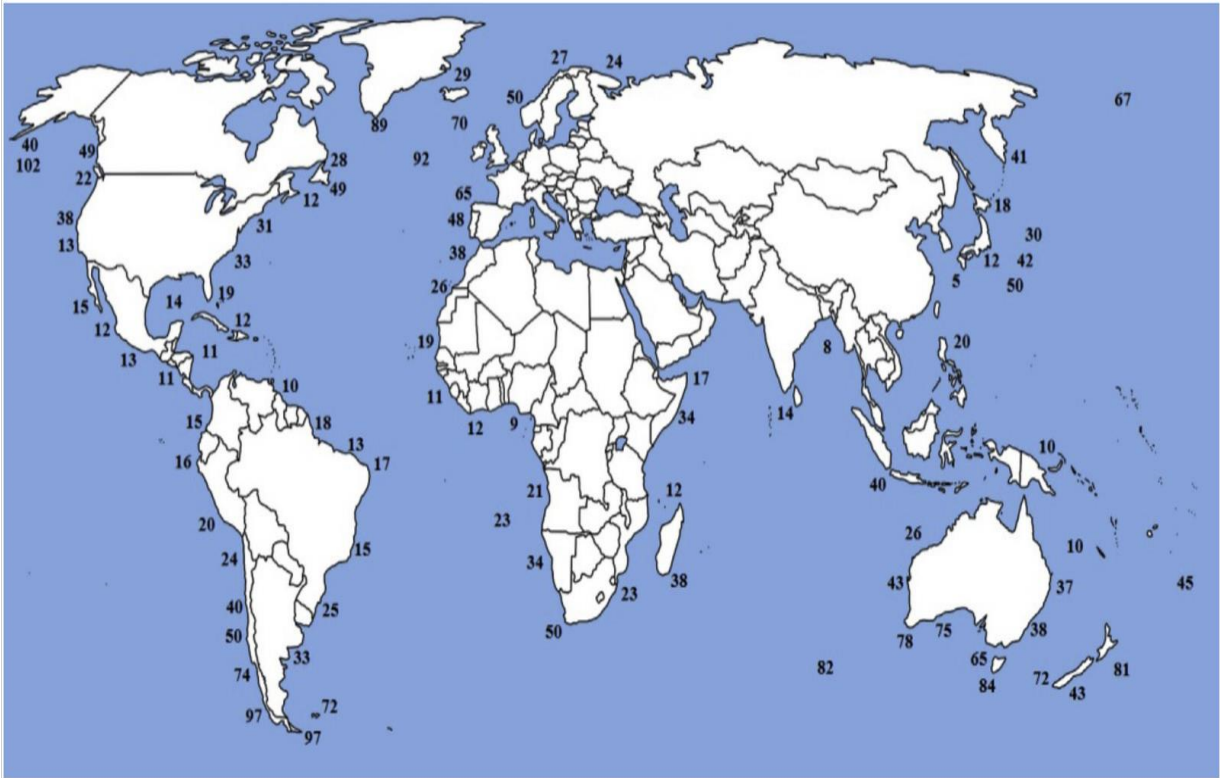


Figure 2.4 ; Wave energy levels (in kW/m length of coast) around the globe.

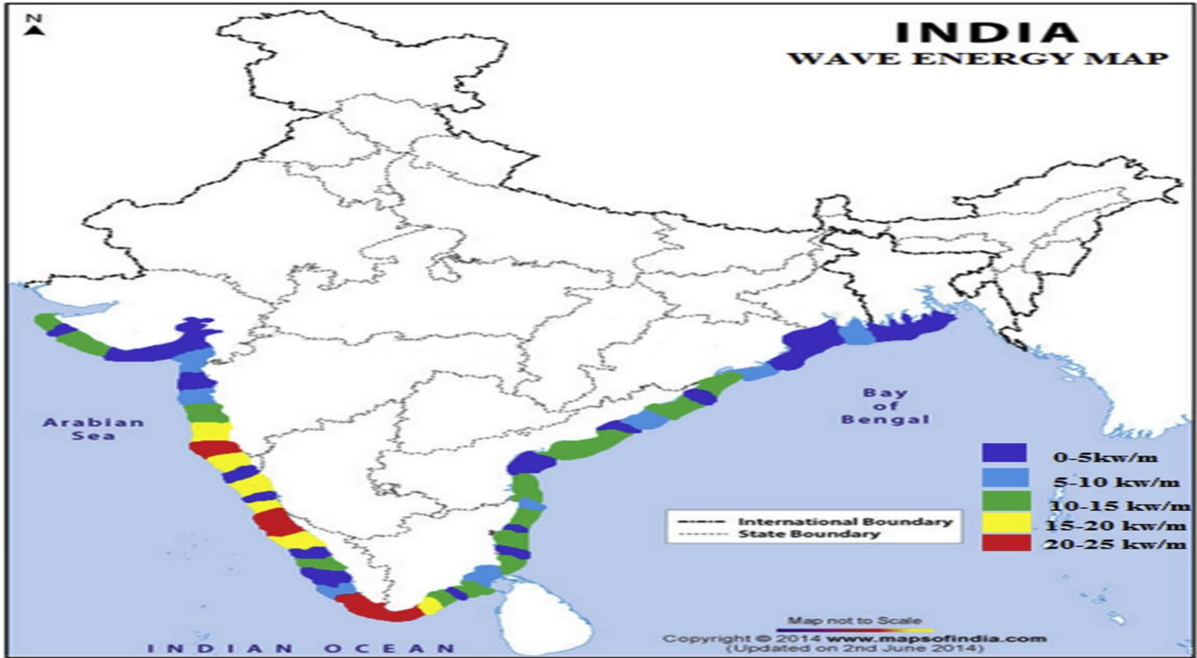


Figure 2.5 India wave energy map

Table2.2 Distribution of wave power potential along the Indian coastline.(Sannasiraj and Sundar, 2016)

| Sl. No. | Places | State/UT | Lat. | Lon. | H_s (m) | T_{mean} (s) | q_{mean} () | Power (kW/m) | L (m) |
|---------|-----------------|-------------|-------|-------|-----------|-----------------------|----------------------|--------------|-------|
| 1 | Kendrapara | Orissa | 20.50 | 87.00 | 1.3 | 7.1 | 173 | 6 | 80 |
| 2 | Bideipur | Orissa | 21.00 | 87.00 | 0.8 | 5.6 | 175 | 2 | 49 |
| 3 | Chandipur | Orissa | 21.00 | 87.41 | 0.8 | 3.5 | 188 | 1 | 19 |
| 4 | Dantan | West Bengal | 21.50 | 87.50 | 0.6 | 7.0 | 181 | 1 | 75 |
| 5 | Nandigram | West Bengal | 22.00 | 88.00 | 0.7 | 4.4 | 196 | 1 | 30 |
| 6 | Bakhhali | West Bengal | 21.50 | 88.50 | 1.3 | 6.4 | 177 | 5 | 64 |
| 7 | Sundarban | West Bengal | 22.00 | 89.00 | 1.1 | 5.8 | 186 | 3 | 52 |
| 8 | Khulna District | Bangladesh | 22.00 | 89.50 | 0.3 | 8.5 | 195 | 0 | 114 |

Table2.3 Distribution of wave power potential along the Indian coastline. (Sannasiraj and Sundar, 2016)

| Contour power level (kW/m) | Contour length (km) | Total power flux crossing contour (GW) |
|----------------------------|---------------------|--|
| 0e5 | 1530 | 3.825 |
| 5e10 | 822 | 6.165 |
| 10e15 | 1634 | 20.425 |

15e20

665

11.64

20e25

400

9

| State | Contour length (km) | Total power flux crossing contour (GW) |
|----------------|---------------------|--|
| Gujarat | 0e5 | 465 |
| | 5e10 | 110 |
| | 10e15 | 325 |
| Maharashtra | 0e5 | 90 |
| | 5e10 | 115 |
| | 10e15 | 120 |
| | 15e20 | 210 |
| | 20e25 | 130 |
| Karnataka | 0e5 | 130 |
| | 15e20 | 215 |
| | 20e25 | 95 |
| Kerala | 0e5 | 130 |
| | 5e10 | 60 |
| | 10e15 | 65 |
| | 15e20 | 125 |
| | 20e25 | 85 |
| Tamil Nadu | 0e5 | 75 |
| | 5e10 | 110 |
| | 10e15 | 529 |
| | 15e20 | 115 |
| | 20e25 | 90 |
| Andhra Pradesh | 0e5 | 150 |

| | | |
|-------------|-------|-----|
| | 5e10 | 85 |
| | 10e15 | 550 |
| Orissa | 0e5 | 235 |
| | 5e10 | 160 |
| | 10e15 | 45 |
| West Bengal | 0e5 | 255 |
| | 5e10 | 182 |

Table 2.4 Wave power contour along different maritime states (Sannasiraj and Sundar, 2016)

One of the earliest works reported on the distribution of wave power potential along the Indian coast was due to NarasimhaRao and Sundar (1982). They employed the data from National Institute of Oceanography, NIO. The data was collected from ships and Indian daily weather reports covering the period 1968 to 1973. For understanding the wave characteristics this amount of data would suffice. The season wise distribution of mean wave height, wave period and the power potential along the Indian coast are reported in Table 2.1.

The offshore wave climate off Indian coasts was extracted at salient points. The distributions of wave power potential along the Indian coastline are projected in Table 2.1. These details are also presented along the coastal map of India in Figure 2.2. From the map, it can be seen that the contour 10e15 kW/m is distributed almost evenly along the western and eastern coasts. Further, the wave contour of 15e20 kW/m is observed along the west coast, off viz., Maharashtra, Goa, Karnataka and Kerala. This presence of higher power along the west coast could probably be due to the strong waves during SW monsoon. Maximum wave power is obtained at southern tip of Indian peninsula (Kanyakumari, Nagercoil district, Koodankulam) which could be due to effect of refraction and the presence of strong winds prevailing in the region.

The distribution of wave power in a finite range and the length of coastline over which it is spread are grouped and presented in Table 2.2. It is also projected as pictorial representation, i.e., the distribution along the length of coast and total power available in each power contours in Figure 2.3a&b respectively. The wave energy concentration along the coastal stretch of different maritime states is projected in Table 2.3. It is to be noted that the revised estimate shows the total power available along the coast line is about 50 GW.

From the data shown above, it can be agreed that years of data of a site wave height, wave period, and the region climatic change are needed in the estimation of the site wave potential to the end that feasible site for wave energy is sought out, to determine wave energy potential, consider factors like wave height, period, and power density. Conduct a site assessment to measure these parameters, assess seasonal variations, and use numerical models to estimate potential energy production. Collaboration with oceanographers and utilizing wave energy resource maps can enhance accuracy in evaluating the feasibility of harnessing wave energy at a specific location. and like

Sannasiraj and Sundar, (2016) stated in his article ‘Assessing of wave energy potentials and its harvesting approach along Indian coastline’ A realistic estimate at each site can be made based on detailed survey along a particular coastal.

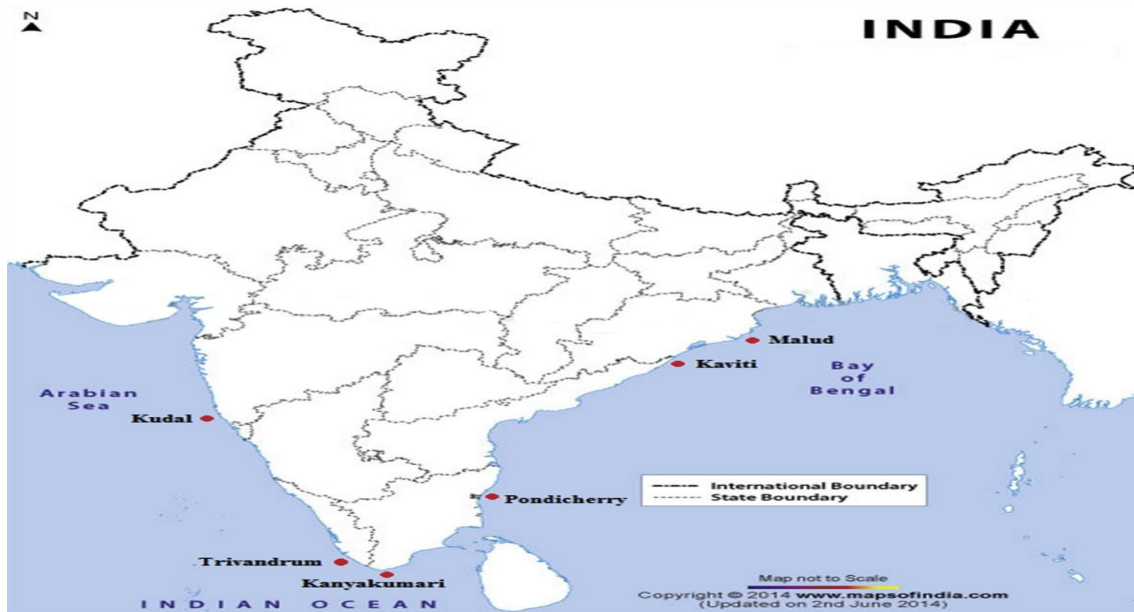


Figure2.6 Potential coastal locations for wave energy harvesting. (Sannasiraj and Sundar, 2016)

Table2.5; Potential coastal locations for wave energy harvesting (Sannasiraj and Sundar, 2016)

| Sl. No. | State/UT | Place | Lat. | Lon. | Water depth (m) | H_s (m) | T_s (s) | Power (kW/m) |
|---------|----------------|---------------|--------|--------|-----------------|-----------|-----------|--------------|
| 1 | Maharashtra | Kudal | 15550N | 73320E | 11e12 | 2.37 | 8 | 21.95 |
| 2 | Kerala | Trivandrum | 8280N | 76540E | 15e20 | 2.4 | 8.9 | 25.08 |
| 3 | Tamil Nadu | Kanniyakumari | 840N | 77320E | 12e13 | 2.4 | 8.3 | 23.39 |
| 4 | Tamil Nadu | Puducherry | 11540N | 79500E | 5e8 | 1.67 | 7.77 | 10.59 |
| 5 | Andhra Pradesh | Kaviti | 19000N | 84430E | 10e14 | 1.97 | 7.87 | 14.96 |

2.5 TYPES OF WAVE ENERGY CONVERTER (WEC)

There are different types of WEDs, and it can be classified based on the site they are mounted. According to the water depth, it can be classified as deep water, intermediate water, and shallow water. Generally, here is the list of some common wave energy converter deployed.

2.5.1 Wave Topping Device

Wave overtopping is another form of wave energy harvesting methodology. Wave breaking effect is used to raise the water level into the reservoir that sits higher than the water surface. The waves break when they start to face reduction on water depth while approaching the shoreline area. Typically, wave-overtopping device is present in two general types. It can be either fixed or floating. The earliest invention on overtopping concept is a tapered channel wave power device or also known as (TAPCHAN). This fixed WEC type was constructed in 1985 at Norway.

Overtopping wave power device is a wave harvesting device which has a huge structure that allows it to catch the sea water. When the wave reaches the channel, the water falls through the hole and passes through the turbine, which is connected to a rotating electrical generator. The turbine produces electrical energy from both potential energy and kinetic energy because potential energy is continuously converted to kinetic energy after a few moments. However, the majority of the most recent innovations in coastal structures have been related to enhancing their hydraulic performance specifically in relation to lowering reflection and overtopping, boosting structural stability and reducing impact forces.

As a result, new techniques for creating both conventional and unconventional breakwater designs were created (L. Franco, 1996). As an extension of earlier research on WECs overtopping devices, such as Wave Dragon (Kofoed et al., 2006), WaveCat (Fernandez et al.,

2012) a new WEC called Overtopping Breakwater for Energy Conversion (OBREC) is an ongoing project. To generate energy, the apparatus is comprised of a rubble mound breakwater featuring a front reservoir that is intended to catch overtopping waves. Then the low head turbines use the difference in water levels between the reservoir and the mean sea level to extract electricity. The Overtopping Breakwater for Energy Conversion (OBREC) from hydraulic perspective can be viewed as contemporary adaptation of the Phoenicians' rock wave-wall, also called a carved breakwater (J.L. Lara et al. 2008).

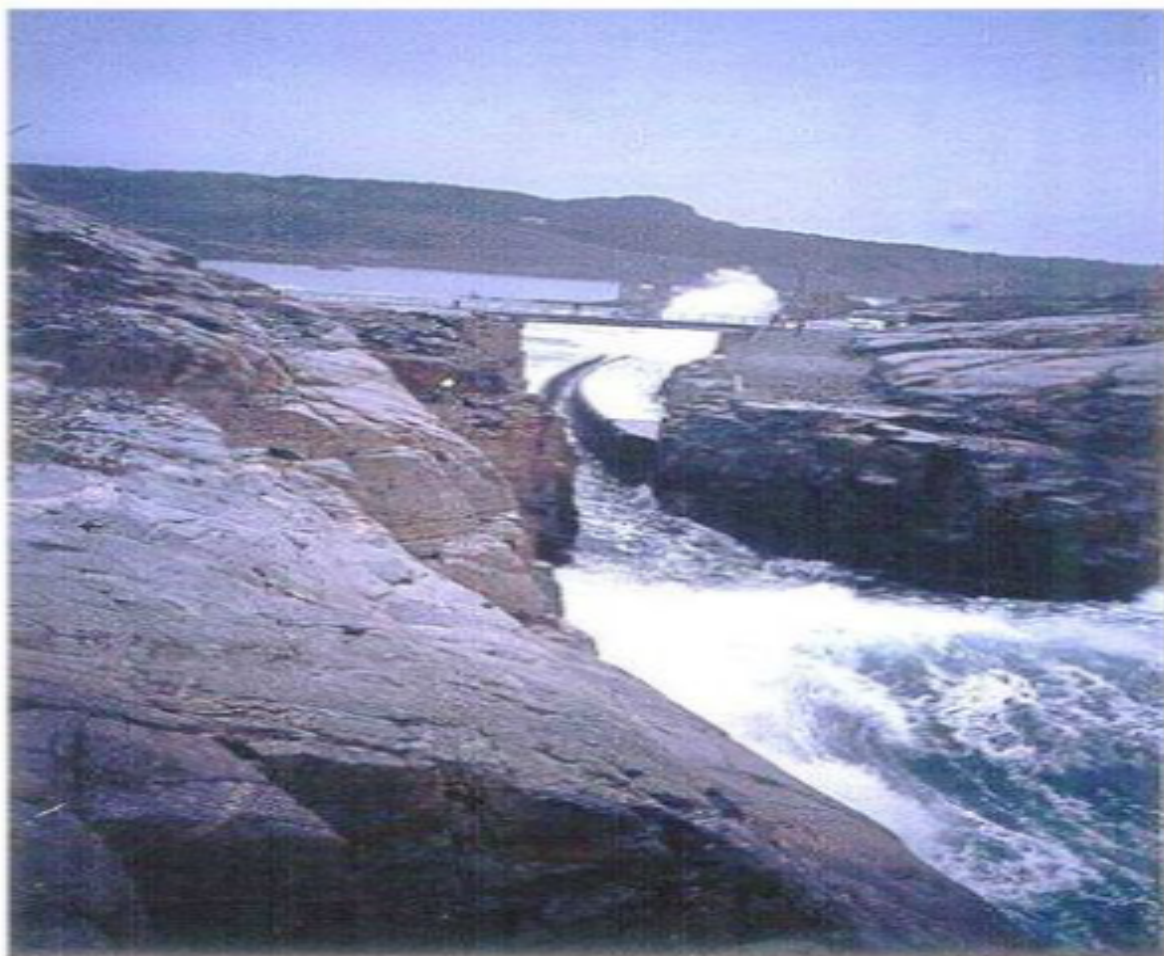


Figure 2.7 TAPCHAN constructed in Norway, 1985

2.5.2 ATTENUATOR

Ning et al. (2016) proposed a hybrid wave attenuation and energy harvesting structure (WAAEHS) combining the oscillating floating-type WECs with the vertical-pile-constrained floating breakwater, and examined the performance of this hybrid device based on linear potential flow theory. These devices incorporate a float, or a number of floats that are shaped or distributed to be aligned in the direction of wave travel. Their overall length may be large compared to the swell wavelength. However, they are also wavelength dependent. Unlike a point absorber they need to be slack moored so that they can be able to maintain their principal axis normal to the oncoming waves. (Jenny Hayward, et al. 2011)

Attenuator WECs lie parallel to the wave direction (i.e., have their principal axis perpendicular to the wave front) and effectively “ride” the waves [185]. From the perspective of the power capture type, attenuator WECs can be classified into two types: hinged-float-based devices and flexible-tube-based devices (see Figure 2.8).

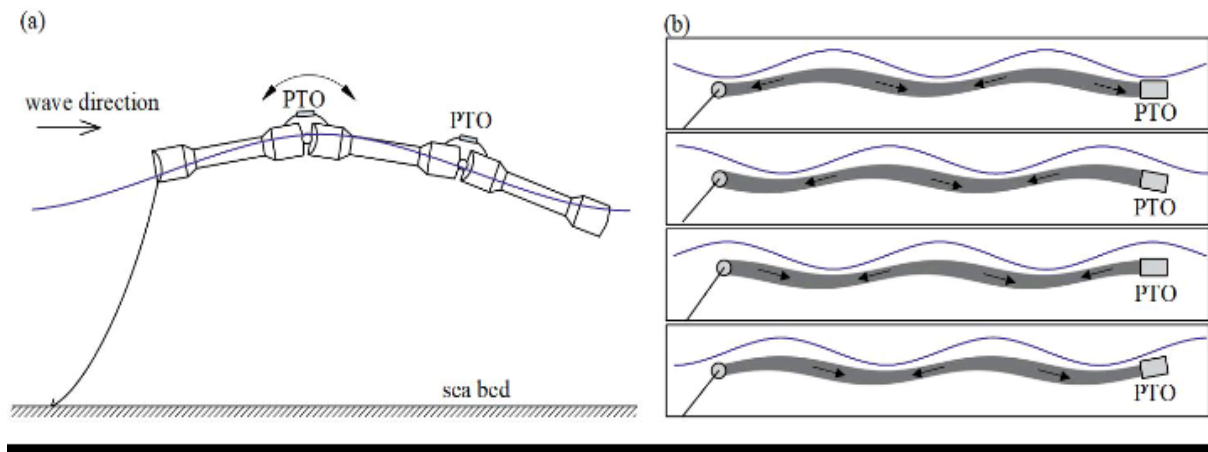


Figure 2.8 Working principles of attenuator devices: (a) hinged-float-based and (b) flexible-tube-based

Hinged- Float- Based

Most of the attenuator WECs that have been proposed so far are hinged-float-based devices (also called the “raft”-type WECs by many writers, a subclass of oscillating type WECs, which are generally composed of a series of semi submerged articulated floaters (Figure 6.1a). The hinged floaters use relative rotations around connection joints to drive a power take-off (PTO) system, such that the ocean wave energy can be converted into useful energy. The PTO system of a hinged-float based device generally consists of hydraulic cylinders and some other components. As ocean waves pass through the device, the movement around each hinge is excited, which in turn drives the hydraulic cylinders. The pressurized hydraulic fluid can be further used to drive a motor to generate electricity or pressure water for sea-water desalination.

Flexible- Tube Based

The flexible-tube-based attenuator WEC, which is also called a “bulge wave” device, is mainly composed of a fully submerged flexible tube. The tube is closed at both ends and filled

completely with water (Figure 6.1b). A “bulge wave” can be formed inside the tube under wave action. The bulge wave then drives a standard low-head turbine located at the far end of the device to generate electricity.

Attenuator is a multiple-segment device floating parallel to the direction of the waves. The actuation mechanisms usually utilize the rotational motion at the joints of the segments. The varying heights of waves at each joint of the device will actuate the hydraulic pumps or other PTOs. One typical attenuator is Pelamis, which has the PTO system driven by hydraulic cylinders at the joints.



Figure 2.9 Pelamis Wave Power

POINT ABSORBER

The Point Absorber concept was first defined in 1975 (Budar, K et. al, 1975) referring to a WEC with relatively small dimensions with respect to the wavelength. This device refers to devices that incorporate a float that is small compared to the swell wavelength. The float is free to follow the movement of the wave and accept wave energy from any direction. It can be tethered so that it is submerged and moved by the pressure of the wave passing overhead, or it can float on the surface and track or heave with the movement of the sea surface. (Jenny Hayward.etel., 2011). Point Absorber is a typical style of float oscillating body, which

usually utilizes a submerged or floating body to trap the oscillating force of the wave. It mostly uses vertical translational motion for its actuation mechanisms. The major advantage of point absorber is that it can harvest energy from waves in all directions at one point in the ocean. It's usually placed at or near the ocean surface away from the shoreline and may occupy a variety of ocean depths ranging from shallow to very deep water depending on the OWEC design and the mooring system. Point absorbers can be further classified as (1) one-body and multi-body Pas according to design geometry, (2) floating and submerged devices, according to the deployment manner and (3) single-DoF and multi-DoF prototypes, according to the operating DoFs.

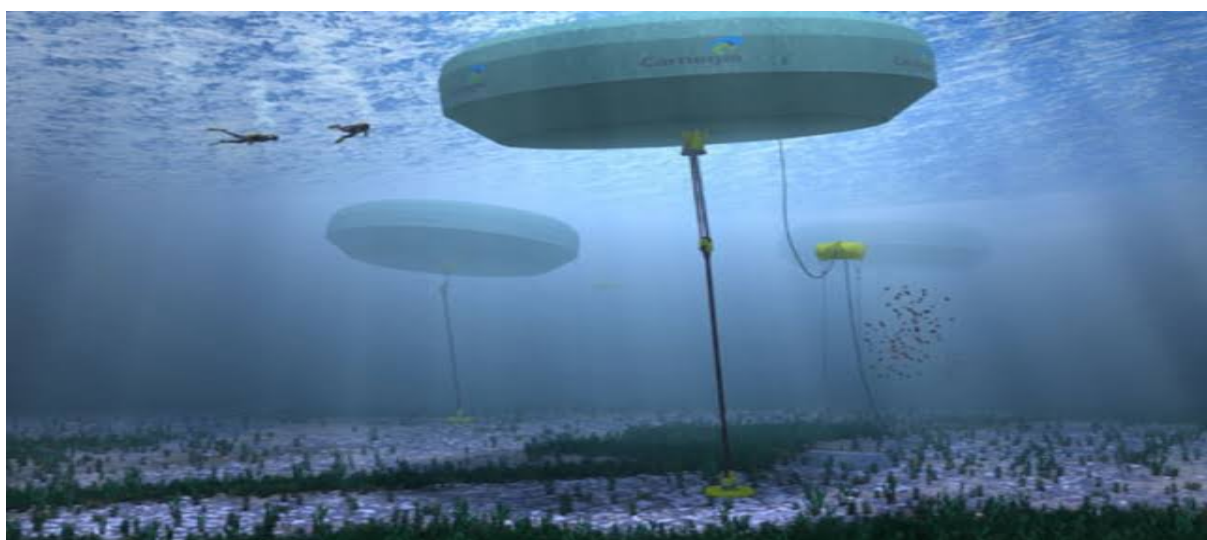


Figure 2.10 An Anchored Point absorber

OSCILLATING WATER COLUMN

The oscillating water column (OWC) has attracted huge attention for its environmental adaptability, strong durability and easy integration (Mustapa et al., 2017). The motion of the incident waves passing through the submerged opening, forces air to actuate the air driven turbine to realize energy. The turbine is an indirect wave energy conversion device which can be near-shore or off-shore. Shore-based OWCs such as: LIMPET 500 (Jingjin Xie, et. al 2013) . Some other device, like Mighty Whale is an OWC based device for offshore operation which

is a combination of both point absorber and OWC. Evans (1978) devised a basic analytical method based on potential flow and linear wave theory to ascertain an OWC's efficiency in absorbing wave energy. In two dimensions, the approximation dealt with two completely submerged parallel plates, or in three dimensions, a spherical tube. Owing to the comparatively low surface length to wavelength ratio, the chamber's free surface is thought to move like a piston, with the energy being collected by a float that is connected to a spring and damper system. In order to address the spatial variation and pressure distributions over the chamber free water surface, Evans (1978) extended his research by creating a pressure distributions over the chamber free water surface, Evans (1978) extended his research by creating a pressure distribution theory based on the earlier linear potential theory and establishing reciprocal linkages (Evans, 1982). Later, Falnes and McIver expanded the pressure distribution theory to include floating structure (Falnes and McIver, 1985). More recently, Celik and Altunkaynal (2018) studied the link between the chamber opening height and the free surface elevation profile under different wave circumstances in an analytical experimental investigation of bottom fixed OWC.



Figure 2.11 Oscillating water column installed in Australia

CHAPTER THREE

MATERIALS AND METHODS

The focus of this project work is to find ways to harvest available wave energy along the Atlantic Ocean shore line or some local towns located on the tributaries connecting the ocean. Within the catchment area of the University of Benin, several towns lies along the shoreline

and tributaries linking the Atlantic ocean. These are likely to have measurable wave activities that can be tapped and converted to electricity for the benefit of the locals. One of these shoreline or tributary towns closest to the University of Benin is Gelegele, an old seaport used for the slave trade of several centuries ago.

Figure 3.1 Location of Gelegele Relative to Parts of Edo State

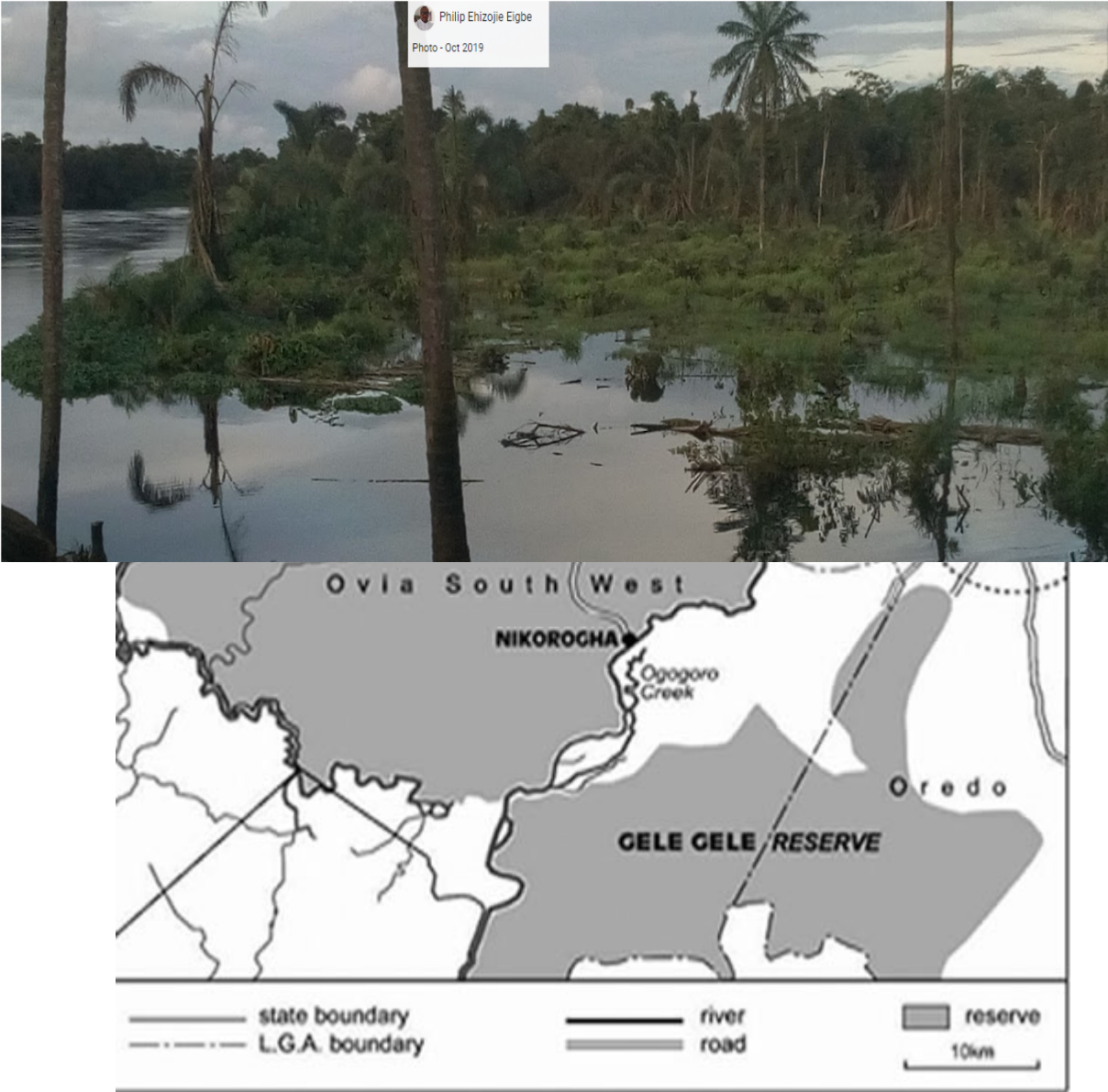


Figure 3.2 A Snap Shot of Parts of Gelegele Seaport (Philip Ehizojie Eigbe, 2019)

The primary objective of the design of the wave energy device targeted by this project work is to develop a simple device to harness wave energy with emphasis on simplicity, efficiency, adaptation of device to suit local conditions, the use of locally sourced materials and cost effectiveness of the device as the design criteria.

3.1 Methodology

Earlier in Chapter One, a brief summary of the methodology to be followed in the execution of this project work was given. In line with that summary the methodology to be followed is hereby broadened as follows.

1. Carry out a physical survey of the location suitable for exploitation.
2. Measurement of the average wave height, timing of wave cycles, frequency of wave occurrence, water depth.
3. Design of a suitable wave energy tapping device
4. Find out if the materials for the design are available locally
5. Determine if the engineering facilities are available for fabricating the component designed.
6. Estimate the cost for all the component required

3.1. Determination and the Physical Survey of a Suitable Location

3.1.1 Site Selection

Upon arrival at the chosen location at about 11:00am and upon making several inquiries through residence, we were directed by to a water front claim by the locals to be free of human activities and having considerable wave activity. The location is called Gelegele Olidiana. During the site selection we were able to confirm the claims made by the locals.



Figure 3.3 Entrance of Gelegele community, Ovia North-East L.G.A.

3.1.2 Site Survey and Information

This location is quite large, measuring about 40.1km from University of Benin main gate to the community. We left main gate by 9:00am and arrived at 11:00am at the community and immediately we were called upon by the community security officers for a short inspection and interrogation. Before we started carrying out measurement, we were informed by the locals that the wave activity varied depending on the time of the day. According to the information gathered, the wave activity is least in the morning and evening but at its peak at noon from around 2pm to 4pm. So we waited till the wave activity was at its peak before carrying out measurement.



Figure 3.4 Snap shot of Gelegele Olidiama River Spot, 2024

3.2 Data Collection

The wave activity experienced here at Gelegele Olidiama seaport is not a highly intense kind of wave activity compared to what is experience at a very active ocean front. The rise and fall are just moderate and therefore would only be suitable for a low-level kind of wave energy harvesting device. The following report gives an insight into the level of wave activity going on at this location.

3.2.1 Wave Height

The rise and fall of the water surface is an activity which is the result of human activity and natural forces. Human activity like the movement of objects over the water surface or below the surface of a body of water can cause ripples that accumulate to form larger ripples and eventually waves that propagates in the form of troughs and crests which are then seen as the rise and fall of the surface of the body of water. At this location a depth measuring staff was found installed and it was graduated to read off the depth of water at any time..



Figure 3.5 Photo of the fixed stick calibrated for measuring the wave height

The observations were made and the results are as follows;

| Parameters | Values |
|----------------|--------|
| Wave height | 22cm |
| Wave period | 1.13s |
| Wave height | 22cm |
| Wave frequency | 0.88Hz |
| Water depth | 67m |

Table 3.2a Table of Readings of Wave Data Collected

3.2.2 Wave Frequency

The method of the pole as a reference point was also implemented in determining the wave period. We made use of a stop watch to record different time intervals as the water wave cut across the pole. We then derived the wave frequency by measuring the inverse of the wave period.

$$T = \frac{\text{number of cycles}}{\text{time taken (s)}}$$

$$F = \frac{1}{T}$$

Where $F = \text{frequency}$, $T = \text{Period}$

3.2.3 Depth of the Body of Water at this Location

In determining the depth of the water, we had to improvise because we didn't have enough accurate equipment to determine the water depth. We attached a weight to the end of a string rope and kept on releasing it till it got to the bottom of the water then we marked. We brought

it out and measured the part of string that was fully immersed in the water with a tape. We did this for several locations and got different depth at different points.

3.3 Design of a Suitable Wave Energy Tapping Device

In pursuit of these objectives, two distinct design concepts were explored and proposed; Oscillating water column and magnetic point absorber

3.3.1 Concept one: Oscillating Water Column

This design concepts harness wave energy by using the rise and fall of water within a chamber then the air inside the chamber is compressed or extended to actuate an air-driven turbine and generate electricity.

Design Stage

For the first concept, we made use of AutoCAD 2016 software to create designs for various component, starting with the well turbine and subsequently moving on to the water column. After completing the individual designs, we proceeded to assemble the component.

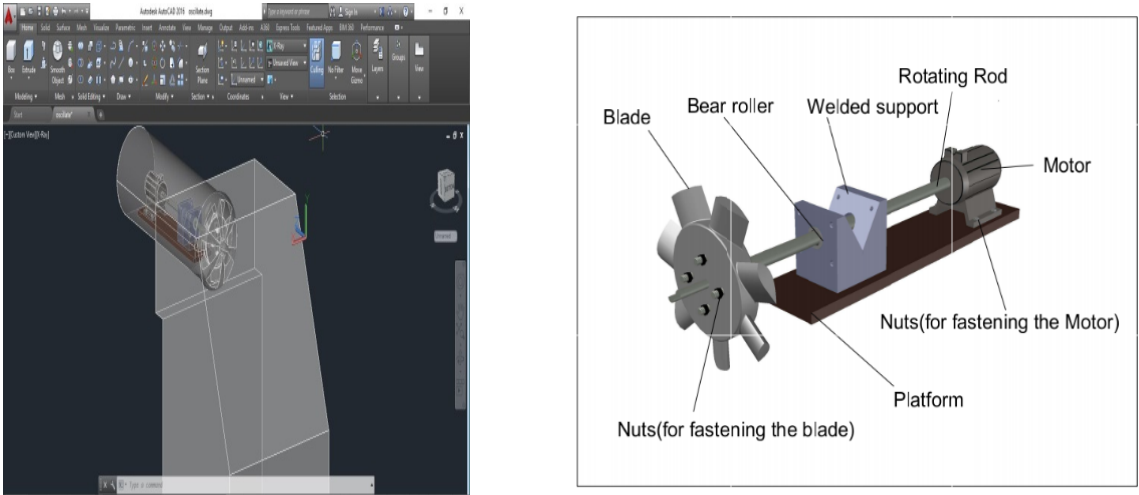


Figure 3.5 Auto CAD Design of an oscillating Water Column

Prior to moving further with the simulation, we conducted additional study on the compatibility of our design concept using site data, and we discovered a few design flaws.

Challenges of Oscillating Water Column

- i. **High Initial and Maintenance Cost:** The OWC systems require specialized power take-off systems, such as turbines or linear generators to convert the oscillating motion of the water column into usable electricity. These components can be expensive to manufacture and install.
- ii. **Mechanical Complexity:** The Oscillating water column involves complex mechanical components such as the well turbines, air chambers and power take-off system.
- iii. **Environmental Impact:** The fixed structures of the Oscillating Water Column anchor to the seabed can alter local currents and potentially impact marine life. Also the sound produced by the well turbine can cause disturbances to marine habitats.
- iv. **Variable Energy Output:** A major problem of the Oscillating Water Column is the bidirectional airflow caused by waves. Well turbines, can be less efficient at higher airflow rates.
- v. **Air Leakage:** The OWC especially fixed ones can be susceptible to air leakage from the chamber and vortexes which eventually reduces efficiency.

3.3.2 Concept two: Point Absorber with magnet

A wave point absorber consists of a floating structure that moves up and down with wave motion. This floating structure can be buoy or a platform. Inside the floating structure, a permanent magnet is mounted. Below the magnet, a fixed cylinder houses a coil of wire. As the waves cause the floating structure to moves relative motion induces an electrical current in the coil according to Faraday's law of electromagnetic induction. The magnitude of the induced current depends on the strength of the magnet, the number of turns in the coil, and the velocity of the magnet's movement relative to the coil.

3.3.3 Design Component

Overview of utilized modeling software

The design of the point absorber was done using Fusion 360, a 3D computer-aided design (CAD), manufacturing (CAE) software developed by Autodesk. It is a cloud-based platform that integrates design, engineering and manufacturing processes in a single interface. It also includes simulation capabilities for testing the structural, thermal and modal properties of designs, helping to optimize performance and reduce physical prototypes.

Life buoy

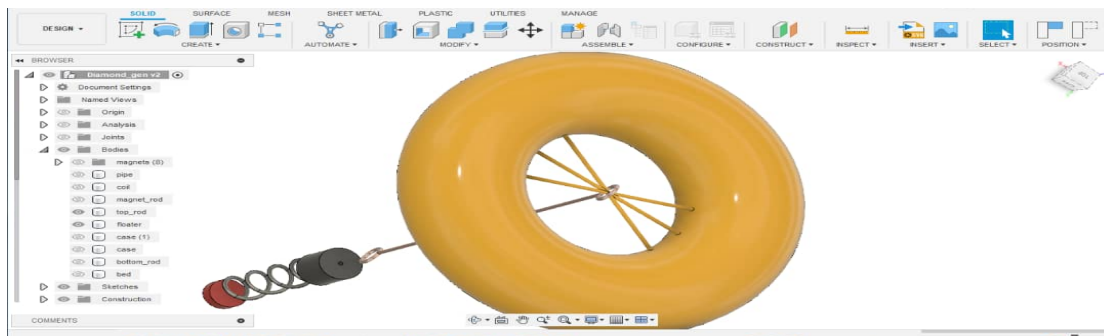


Figure 3.7 A design life buoy with fusion 360 autodesk

Safety buoy with a diameter of 0.5m was design to keep the device afloat. The buoy weight is lesser than the total weight of the component under the water. This is done to validated Archimedes principle of floatation.

Metal rod

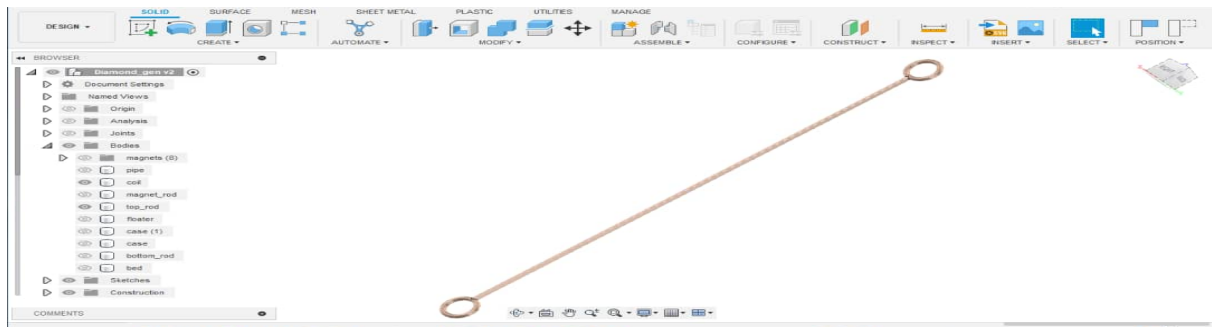


Figure 3.8 A metal rod with fusion 360 autodesk

The stainless rod was design to have circular hook that connects the movement of the buoy to the magnet. It used instead of a rope because of it durability. It length is 12.5cm long having a 0.5cm diameter.

Magnet

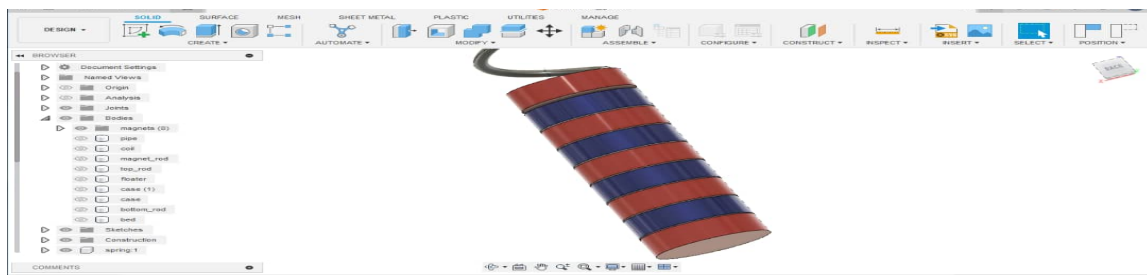


Figure 3.9 A designed cylindrical magnet with fusion 360 Autodesk

For the magnet to be able to move across the coil efficiently a bar cylindrical magnet was designed instead of a ring magnet which might not properly align in the housing due to its size. The magnetic field strength of the magnet is 0.5 Tesla and the diameter size is 0.01m.

Copper wire

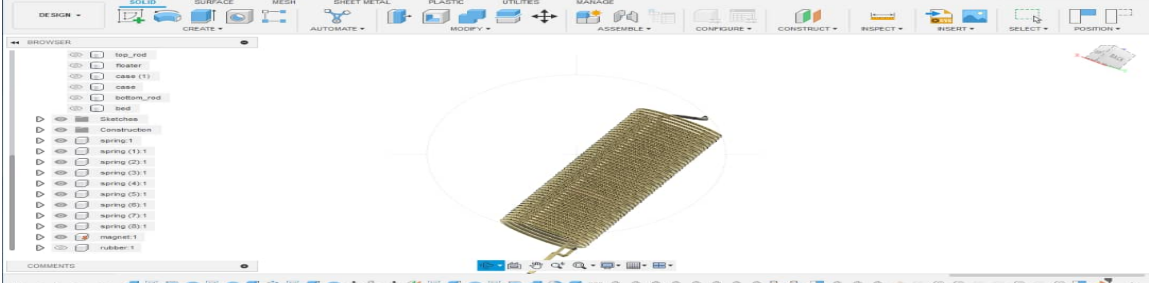


Figure 3.10 A designed copper wire buoy with fusion 360 Autodesk

The copper wire was turn 50 turns around the PVC pole having a radius of 0. 5mm. The loops or windings can be tightly packed or loosely spaced but the former was used in the case of this project.

Compression spring

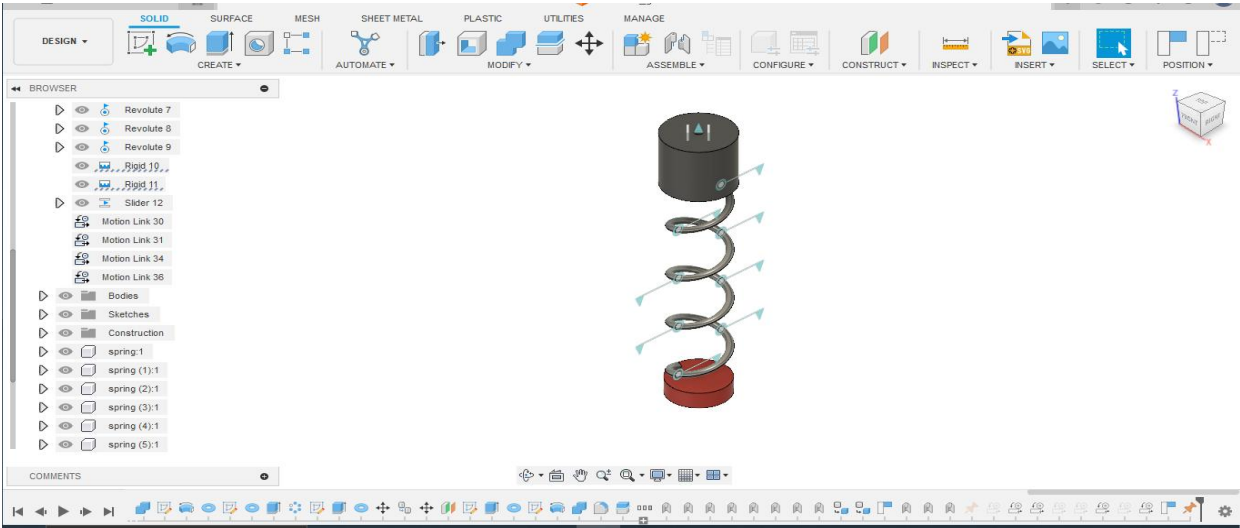


Figure 3.11 A designed life compression spring with fusion 360 Autodesk

The compression spring is placed between the fixed point on the buoy and the movable component; the rod connecting the cylinder magnet to the buoy. During compression the movable part is loaded and hence the magnet assemblies remains in a specific position within the coil, creating a consistent gap for optimal voltage generation when waves move the buoy. Also the compression spring is design to assist the magnet in returning o its optimal position within the coil when the wave energy subsides.

Heave plate and housing

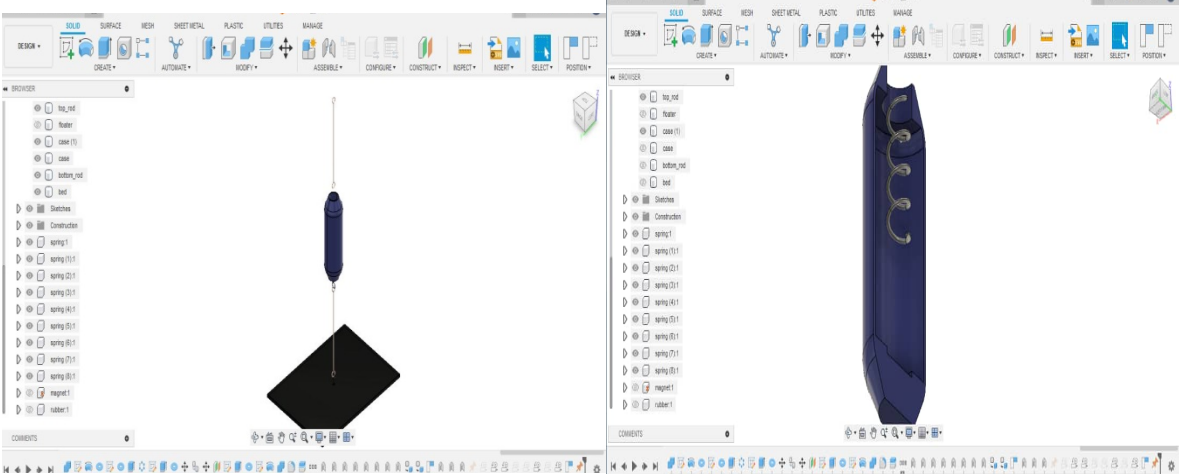


Figure 3.13 A designed housing and heave plate with fusion 360 Autodesk

The heave plate of 1.5m diameter was used as the anchor plate due to the high large surface area impact on the seabed.

Table 3.2b of comparison of the design concept

| | | | | | | |
|----------------|------------|------------|------|----------------------|---------------|-------------|
| Design Concept | Simplicity | Efficiency | Cost | Environmental Impact | Survivability | Scalability |
|----------------|------------|------------|------|----------------------|---------------|-------------|

| | | | | | | |
|-------------|----------------------------------|---|---------------------------------------|----------------------|--------|-----------------------------------|
| Concept one | Complex in designing wall column | Can vary depending on design | High initial and maintenance cost | High negative impact | Strong | Difficult to scale a well turbine |
| Concept two | More simpler to design | Higher efficiency due to direct conversion of wave motion | High initial but low maintenance cost | Less negative impact | Strong | Easy to scale |

Based on the ratio of comparison and description from our site survey, the design to be used should be able to harness energy from small waves, simple to design, must have low maintenance cost efficient, must be scalable to different unit and have less negative impact to the water environment. Based on the criteria, ratio of comparison and observation from our site survey, we selected concept two for detail design and development. Concept one can be an alternative in a different site having high wave activity.

3.4 Material Selection and Market Survey for Material

Due to the methodology of this project, we selected materials to be used for this design based on cost, durability, efficiency and availability. Also a market survey was done on where the materials can be purchased.

Table 3.2c of material selection and availability

| S/N | Preferred Materials | Material type | Place of availability |
|-----|---------------------|----------------------------------|-------------------------|
| 1 | Life buoy | Plastic | Local vendor |
| 2 | Rod | Stainless rod | Hot shop |
| 3 | PVC casing | Aluminum | Electrical store |
| 4 | Magnet | Neodymium rectangular bar magnet | Electrical/machine shop |
| 5 | Copper wire | Copper | Electrical store |
| 6 | Compression spring | Compression type | Automobile workshop |

We used fishing bobber as the buoy in the design because it's readily available, inexpensive and it also provides enough buoyancy to demonstrate the rise and fall motion caused by waves. Also the bright visibility of the fishing bobber makes it easy to track the movement of your design. Metal rod was used instead of a rope because it's more rigid and it helps maintain precise alignment between the magnet and the copper coil. Rope can degrade over time due to exposure to sunlight and friction but a metal rod is less affected by these factors and hence it can provide a longer lifespan for the device. PVC was used in the design because it is cheaper than most metal and it is much lighter, this makes it easy for the device to be deployed and tested in an environment. PVC piped is lightweight and very easy to cut, drill and connect using solvent or adhesives and with these characteristics it enhances quick modifications and adjustments during development stage. We used a neodymium rectangular bar in the design with strength of 1500 Gauss (1.5 Tesla). A weak compression spring was used as a buffer at the

bottom of the rod to limit the downward movement of the magnet and restrict it from hitting the bottom of the housing.

3.5 Tools and Fabrication Facilities Availability

For fabrication to be carried out on this design, specific tools and facilities must be available or affordable. Hence we made our research and conduct our physical survey of the location of the basic tools and facilities needed.

3.5.1 Tools needed for fabrication

The following are the fundamental engineering tools or machinery required for component assembly, drilling or cutting during the fabrication phase

- a. Drilling machine
- b. Utility knife
- c. Pliers
- d. Small caliper

a. Drilling machine

This tool has a twisted drill bit and it will be needed to create hole in the PVC pipe, metal rod and other component for assembly. This tool is available in machine shop and woodwork workshop.

b. Utility knife

This tool is useful in scoring marked line, cutting and creating shapes with the PVC materials. Also utility knife can be carefully used to strip a short section of insulation from the ends to expose the metal conductor for electrical connections. Utility knife can order and purchased from retailers like eBay, Aliexpress and even from building stores.

c. Pliers

This tool will be needed for gripping and manipulating the copper wires. Also if there is a need for a tool to hold small component together while securing them with glue tape, the plier is best suitable for the task. This tool is one of the most important engineering instruments and it can be found in any electrical work shop or school laboratory.

d. Small Caliper

This tool will be useful in taking precise measurements of the coil winding. This instrument is available in an electrical workshop.

3.5.2 Facilities/workshop

Apart from having the basic tools or equipment, a workshop that is conducive and well equipped is required for effective fabrication. Based on the nature of our project we found out two vital workshop, namely;

a. Hot shop

b. Electrical shop

a. Hotshop

During our Engineering Laboratory training we were educated on the function of an hot shop and hence we recommended the facilities for constructing and welding rod that will anchor the device to the bottom of the water.

b. Electrical workshop

This workshop will be conducive for measuring the copper wire, connecting the magnet to cut across the coil. The multimeter as a very important tool in this design can be found in an electrical workshop which functions in measuring the voltage induced from the magnetic flux.

3.6 Bill of Material and Quantity

| S/N | Parts | Quantity & dimension | Estimated cost |
|-----|----------------|--|----------------|
| 1 | Fishing bobber | 1 pieces, 4grams, 2'' in diameter, 3'' in length | #2500 |
| 2 | Metal rod | 3 pieces, 0.5cm in diameter, 12mm in length, 500kg | #12000 |

| | | | |
|-------|--------------------|-------------------------------------|---------------|
| 3 | Magnet | 1 pieces, 150mm in diameter | #2000 |
| 4 | Copper wire | 400000cm in length, 3cm in diameter | #4000 |
| 5 | Compression spring | 2 pieces, 3cm in diameter | #320 |
| 6 | Heave plate | 1 piece, 1.5cm in diameter | #2000 |
| 7 | PVC casing | 4'' diameter, 10mm in thickness | #2000 |
| TOTAL | | | #24820 |

Table 3.6 Table of bill of material and quantity

CHAPTER FOUR
RESULT AND DISCUSSION

In accordance with the methodology outlined in chapter 3, the findings and analysis derived from our measurements of wave activity and the resulting induced voltage are stated below

4.1 Result Analysis For Wave Activity In Gelegele Olidiama Community

Wave Period and wave frequency

| S/N | Wave period (T) | Wave frequency (f) | Time of measurement(t) |
|-----|-----------------|--------------------|------------------------|
| 1 | 0.89 | 1.12 | 11:15pm |
| 2 | 0.9 | 1.1 | 12:45pm |
| 3 | 1.1 | 0.9 | 2:15pm |

Table 4.1a Table of result of the wave period and frequency taken at different time interval

With the use of a digital stop watch we calculated the wave period for different time. The number of cycle used which is also known as the Wave crest (n) is 20cycles, then we carried out our measurement at 12:15pm, 12:45pm, and 2:15pm respectively. Below are the result obtained;

$$\text{Wave period} = \frac{t}{n} = \frac{17.54}{20} = 0.89$$

$$\text{Wave period} = \frac{t}{n} = \frac{17.9}{20} = 0.9$$

$$\text{Wave period} = \frac{t}{n} = \frac{22.2}{20} = 1.1$$

$$\text{Average period} = \frac{T_1+T_2+T_3}{3} = \frac{0.89+0.9+1.1}{3} = \frac{2.89}{3} = 0.96s$$

We examine from our findings that the wave period differs at different time of the day. We then made inferences based our knowledge and observations from the locals that the wave period at Gelegele community is higher in the afternoon.

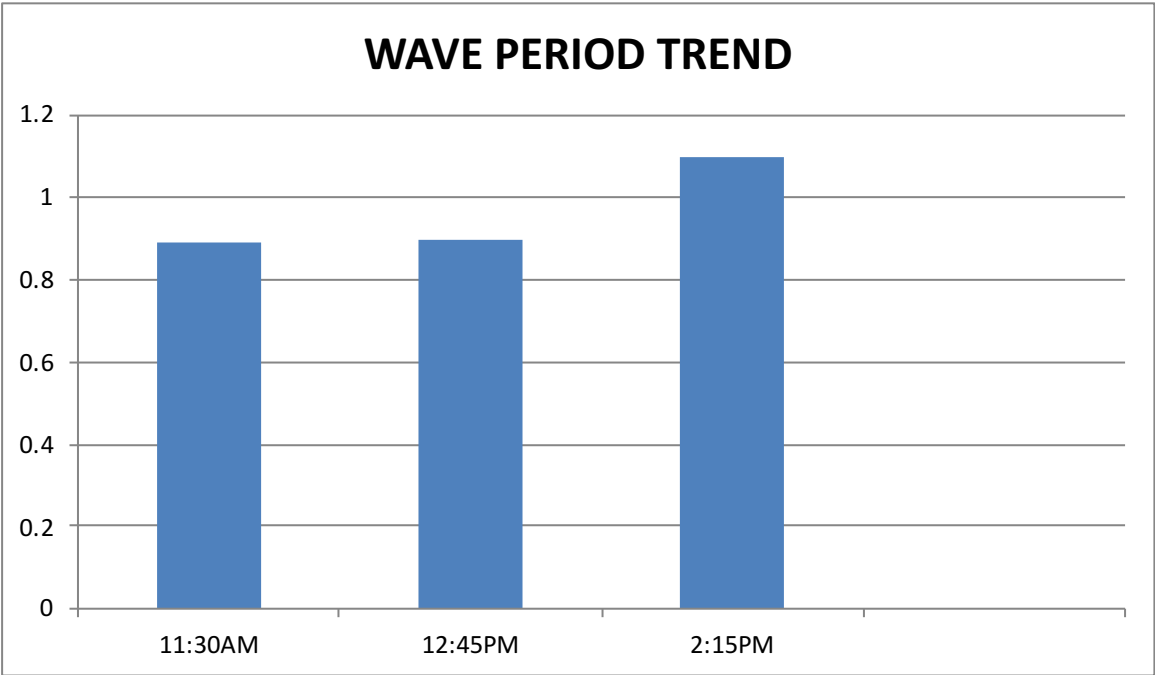


Table 4.1b Table of result of wave period trend measured in Gelegele Olidiana

Wave Height

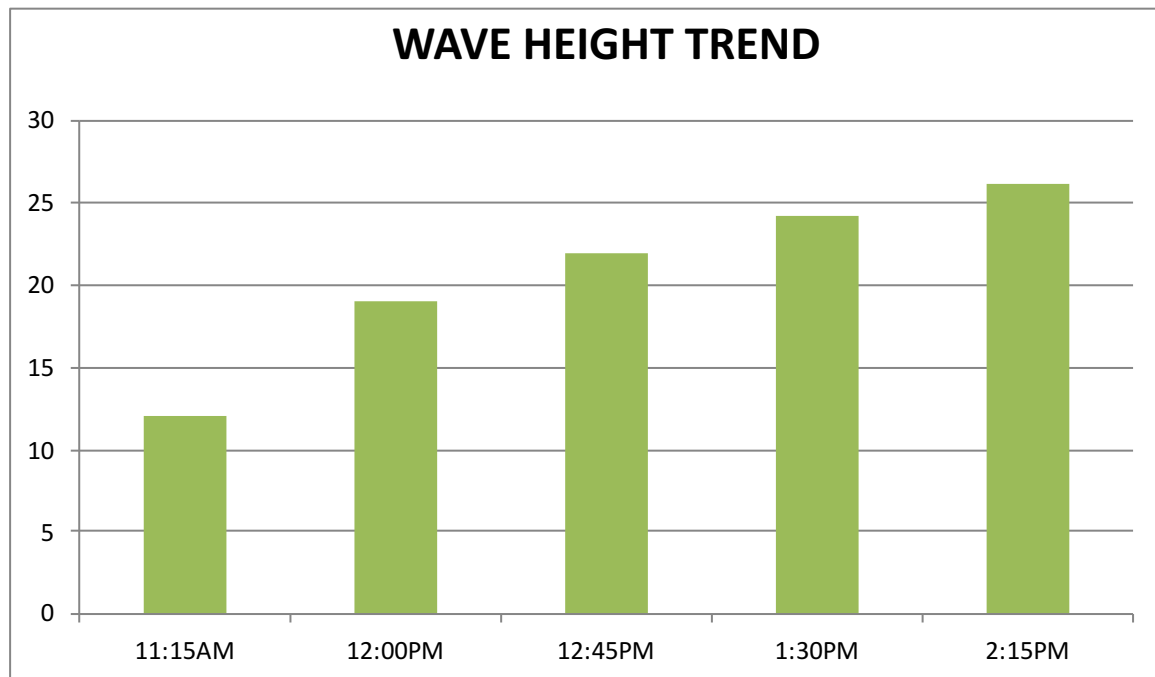
Table 4.1c: Table of wave height measured in respect to time

| S/N | Wave height (cm) | Measurement time |
|-----|------------------|------------------|
| 1 | 12 | 11:15am |
| 2 | 19 | 12:00pm |
| 3 | 22 | 12:45pm |
| 4 | 24.3 | 1:30pm |
| 5 | 26.2 | 2:15pm |

$$\text{Average wave height} = \frac{H_1+H_2+H_3+H_4+H_5}{5} = \frac{12+19+22+24.3+26.2}{5} = 20.7\text{cm}$$

From analyzing the result, we observed that as the measurement was taken five times at 45 minutes interval the wave height increases having an average wave height of 20.7cm.

Table 4.1d: Table of Wave trend analyzed at Gelegele seaport



4.1.3 Water depth

The water depth for the spot = 150 cm

The water depth measured at the middle of the river = 670cm

We measured the water depth from different position and we observed that deeper water propagates stronger waves than shallow water. On further analyzing and observation we discovered that in shallow water, the water particles near the bottom are restricted in their circular motion by the seabed. This is why the wave we observed was moderate.

4.1.4 Wave velocity

Considering how the wave velocity will affect the reciprocating movement of our design submerged in the water, we analyzed the wave period and gravity to determine the trends in the wave velocity.

$$V = g \frac{2\pi}{T}$$

Where v = wave velocity, g = acceleration due to gravity, T = wave period

$$v = 9.81 \times \frac{2\pi}{0.89} = 69.25 \text{ m/s}$$

4.2 Analysis of Result of the Induced voltage

Relationship between Wave period and The Electromagnetic force

The wave period influences the range of the change in time (dt) needed in determining the induced voltage. We analyzed that during one wave period (T), the magnet in the point absorber will complete one full up and down cycle within the coil. We then went further to breakdown the wave period into countless infinitesimal time intervals (dt)

$$T_1 = 0.89$$

$$T_2 = 0.9$$

$$T_3 = 1.1$$

Number of interval = 2

$$\text{Average } dt = \frac{T}{N}$$

Using the average period (T) = 0.96s

$$dt = \frac{0.96}{2} = 0.5s$$

Tables 4.2a; Tables of the Wave period analysis with time

| S/N | Wave period (T) | Change in time (dt) |
|-----|-----------------|---------------------|
| 1 | 0.89 | 0.44 |
| 2 | 0.9 | 0.45 |
| 3 | 1.1 | 0.55 |

We confirmed from our result that increase in the wave periods leads to increase in the movement of the magnet in the coil

4.2.1 EMF Mathematical Simulation

The reciprocating motion of the magnet across the coil result to a magnetic flux and to a magnetic flux and for the induced voltage to be determined we employed the principle of faraday law of electromagnetism.

$$Emf = -N \frac{d\phi}{dt}$$

Where; Emf = induced voltage, N = number of coil turns, $d\phi$ = magnetic flux, dt = change in time

Number of coil used = 50 turns,

Time (dt) = 0.5s

Radius of wire = 0.25mm

$$\text{Area of the wire} = \pi r^2 = 3.14 \times 0.25 = 0.8 \text{ mm}^2$$

$$\text{Magnetic field strength (B)} = 1 \text{ T}$$

$$\text{Magnetic flux } (\phi) = B \times A = 1 \times 0.8 = 1.8 \text{ Wb}$$

$$\text{E.M.F} = -50 \times \frac{1.8}{0.5} = -180 \text{ v}$$

Analysis of the Power Output

$$P = IV$$

Where;

P = power, I= current, V= voltage

In measuring the current produced by our design, the ammeter or galvanometer is the appropriate instrument to use. Although the challenge is that we can only employ such method if the design was fabricated. Nevertheless, we improvise with mathematical simulation or formula to obtain our values.

Step 1

Determine resistance of the wire

$$R = \frac{\rho l}{A}$$

Where; ρ = resistivity, l = length, A = area and R =resistance

$$\rho = 1.68 \times 10^{-8},$$

$$L = 15700$$

$$A = 3.14 \times 0.003^2 = 2.82 \times 10^{-5} \text{ mm}^2$$

$$R = \frac{\rho l}{A} = \frac{1.68 \times 15700}{3.14 \times 0.003^2} = 9.3 \text{ ohms}$$

Step 2

We use ohms law to determine the current from the resistance and voltage

$V=IR$, where V = voltage, I =current, R = resistance

$$I = \frac{V}{R} = \frac{108}{9.3} = 11.61A$$

$$\text{Power} = IV = 11.61 \times 108 = 1253.88W = 1.25Kw$$

4.3 Analyzing Factors Influencing The Output

We analyzed based on the result we got and we observed that there are three major parameters that affect the induced voltage generated. These are ;

- a. The number of turns
- b. The magnetic strength
- c. The speed of magnet across the coil

Number of turns

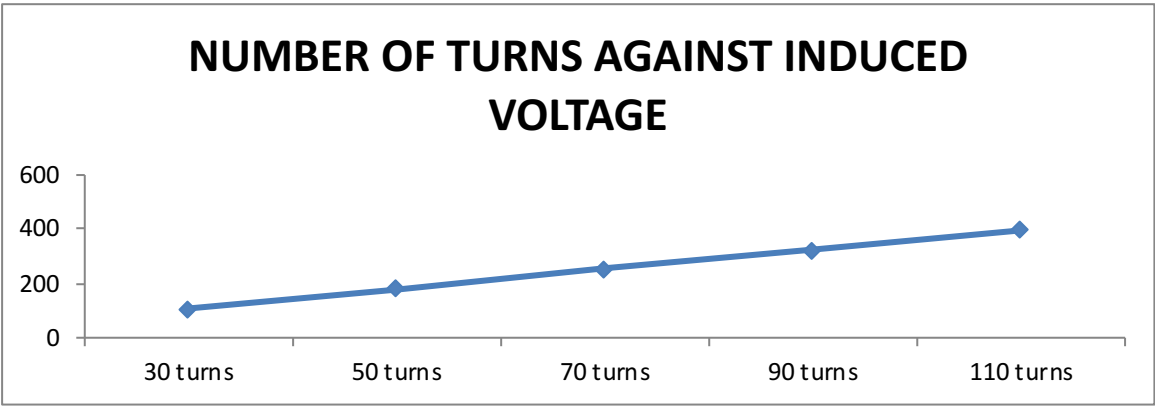
After conducting the mathematical simulation using electromagnetic induction for the different number of turns of the copper wire, we observed that increase in turns of the coil leads to increase in the induced voltage.

Table 4.3a; Tables of the estimated Induced voltage in respect to number of turns

| S/N | Number of turns | Induced voltage (E.M.F) |
|-----|-----------------|-------------------------|
| 1 | 30 | 108v |
| 2 | 50 | 180v |
| 3 | 70 | 252v |
| 4 | 90 | 324v |
| 5 | 110 | 396v |

From our result analysis, the number of turns in the coil might be suitable for low voltage generation, but potentially more turns could be explored for higher output. Hence to improve the power efficiency of our designs, the number of coil used should be above 50 turns as the induced voltage increase when then the number is higher.

Table 4.3b; Chart Area of the Induced voltage relationship with number of turns



4.4 Discussion

The project was carried out according to the aims and objectives outlined in chapter one and was done within the scope of work stated. The wave activity experienced in the community of Gelegele was studied and analyzed. The data collected from the site gave us the insight of the best suitable wave energy harvesting unit to design. Estimation of materials and dimension were taken to design a point absorber using magnetic induction principle to generate electricity. The design was done with the software, Fusion 360 which utilizes Computer –Aided Design (CAD) and Computer Aided Engineering (CAE) for geometric and mathematical modeling.

The value obtained from our device was 108v and the power output simulated was 1.27Kw per wave period. This power can be utilized to run street light and phone charging center for locals. This design can be improved to be more efficient if the materials quality, quantity and wave activity increases.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The main findings and achievement of the project work are stated below;

- a. Wave activity in Gelegele community was surveyed and data collected. The observation is the community experience low waves compare to another coastal region in Nigeria.
- b. Design and developed a point absorber to harness energy in site that experienced low waves
- c. The device is simple to design and materials are less expensive and easily affordable. Also the device can be scale to different size and the power can be integrated together to yield enough energy as the output
- d. The device designed gave an output of 180v per 0.5s. If we have 10 of the same device installed in the site, the energy yield will be equivalent to 1800v.

5.2 RECOMMENDATION

Our design concept can improve in the following ways given more time and proper funding;

- A battery should be added to the device as storage and dispersion of power when the wave is low.

- Multiple magnets can be added to generate high magnetic field strength for maximum output.
- Further study of the wave activity should be done to determine the current wave trend
- IMO and other marine bodies should give access to young engineers to explore wave activity in the country as backup plan for power generation
- This device should be fabricated, tested and installed in Gelegele community and location having similar wave activity.
- Raise public awareness and acceptance of wave energy as a clean and renewable energy source through education; seminar, academic conferences
- Facilitate knowledge sharing and collaboration among researched, developers and stakeholders to promote the lessons learned from the wave energy project.
- Develop a clear framework for the deployment and operation of wave energy converters to ensure environmental protection, safety and compliance with international standards

REFERENCES.

- Ning D.Z., Zhao, X.L., Goteman, M., Kang, H.G., (2016) 'Hydrodynamic performance of pile-restrained WEC-type floating breakwater; an experimental study' *Renewable Energy*, 95, pp. 531-541
- Evans DV, R Porter., (1995) 'Hydrodynamic characteristics of an oscillating water column device' *Applied Ocean research* 17(3), pp 155-164
- Falnes, Johannes (2007), 'A review of wave-energy extraction' *Marine structure* 20 (4), pp 185-201
- Sanil Kumar.V, Shanas PR and Dubhashi K.K.(2014) 'Shallow water wave spectral characteristics along the eastern Arabian Sea' *Natural hazards* 70(1), pp(10)
- Mohammed Faizal, Ahmed .M. Rafiuddina and Young-Ho Lee (2014) 'A design outline for floating point absorber wave energy converters' *Advances in mechanical Engineering* 6, 84(6), pp97
- Amir Vosough.,(2011) 'Wave energy' *International journal of multidisciplinary sciences and engineering*, 2(7), pp 60-63
- Dr. Sharmita Nandi., (2023) 'Wave energy – the renewable energy of the future' *Journal of research in humanities and social science*, 11(2), pp 275-281
- Kofoed Jens Peter, Frigaard Peter and Kramer Morten Bech., (2006) 'Recent development of wave energy utilization in Denmark' 31(5), pp 181-189
- Budar K and Falnes Johannes., (1975) 'A resonant point absorber of ocean-wave power' *Nature* 256, pp 478-479
- Mustapa M.A, Yaakob O.B and Ahmed Yasser., (2017) 'Wave energy device and break water integration: A review' *Renewable and sustainable energy reviews* (77), pp 43-58

- Altunkaynak Abdusselam and Celik Anil., (2020) ‘Determination of hydrodynamic parameters of a fixed OWC by performing experimental and numerical free decay tests’ *Ocean engineering* (204), pp 26-32
- Falnes Johannes and McIver P., (1985) ‘Surface wave interactions with systems of oscillating bodied and pressure distributions’ *Applied ocean research* 4(7), pp 225-234
- Hayward Jenny, Peter Osman (2011) “The potential of wave energy” *CSIRO*
- Renzi.E.,Wei.Y, Dias.F, (2018) “The pressure impulse of wave slamming on oscillating wave energy converter” *Journal of fluids and structures* 3(82), pp 258-271
- Bingyong Guo and John, V. Ringwood (2021) ‘A review of wave energy technology from a research and commercial perspective’ *IET renewable power generation* 14(15), pp 3065-3090
- Uihlein, A. and Magagna, D. (2016) ‘Wave and tidal current energy- A review of the current state of research beyond technology’ *Renewable and sustainable energy reviews* 58, pp 1070-1081
- Ameya Paleja (2023) ‘Beating heart-inspired wave energy converter now closer to deployment’ *Interesting engineering*.
- Smith, J. (2023). ‘Wave energy potential: A review of global resources.’ *Renewable Energy*, 45(2), pp 123-135
- Scott, W., and Hughes, D. (2022). ‘Wave energy resource assessment in challenging oceanographic environments: Case study of the North sea’. *Renewable energy*, 38(1), pp 78-91
- Johnson, A., and Williams, B. (2022). ‘Wave energy conversion technologies: A comprehensive review.’ *Journal of ocean engineering*, 18(4), pp 567-578

Charlier, R.H., and Babarit, A. (2013). 'Wave energy converters: A review proceedings of the institution of mechanical engineers' *Journal of engineering for the maritime environment*, 22793), pp 177-196

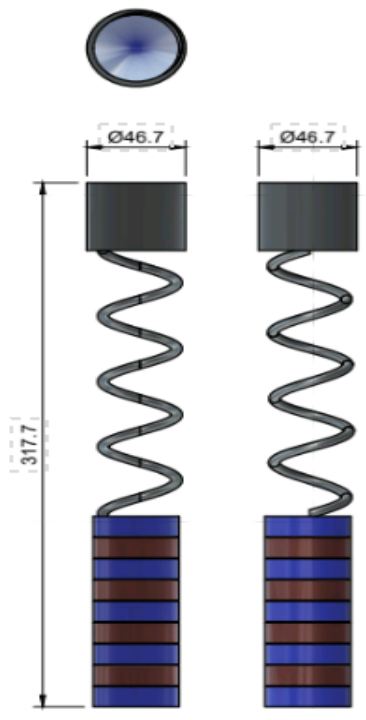
Oumer, A.N. (2019). 'A comprehensive review on wave energy conversion technologies' *Energy reports*,5, pp 688-698

APPENDIXES.

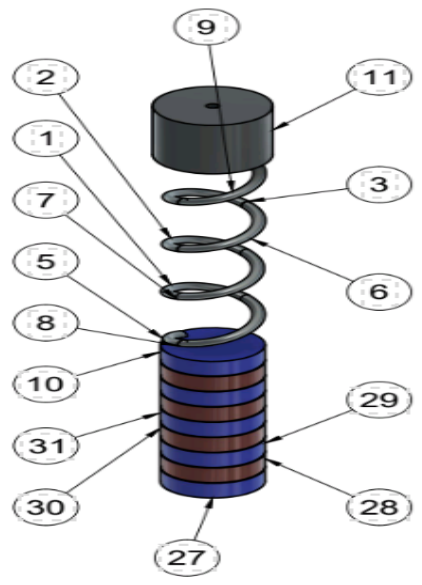








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| | | Document type | Document status |
| | | Title Design | DWG No. |
| | | Rev. | Date of issue |
| | | | Sheet 2/5 |



| Parts List | | | |
|------------|-----|-------------|---------------------|
| Item | Qty | Part Number | Material |
| 1 | 1 | Spring | Steel |
| 2 | 1 | Spring (1) | Steel |
| 3 | 1 | Spring (2) | Steel |
| 4 | 1 | Spring (3) | Steel |
| 5 | 1 | Spring (4) | Steel |
| 6 | 1 | Spring (5) | Steel |
| 7 | 1 | Spring (6) | Steel |
| 8 | 1 | Spring (7) | Steel |
| 9 | 1 | Spring (8) | Steel |
| 10 | 1 | Magnet | Steel |
| 11 | 1 | Rubber | Acetal Resin, Black |
| 27 | 1 | Component32 | Steel |
| 28 | 1 | Component33 | Steel |
| 29 | 1 | Component34 | Steel |
| 30 | 1 | Component35 | Steel |
| 31 | 1 | Component36 | Steel |
| 32 | 1 | Component37 | Steel |
| 33 | 1 | Component38 | Steel |
| 34 | 1 | Component39 | Steel |

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