INTRODUCTION

The world is facing an increasing demand for energy while simultaneously striving to minimize the environmental impact of energy production. One potential solution is to harness the vast energy resources of ocean waves, which scientists estimate could generate 2 Terawatt (TW) per year worldwide. This theoretical energy from waves corresponds to 8×106 Terawatt hours (TWh) per year, which is about 100 times the total hydroelectric generation of the whole planet. Furthermore, by utilizing wave energy, we can reduce our reliance on fossil fuels, which contribute to about 80% of the gross primary energy. The International Energy Agency (IEA) predicts that fossil fuels will continue to contribute to the majority of energy consumption through 2030.

Electricity generation from ocean waves presents a viable solution to this issue. In particular, the potential for wave energy in India is immense, with an average potential of 14 kW/m and approximately 7500 km of shoreline. Even with just a 10% utilization, the energy generated could be anywhere around 3750 × 103 to 7500 × 103 kW.

The development of wave energy conversion technologies has been ongoing for many years. However, the cost associated with constructing, repairing, setting up electric cables, grain storage facilities, scale machines, equipment, and project management is not dependent on the size of the wave energy converter (WEC). Larger devices that generate larger amounts of energy are better than smaller devices due to the economies of scale.

One of the challenges of wave energy is the arbitrary nature of wave motion. To convert this unsteady input into a constant and steady output in the form of electricity, a mechanism that absorbs the forces from the waves must be developed. This absorber can be a buoy, and the absorbed energy can be converted into electricity using a Linear Permanent Magnet Generator or in several stages using hydraulic and mechanical transducers. The efficiency of the generator system of the WEC is a topic of ongoing research, with the goal of increasing the efficiency of the entire system.

In addition to the efficiency of the WEC, the location of its implementation is also an important factor to consider. Constraints and requirements must be met to ensure that the WEC functions effectively and sustainably.

This project aims to explore the feasibility of generating electricity from ocean waves by investigating the different technologies available for wave energy conversion, as well as the challenges and potential for implementation. By harnessing the immense energy potential of ocean waves, we can contribute towards the reduction of air pollution and minimize our reliance on fossil fuels

History:

- The first known patent to use energy from ocean waves dates back to 1799 and was filed in Paris by Girard and his son.

- An early application of wave power was a device constructed around 1910
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- From 1855 to 1973 there were already 340 patents filed in the UK alone.

- Modern scientific pursuit of wave energy was pioneered by Yoshio Masuda's experiments in the 1940s.

- A renewed interest in wave energy was motivated by the oil crisis in 1973.

- In 2008, the first experimental wave farm was opened in Portugal

Agucadoura Wave Farm
(Portugal)

How Waves Form ?

Waves are formed due to the movement of energy through water. This energy can come from various sources, such as wind, earthquakes, and even the gravitational pull of the moon and sun. When energy from these sources is transferred to the water, it causes disturbances that propagate through the water in the form of waves.

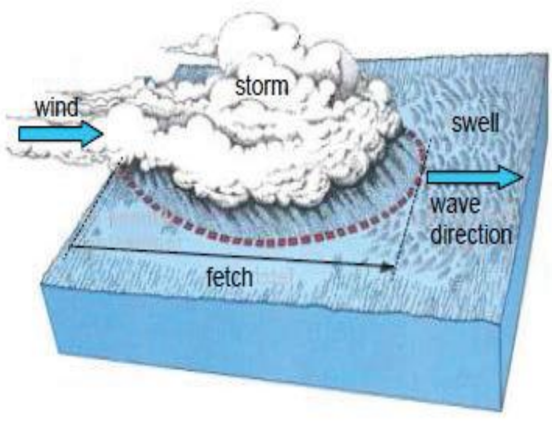
Wind waves are the most common type of waves and are formed by the transfer of energy from the wind to the water. As wind blows over the surface of the water, it creates ripples that eventually grow into larger waves. The size and strength of wind waves are determined by the wind speed, duration, and fetch (distance over which the wind blows).

Tsunamis, on the other hand, are formed by underwater earthquakes or volcanic eruptions. The sudden movement of the earth's crust causes a large displacement of water, which in turn generates a series of waves that travel across the ocean at high speeds

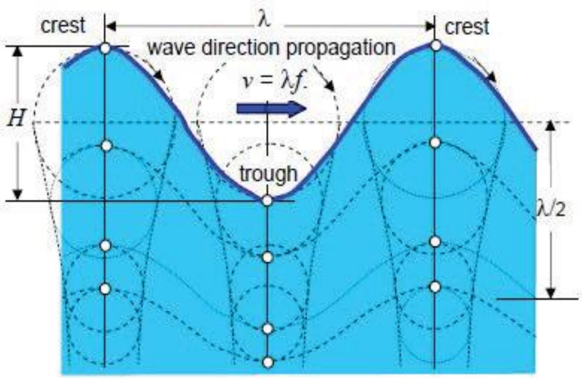
Another type of wave is a tidal wave, which is caused by the gravitational pull of the moon and sun on the earth's oceans. Tidal waves are characterized by their long wavelength and are most pronounced during high and low tides.

Overall, waves form due to the transfer of energy to water and the subsequent propagation of disturbances through the water. The type of wave and its characteristics are determined by the source of the energy and the conditions in which it is formed.

- A few factors determine how strong an individual wave will be. These include:
    - Speed of wind: The faster the wind is traveling, the bigger a wave will be.
    - Time of wind: The wave will get larger the longer the length of time the wind is hitting it.
    - Distance of wind: The farther the wind travels against the wave (known as fetch), the bigger it will be.



Formation Of Waves Due To Storm



Sea Waves Propagation

Wave Formation In India:

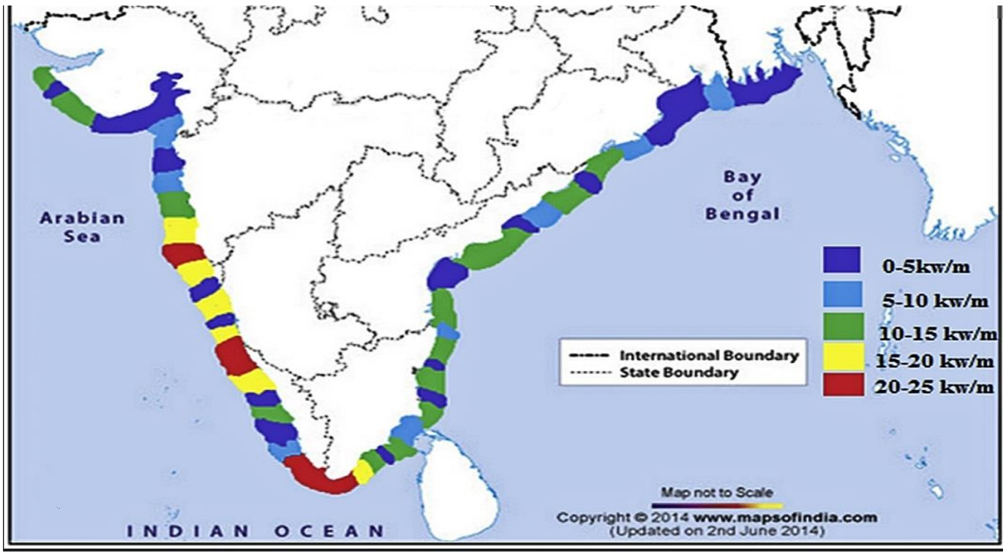
India has a vast coastline of approximately 7,500 kilometers, which is exposed to the Arabian Sea in the west, the Bay of Bengal in the east, and the Indian Ocean in the south. Due to this, India experiences a considerable amount of wave activity along its coastline.
The intensity of wave formation near India depends on various factors such as wind speed, ocean currents, and weather conditions. During the monsoon season, which usually lasts from June to September, the southwest monsoon winds create large waves in the Arabian Sea and the Bay of Bengal, particularly along the western coast of India. These waves can reach up to 3-4 meters in height in some areas.

The eastern coast of India, particularly the Bay of Bengal, experiences lower wave heights compared to the western coast. This is because the prevailing winds in the Bay of Bengal are relatively weaker, and the coastline is sheltered by the landmass of Southeast Asia.
However, it is important to note that wave heights can vary significantly depending on the location and the time of the year. Some areas along the Indian coastline may experience higher wave heights during cyclones or other extreme weather events.

Overall, India's coastline experiences a considerable amount of wave activity, particularly during the monsoon season. The exact height and intensity of waves can vary depending on several factors and can have significant impacts on coastal communities and ecosystems.

Wave Potential In India :

The western coasts of four shallow water areas and east coasts waves of India are studied on the basis of data collected from one year of measurements and the variations are reviewed Many study indicates that 83-85% of the electricity generation occur during the summer monsoon period (June-September). Near Pondicherry Coast, the wave of 31.8 kW/m was the most cost effective. The power generation during summer monsoon is higher than usual; the western coast of India has higher capacity than eastern coast (15.5 to 19.3 kW/m). it has been found that on the contrary, the power generation in the studied locations is lower than the hot zones (1.8 to 7.6 kW/m). The wave power potential in India is shown below:



Wave Potential In India

Benefits

Generating energy from ocean waves has several benefits, including:

- Renewable energy source: Ocean waves are a renewable energy source, which means that they will never run out. As long as the sun and moon continue to create tides and waves, there will always be an opportunity to generate energy.

- Low carbon emissions: Generating energy from ocean waves does not produce any greenhouse gases, which makes it a clean and environmentally friendly source of power. Unlike traditional power plants that rely on fossil fuels, wave energy converters do not contribute to air pollution or climate change.

- Predictable and consistent: Waves are a predictable and consistent source of energy, which makes it easier to plan for and integrate into the power grid. Unlike solar or wind power, wave energy can be generated 24/7, regardless of the weather conditions.

- Low maintenance costs: Wave energy converters are designed to withstand the harsh ocean environment, which means that they require minimal maintenance compared to other forms of renewable energy, such as wind turbines.

- Economic benefits: Developing wave energy projects can create jobs and stimulate local economies, particularly in coastal communities. It can also reduce reliance on imported fossil fuels and promote energy independence.

- Long lifespan: Wave energy converters have a lifespan of around 25 years, which is longer than most other renewable energy technologies. This makes them a cost-effective option in the long run, as they require less frequent replacement.

In summary, generating energy from ocean waves has several benefits, including its renewable nature, low carbon emissions, predictability, low visual impact, low maintenance costs, economic benefits, and synergy with other ocean uses. As technology advances and wave energy becomes more efficient, it has the potential to play an important role in our transition to a more sustainable energy future.

Challenges

Despite the benefits of generating electricity from ocean waves, there are still some significant challenges that need to be addressed. These challenges include:

- Capital Cost: The cost of developing wave energy converters (WECs) and deploying them in the ocean is currently high. The technology is still in its early stages, and costs may come down as it matures, but at present, it remains an obstacle.

- Reliability: Wave energy is a relatively new technology, and there is still much to be learned about how to design and build reliable WECs. The harsh ocean environment can cause wear and tear on equipment, and it can be challenging to maintain and repair the devices.

- Environmental impact: While wave energy has a low visual impact, it can still have an impact on marine life. WECs can create artificial reefs, which can attract marine life, but they can also cause underwater noise and vibration that may disturb some species. The long-term impact of WECs on marine ecosystems is still not fully understood.

- Infrastructure: To harness the energy of ocean waves, WECs must be deployed in the ocean, which requires significant infrastructure such as subsea cables and offshore support vessels. This infrastructure can be costly and challenging to install and maintain, particularly in deep water.

- Energy storage: Wave energy is intermittent, and the energy produced varies depending on the weather and sea conditions. To provide a steady supply of electricity, energy storage systems are needed to store excess energy during periods of high wave activity and release it when the waves are low. Developing efficient and cost-effective energy storage systems is a significant challenge in wave energy.

Overall, while the challenges facing wave energy are significant, many researchers and companies are working to address these issues. As the technology matures, it may become an important source of renewable energy that can help reduce our reliance on fossil fuels.

Classifications of WEC'S

There are different ways of classifying wave energy converters. Some of them are, based on the location of the device.

- **Shoreline Devices:**

These devices which are present on the coast. The advantages of these devices are that It is easy to install and maintain. These are to be installed in the hot-spots for better power generation. The implementations of these devices are restricted by shoreline geology, tidal range, conservation of coastal scenery, etc. Examples are, Oscillating Water Column, Limpet, Vizhinjam harbour WEC, etc

- **Near shore Devices:**

These devices are mounted in water depths of up to 20m from the shoreline, within 1 km of the shore. The power developed is transferred to the grid on the shore through electrical cables. Some examples are, Oscillating Water Surge, Osprey, Wave star, etc.

- **Off Shore Devices:**

These devices experience more powerful wave regimes and are present at a depth more than 40m in the deep water. Some examples are, Archimedes Wave Swing (AWS), Pelamis, Salter Duck, Wave Dragon, Penguin, etc.

Based on Operating conditions:

- **Floating devices**:

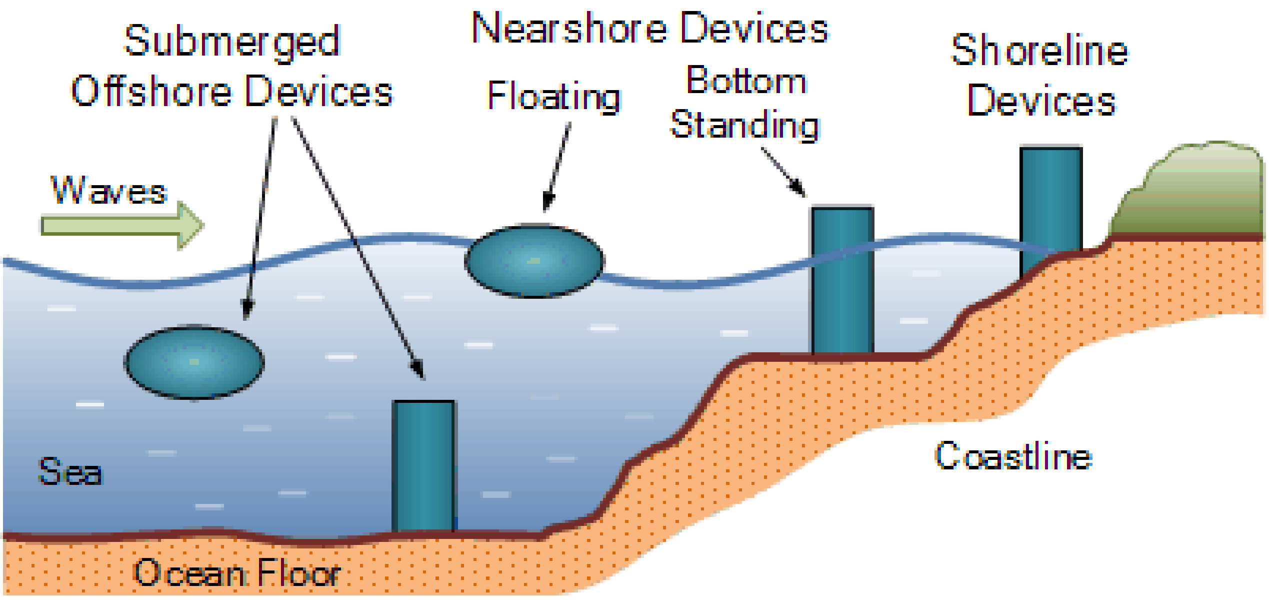
  These devices float on the sea and utilize the surface waves. The converter system and generator are to be housed in the same devices. The Wave star is a classic example for this.

- **Partially submerged devices:**

  These devices are half submerged in water and utilize both the surface and underwater wave currents. The electricity produced can be transferred to the station present on the shore. Oscillating Water Surge is an example for this type.

- **Fully submerged devices:**

  As the name suggests, the devices are underwater and utilize the underwater wave currents and pressure difference. The Archimedes Wave Swing is an example.



Basic Kinds Of Systems

Wave Energy Devices:

- **Wave Profile Devices:**

  They turn the oscillating height of the oceans surface into mechanical energy. They are commonly known as "Wave Attenuators".

- **Oscillating Water Columns:**

  They convert the energy of the waves into air pressure.

- **Wave Capture Devices:**

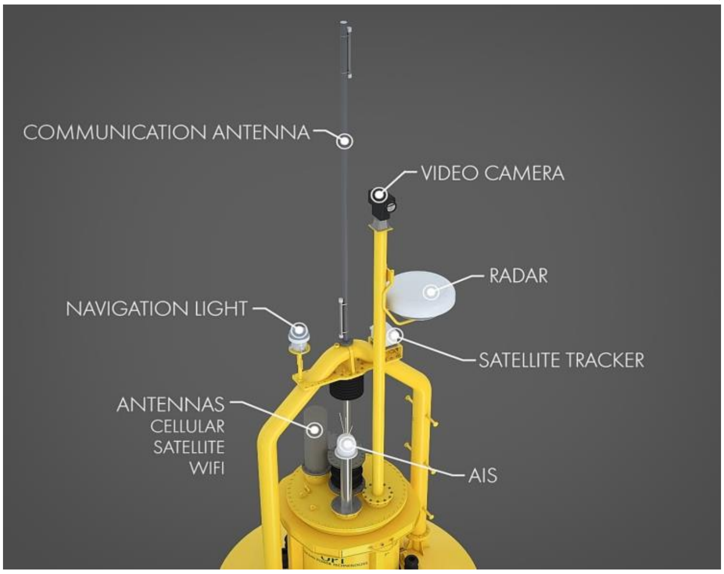
  They convert the energy of the waves into potential energy.

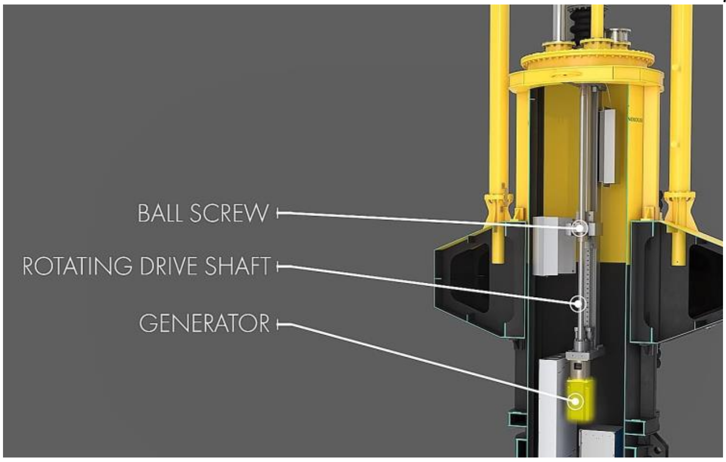
Wave Profile Devices

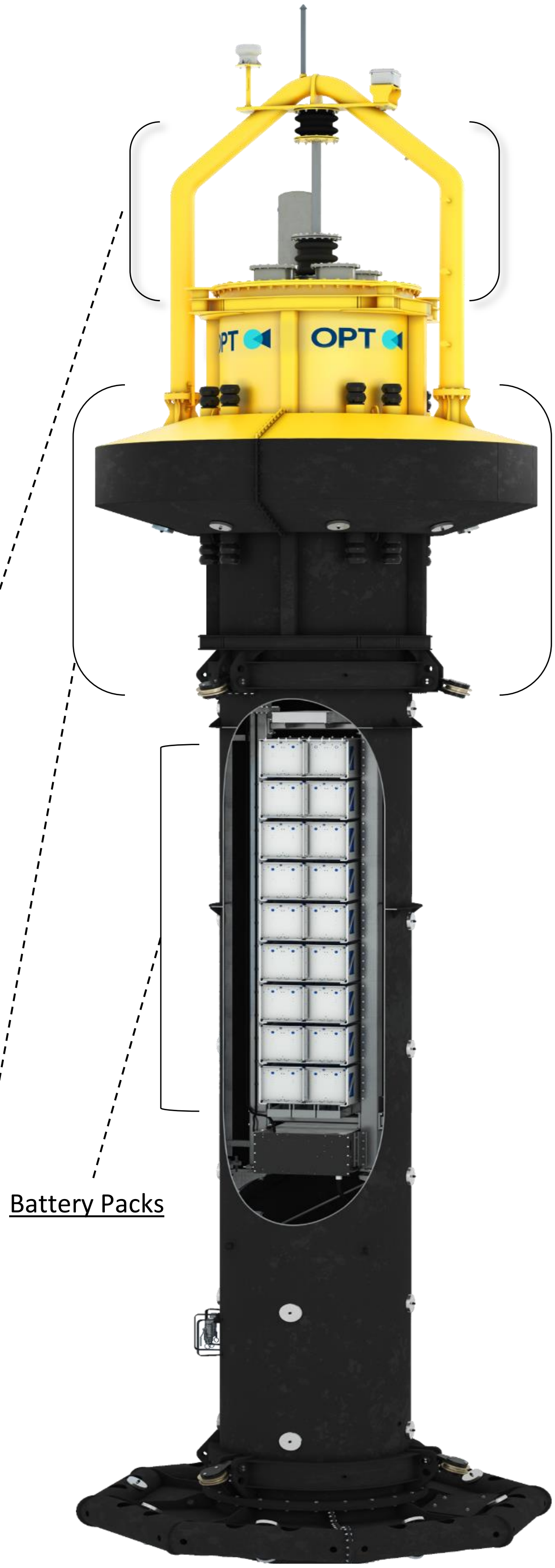
- ## The Power Buoy:

A power buoy, also known as a wave energy converter (WEC) buoy, is a type of device used for extracting energy from ocean waves. It is designed to convert the kinetic energy of the waves into electricity that can be used to power various applications.

Power buoys typically consist of a floating buoy that is anchored to the ocean floor. The buoy is equipped with a mechanical system that converts the up-and-down motion of the waves into rotational motion. This rotational motion is then used to drive a generator, which produces electricity.







Power Buoy

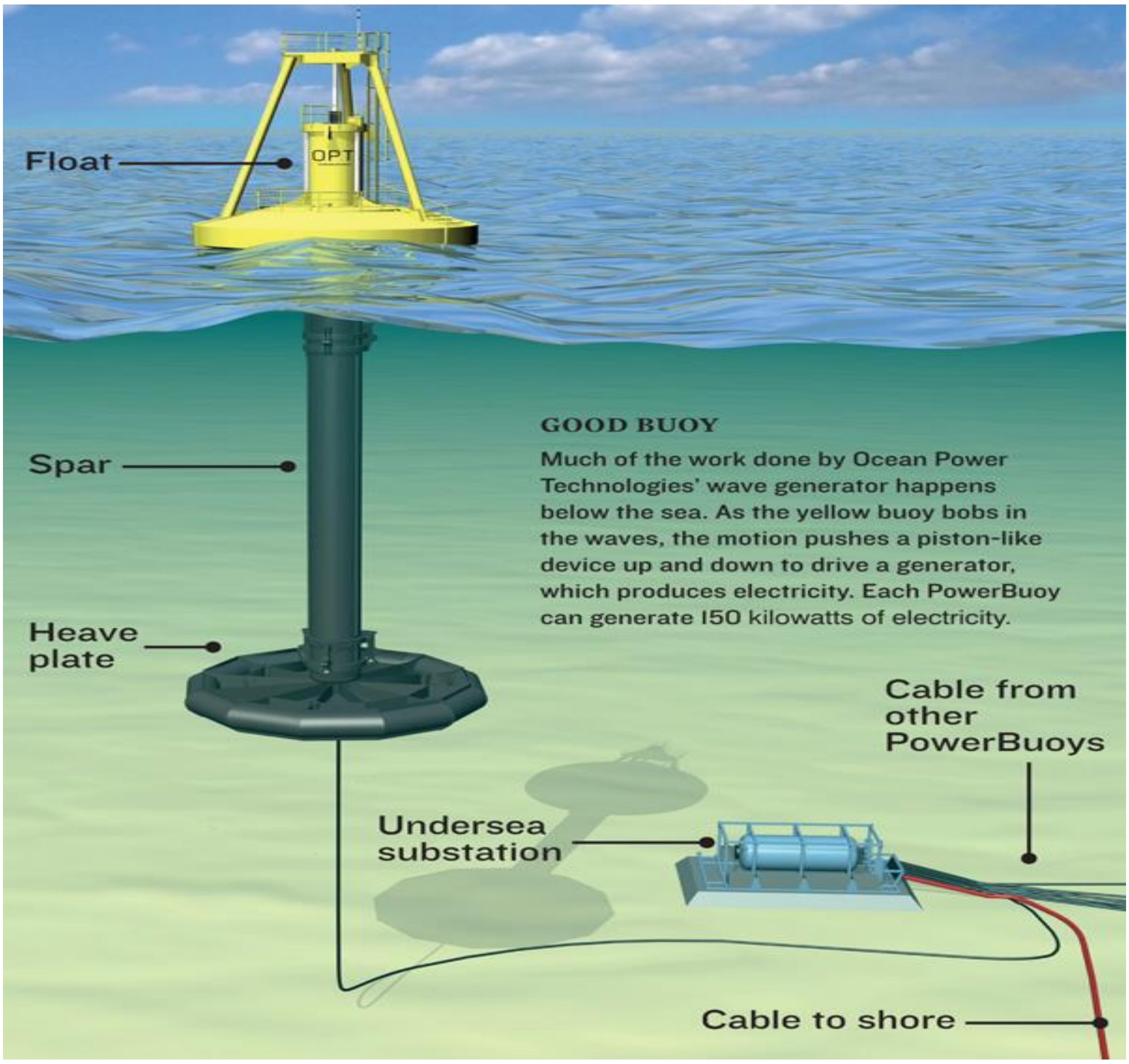
Working:

The working principle of a power buoy can be summarized as follows:

1. **Waves move the buoy**: As ocean waves pass by the power buoy, they cause it to move up and down. The motion of the buoy is typically converted into rotational motion using a mechanical linkage such as a hydraulic cylinder or a linear generator.

2. **Power generation**: The rotational motion is then used to drive a generator, which converts the kinetic energy of the waves into electrical energy. The generator may be located on the buoy itself or on a nearby platform.

3. **Energy storage**: The electricity generated by the power buoy is typically stored in batteries or fed directly into the power grid through a power conditioning unit. Energy storage is important because the power output of the buoy varies with wave conditions, and the electricity must be available on demand.



Examples

PB150 Power Buoy with peak-rated power output of 150 kW. USA

Power buoys offer several advantages over other types of wave energy converters. They are relatively simple in design and construction, and can be deployed in a wide range of water depths. They also have a low visual impact, since they are typically located far from shore and do not require large-scale infrastructure.

However, power buoys also face several challenges. One of the biggest is the harsh marine environment, which can cause damage to the buoy and its components. They also have limited efficiency in converting wave energy to electricity, and may require large-scale deployment to be economically viable. Finally, there are potential environmental impacts associated with the installation and operation of power buoys, including disturbance of marine life and alteration of wave patterns.

- **<u>Archimedes Wave swing (Aqua Buoy):</u>**

The Archimedes Wave swing is a type of wave energy converter (WEC) that uses the motion of waves to generate electricity. It is designed to be placed in the ocean or other bodies of water, where it can harness the power of waves to produce clean, renewable energy.

Archimedes Waveswing power output of 500kW, Orkney,

The Waveswing operates on the principle of buoyancy and the conversion of potential energy into kinetic energy. The device consists of a large, hollow steel cylinder, which is partially submerged in the water. The cylinder is open at both ends and contains a series of internal components that work together to capture the energy of the waves.

As the waves pass over the cylinder, they cause it to move up and down. This motion drives a hydraulic pump that is connected to a generator, which converts the kinetic energy of the waves into electrical energy. The hydraulic pump also drives a set of valves that regulate the flow of seawater into and out of the cylinder, which helps to maintain the device's buoyancy and stability.

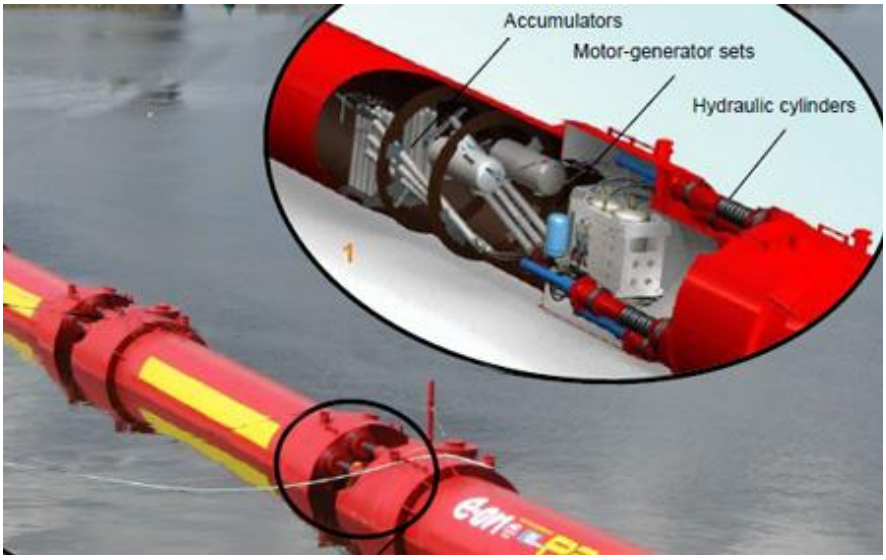
One of the key features of the Waveswing is its ability to automatically adjust to changing wave conditions. The device is designed to move with the waves, and its internal components are engineered to respond to the varying forces of the water to maximize energy production.

- **Wave Attenuators**

Wave attenuators, also known as wave breakers, are devices that reduce the height and energy of ocean waves before they reach a certain area. They work by creating a barrier or obstruction that dissipates the energy of the waves.

There are several types of wave attenuators, but one of the most common is the floating attenuator. This device consists of a series of pontoons or cylinders that are attached to each other by flexible joints. The pontoons are designed to move up and down with the waves, but the flexible joints allow them to move independently of each other. This movement helps to dissipate the energy of the waves and reduce their height.

Wave Attenuators



Working:

the general steps involved in the working of a floating attenuator:

1. The floating attenuator device is anchored to the ocean floor with the help of cables and chains to keep it in position.
2. As the waves pass, the floating attenuator device moves up and down or back and forth, depending on its design. This motion is converted into mechanical energy by hydraulic cylinders or other mechanical components present in the device.
3. The mechanical energy is then converted into electrical energy using a generator or other electrical equipment. This electricity is sent to the shore through cables for further use.

4. The device is also equipped with sensors and control systems to adjust the device's position and settings according to the wave conditions and optimize its performance.
5. The electricity produced by the floating attenuator can be used for various applications, such as powering nearby communities or industries, desalination of seawater, and providing power to offshore oil rigs and other facilities.

Examples:

750 kW Pelamis Wave Energy Converter, Scotland

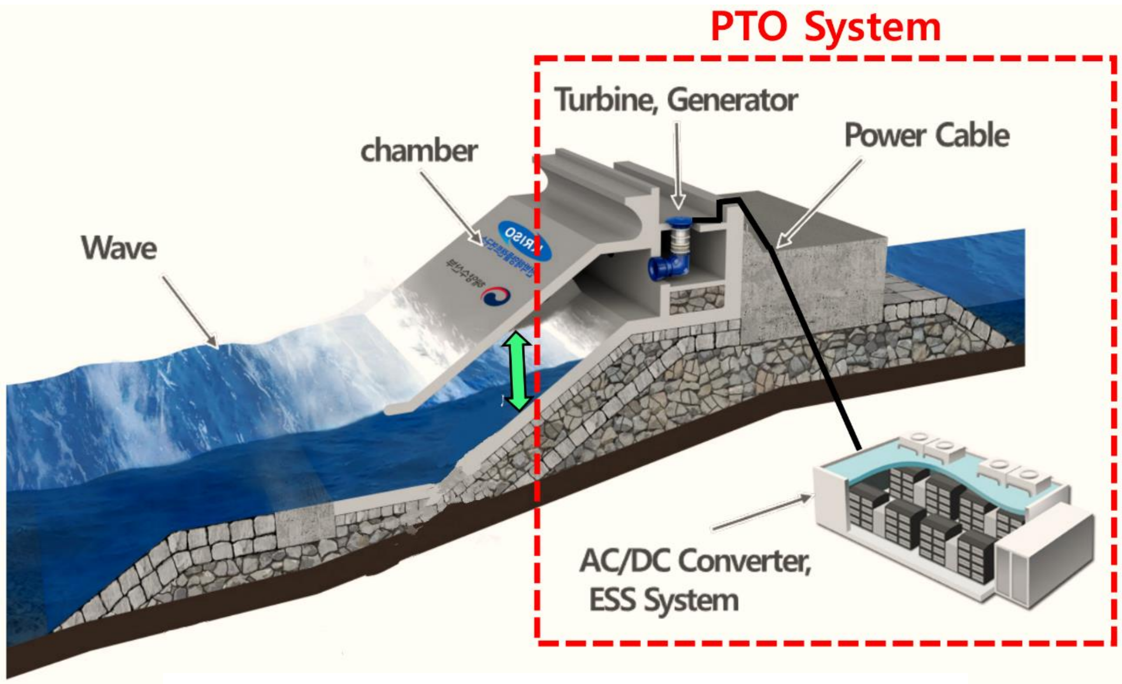
Wave attenuators have several advantages when it comes to generating energy from ocean waves. By reducing the height and energy of the waves, they create a calmer and more predictable environment for wave energy converters to operate in. This can help to increase the efficiency and reliability of wave energy systems. Additionally, wave attenuators can help to protect coastlines and other structures from the damaging effects of ocean waves.

Oscillating Water Column (OWC)

- The Oscillating Water Column, (OWC) is a popular shoreline wave energy device normally positioned onto or near to rocks or cliffs which are next to a deep sea bottom.

- It is a type of wave energy converter that converts the kinetic energy of waves into electrical power. It works on the principle of using the oscillations of the water column inside a submerged chamber to generate electricity using air pressure.

- They consist of a partly submerged hollow chamber fixed directly at the shoreline which converts wave energy into air pressure.



Oscillating Water Column(OWC)

Working:

The working of an OWC can be explained in the following steps:

1. Wave Capture: As waves approach the OWC, they enter a chamber through an opening below the waterline. The chamber is open to the sea at the bottom and closed at the top.
2. Wave Compression: As the waves enter the chamber, the water level inside rises, and the air above the water column is compressed. The compressed air is directed towards a turbine located above the water column.

3. Air Turbine: The compressed air turns a turbine located above the water column, which converts the kinetic energy of the air into mechanical energy.
4. Electrical Generator: The mechanical energy generated by the turbine is used to power an electrical generator, which produces electricity.
5. Air Expansion: As the wave crest passes the opening, the water level inside the chamber falls, and the air in the chamber expands, creating a low-pressure area.
6. Air Intake: The low-pressure area draws in more air from the atmosphere, which enters the chamber through a one-way valve.
7. Repeat: The cycle is then repeated as the next wave enters the chamber, and the process continues as long as there are waves to capture.

Examples

LIMPET (Land Installed Marine Powered Energy Transformer), Scotland, Capacity-500 kW

LIMPET (Land Installed Marine Powered Energy Transformer), Scotland, Capacity-500 kW

500 kW offshore OWC, Port Kembla, Australia

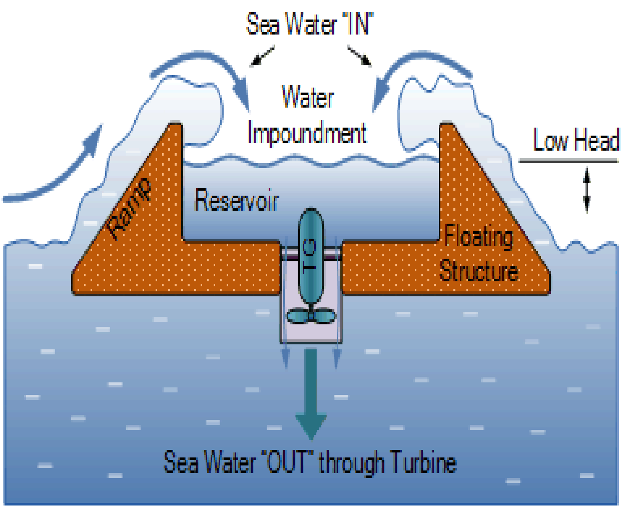
The OWC is a simple and reliable wave energy converter that can be used to generate electricity from ocean waves. It has a low environmental impact and can be used in a variety of marine environments. However, the efficiency of the OWC is limited by the size of the chamber and the speed of the waves. Additionally, the OWC is sensitive to changes in wave height and frequency, which can affect its performance.

Wave Capture Devices

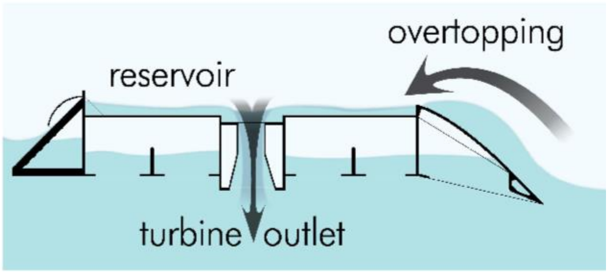
- ## Wave dragon:

Wave Dragon is a floating offshore device designed to harness the power of ocean waves and convert it into electricity. The device is made up of two elongated arms that extend into the ocean, forming a "V" shape. The arms are connected to a large floating platform that houses the power generation equipment.

One of the unique features of the Wave Dragon device is its ability to adjust its position in the water. The device is equipped with a ballast system that can be used to adjust the draft of the platform. This allows the device to adapt to changing wave conditions and ensure that the platform remains stable in all conditions.



Wave Dragon



Working:

The working of Wave Dragon can be described in the following steps:

1. Waves approach the Wave Dragon from one side, causing the arms to rise and fall with the motion of the waves.
2. As the arms rise and fall, they push water through a series of ducts located in the arms, which leads to a central chamber located in the platform.
3. The water in the central chamber rises and falls with the motion of the waves, causing water to be forced in and out of the chamber through a set of turbines.
4. The movement of water through the turbines generates electricity, which is then transmitted to shore through a subsea cable.
5. The platform is designed to pivot around a central point, allowing it to orient itself towards the direction of the waves for maximum efficiency.
6. The device also has a system of ballast tanks that can be filled or emptied to adjust the buoyancy and stability of the device in response to changing wave conditions.

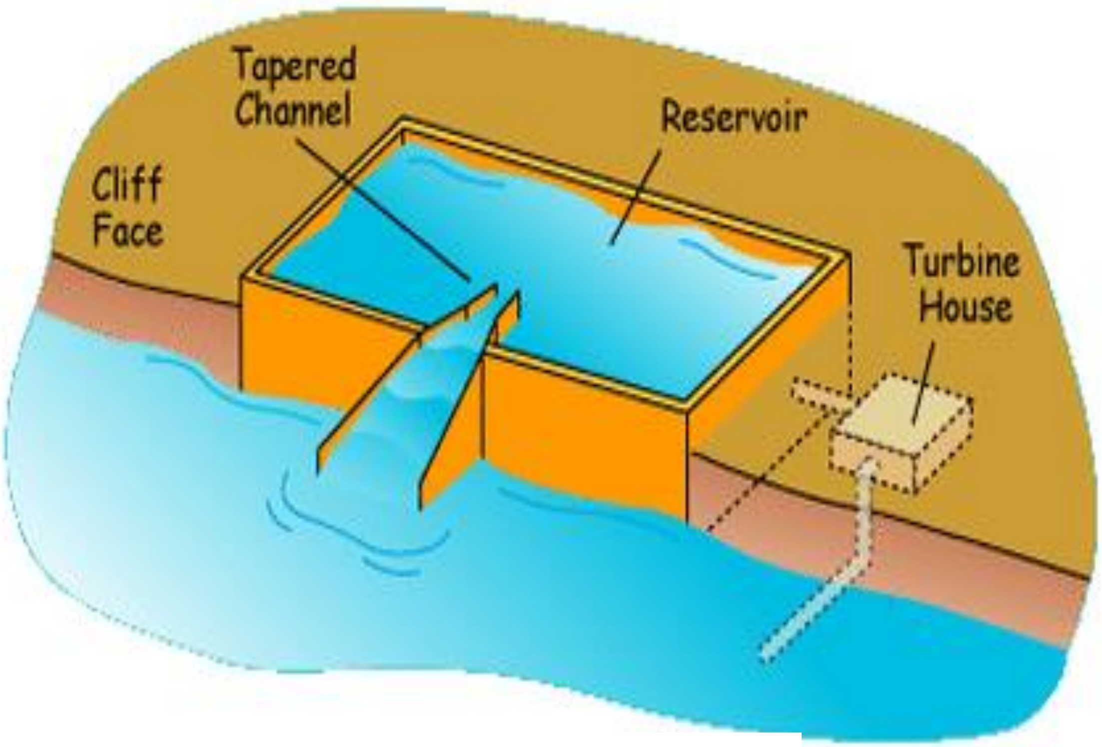
Examples:

Wave Dragon Overtopping Device, Denmark 1.5 to 12 MW of capacity

Wave Dragon has been tested extensively in a number of locations, including Denmark, Wales, and Portugal. The results of these tests have shown that the device is capable of generating electricity in a reliable and efficient manner. The device has also been shown to have a low environmental impact, making it a promising technology for future wave energy projects.

Overall, Wave Dragon is designed to be a low-cost, low-maintenance, and environmentally friendly way to generate electricity from ocean waves. Its modular design allows it to be easily scaled up or down to meet the needs of different applications, from small-scale remote power generation to large-scale commercial energy production

- **Tapered Channel (TAPCHAN):**



Basic Design Of Tapered Channel

A tapered channel is a type of wave energy converter that harnesses the power of ocean waves. It consists of a channel that gradually narrows towards the shore, creating a converging effect on the waves. As the waves enter the channel, they are compressed and their amplitude increases, resulting in a higher energy density.

The tapered channel works by exploiting the fact that waves slow down as they enter shallow water. As the water depth decreases, the wave's speed decreases, and its height increases, causing it to compress. This phenomenon is known as shoaling. In a tapered channel wave energy converter, the channel's width gradually decreases as it approaches the shore, creating a funnel-like shape.

As the waves enter the channel, they are funneled into a smaller area, resulting in an increase in their amplitude. The increased wave energy is then used to power a turbine or generator, which converts the kinetic energy of the waves into electricity.

Examples:

Toftestallen Wave Power Plant, TAPCHAN, Norway 500 kW

One of the advantages of TC-WECs is that they are relatively simple and reliable, with few moving parts that can break down. They also have a relatively low visual impact compared to other wave energy converters, since most of the structure is located underwater. However, they can be relatively expensive to build and maintain, and their performance can be highly dependent on the characteristics of the waves at the site.

Future projects

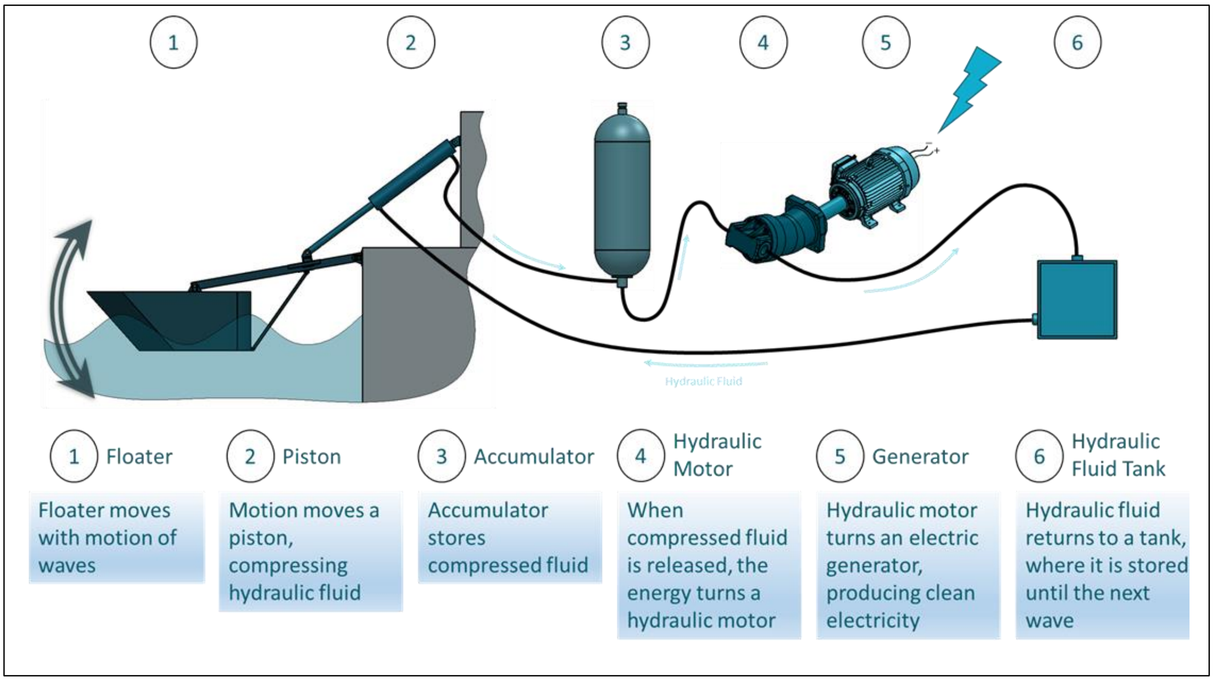
- **Hydraulic Devices**:

  Swedish Eco Wave Power is to build a wave power plant in Turkey. With a capacity of 77 megawatts, it will be the largest wave power facility in the world.

  The technology is based on the waves driving a hydraulic motor which in turn drives an electric generator. The units are mounted on some land-based structure such as a dam, which facilitates assembly, maintenance, and connection to the power grid.

  As the facilities are mounted on dams and the like, they do not need to be anchored to the seabed, which could otherwise negatively affect the nearby marine environment.

Working:



- The floaters draw energy from incoming waves by converting the rising and falling motion of the waves into an clean energy generation process. More precisely, the movement of the floaters compresses and decompresses hydraulic pistons which transmit bio-degradable hydraulic fluid into land located accumulators. In the accumulators, at a pressure is being built.
- This pressure rotates a hydraulic motor, which rotates the generator, and then the electricity is transferred into the grid, via an inverter.

- The fluid, after decompression, flows back into the hydraulic fluid tank, where it is then re-used by the pistons, thus creating a closed circular system.

The system commences production of electricity from wave heights of 0.5 meters. The whole operation of the system is controlled and monitored by a smart automation system. Also, when the waves are too high for the system to handle the floaters automatically rise above the water level and stay in the upward position until the storm passes. Once the storm passes, the floaters return to operation mode.

<u>Jettymounted Wave Energy Device Output 77MW, Gibraltar, Spain</u>

- **Wave Roller:**

  Wave Roller is a device that converts ocean wave energy to electricity. The machine operates in near-shore areas (approximately 0.3-2 km from the shore) at depths of between 8 and 20 meters. Depending on tidal conditions it is mostly or fully submerged and anchored to the seabed. A single Wave Roller unit (one panel and PTO combination) is rated at between 350kW and 1000kW, with a capacity factor of 25-50% depending on wave conditions at the project site. The technology can be deployed as single units or in farms.

Wave Roller Prototype

Working:

The back and forth movement of water driven by wave surge puts the WaveRoller panel into motion. To maximize the energy that the WaveRoller panel can absorb from the waves, the device is installed underwater at depths of approximately 8 – 20 meters, where the wave surge is most powerful. A single panel absorbs 1.5-2 MW of power from the wave surge. The panel spans essentially the entire depth of the water column from the seabed up to the water surface level.

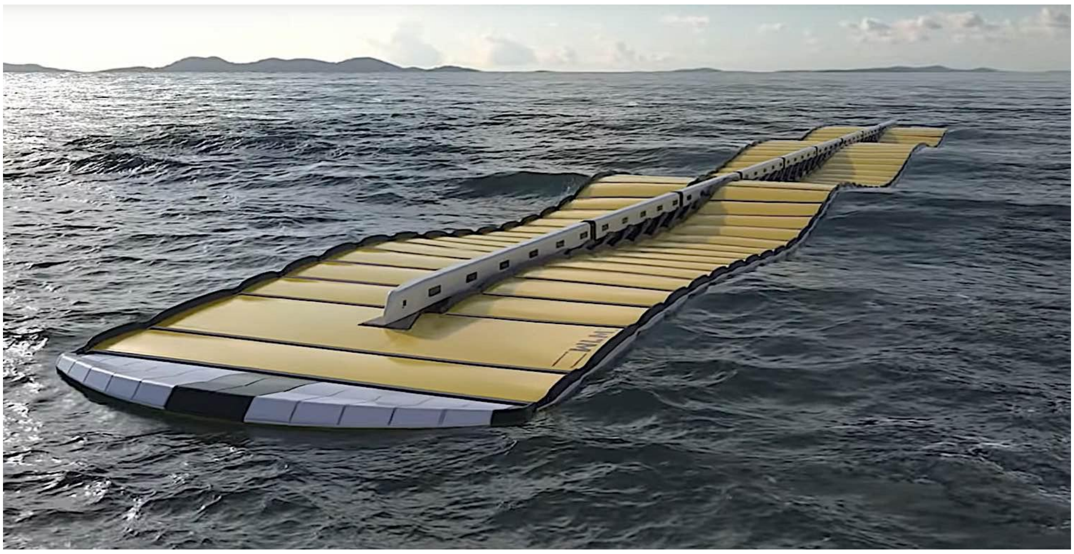
As the WaveRoller panel moves and absorbs the energy from ocean waves, hydraulic piston pumps attached to the panel pump hydraulic fluids inside a closed hydraulic circuit. All the elements of the hydraulic circuit are enclosed inside a hermetic structure inside the device and are not exposed to the marine environment. Consequently, there is no risk of leakage into the ocean. The high-pressure fluids are fed into a power storage and smoothing system, which connects to a hydraulic motor that drives an electricity generator. The electrical output from this renewable wave energy power plant is then connected to the electric grid via a subsea cable.

<u>WaveRoller Output 1.5 MW ,Atlantic ocean, Portugal Cost</u>

- ## SWELS’s Waveline Magnet:

  Sea wave energy limited (SWEL), an R&D company based in Cyprus & the UK, has been developing a unique spine-like floating device that harnesses the energy of waves and converts it into electricity. The wave energy converter (WEC) – dubbed the “Wave Line Magnet” – offers affordable, low maintenance, and climate-friendly alternative to traditional technologies.

  This year(2022), the company unveiled a concept design simulating the mechanism of its latest Waveline Magnet model. SWEL has developed and tested its devices in wave tanks and live sea environments. The R&D indicates that even in its current development state, the Waveline Magnet can produce substantial power levels at an exceptionally low cost, competing even with non-renewable sources.



SWEL’s Waveline Magnet

Working:

- The chains of floats in the design move like a snake as waves pass through, following the curves of the water.
- Lever arms connect the floats to an inflexible spine-like central power system rather than directly to one another.
- The central power system stays relatively still while the floats go up and down with the waves.
- The levers attached to the spine unit cause the electrical generators inside them to rotate.

Over the past decade, SWEL has produced several generations of prototypes. These have undergone wave tank testing at the University College Cork, the University of Cyprus, the University of Plymouth, the LIR National Ocean Test Facility, and Centrale Nantes. Meanwhile, others have been field tested on the open seas. According to SWEL, "one single Waveline Magnet will be rated at over 100 MW in energetic environments."

SWEL's Waveline Magnet Trials

FUTURE SCOPE

The wave energy reward is for those contenders who can better design wave conversion devices, which are aimed at creating a device that will reduce the cost of ocean waves to half the cost of electricity production. Although wind power has so far successful by building new wind turbines and solar industry knows how a panel looks like, but in wave industry we do not have such options for development but it is constantly trying to turn ocean energy into electricity that can be consumed.

It's not surprising when you look at young wave industries. Many wave energy companies are less than ten years old, some of them are much younger, and solar and wind energy have evolved over the decades. Only a few wave energy companies around the world have managed to control the network, and practically no one has developed to the point where they can deliver the power which was promised.

The Ocean is not just about salty water, it's not about oppressions or big blows and it's a very difficult place to try to collect energy. The ocean is simply not like the wind or does not radiate like sunlight. The oceans are growing; the surface and rollers, and the incredible collection of designs reveal its unexpected nature.

Initial Wave Power Directors explain that devices generate electrical energy at the lowest possible cost - at any place, bypassing the surface. If wave energy controls wind and solar energy, most of these projects will turn into historical artifacts, but a little overpowering. It is possible to conclude that this difficult competition between the organizations will be interesting, and this will lead to better energy efficiency.

CONCLUSION

Wave energy can be a possible clean energy technology and can only grow in the future. Wave Energy can be a possible solution to the ongoing power crisis and can contribute greatly towards it in the future, after suitable positive developments in this technology. The carbon footprint can be greatly reduced by using renewable resources like that of Wave Energy.

Advantages of using wave energy as an energy source is that it has high energy density, more consistent, predictable, cleaner and cost effective compared to any other renewable resource. But all good things do not come without a challenge, some of them are faced during installation and some challenges during the operation of the WEC. The WEC’s can be of many types and can be classified based on the location, operation condition, etc.

Different theories have been proposed and patented by researchers and concerned organizations for converting wave energy into electricity. Different variants of the WEC have different power absorbing techniques and different transducing techniques. Some of them use mechanical transducers, some use hydraulic transducers and some directly convert energy into electricity by using electromagnetic transducers and generators.

There has also been great research in the field of power storage. Concerned organizations and researchers are looking for better storage devices that can be used for short time and longtime application. Some popular storage devices are batteries, capacitors, super capacitors, compressed air, SMES, etc. The developments in this area has been carried out from decades and scientists have always improved the previous designs by replacing them with newer ones or upgrading the old ones, only to get more efficiency, better operation capability and less environmental impact.

Different countries have developed their own WEC. Some of them are multipurpose like the CETO from Australia, which not only provides electricity but also desalinates the sea water. The studies conducted by various concerned authorities in this field, it is noted that there both positive and negative impact on the environment. Some of the negatives are that mammals and fishes are disrupted and the overall ecosystem is disturbed.

There can also be cases of oil spills on the sea which is harmful for the mammals and fishes. Some of the positives are that WEC's are renewable resources and do not release harmful gasses into the atmosphere. It has also been found that tourism activities will increase in the region where there are WEC's . Hence it can be concluded that the future of this technology all in all looks very bright and if exploited in the right way could reap results that mankind will relish for the years to come.

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Abstract

From decades, Earth is reminding humans to find better ways to produce power rather than burning fossil fuels which would result in the emission of harmful gases into the environment.

The world energy consumption is expected to increase substantially in the next decade and if the same negligence towards the environment continues, there will be a day when no clean air would be available.

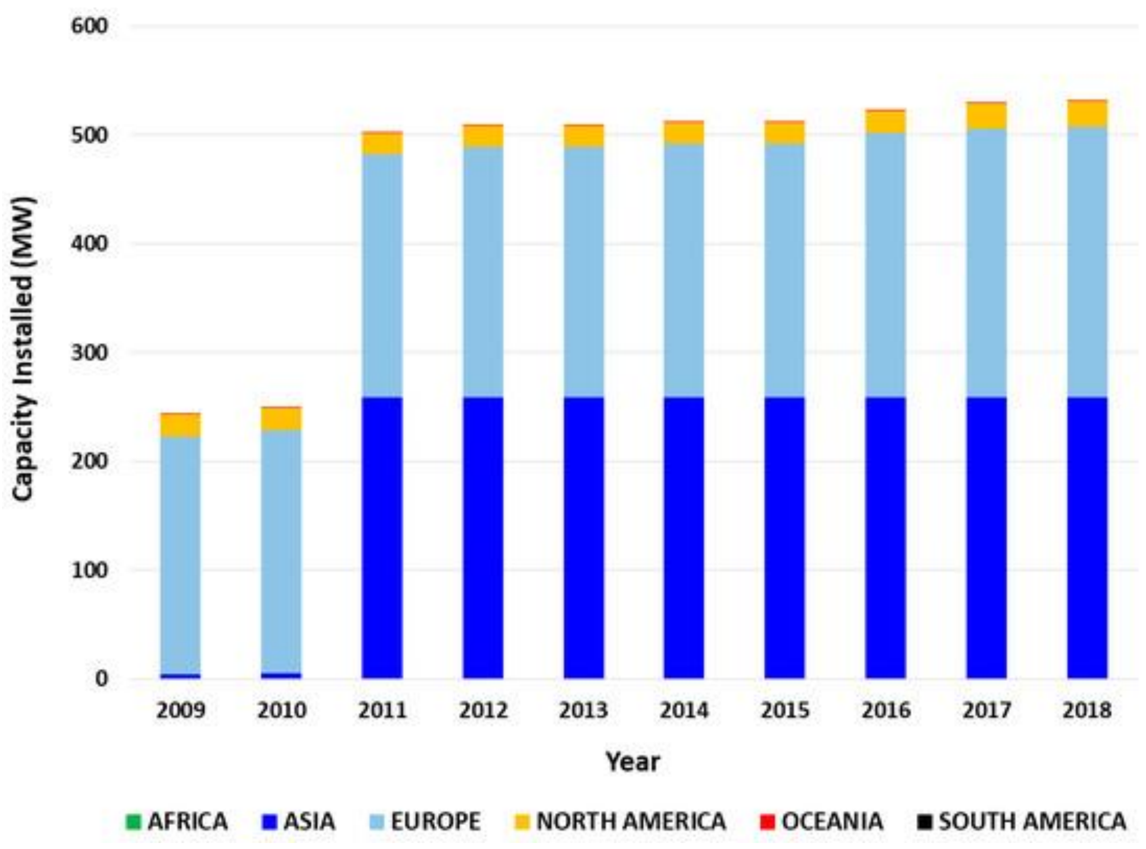
Traditional practices of producing energy, regularly reminds us the serious threat they pose to the environment. Thus there is a need to produce independent and clean electricity. Wave energy can be observed as a possible clean energy resource which can be exploited for power generation purposes. While this method is relatively new and economically competitive, there is a growing trend towards it, which is gaining interest from government and industries.

A vital feature of these waves is that they have the highest energy density when compared to other renewable energy resources.

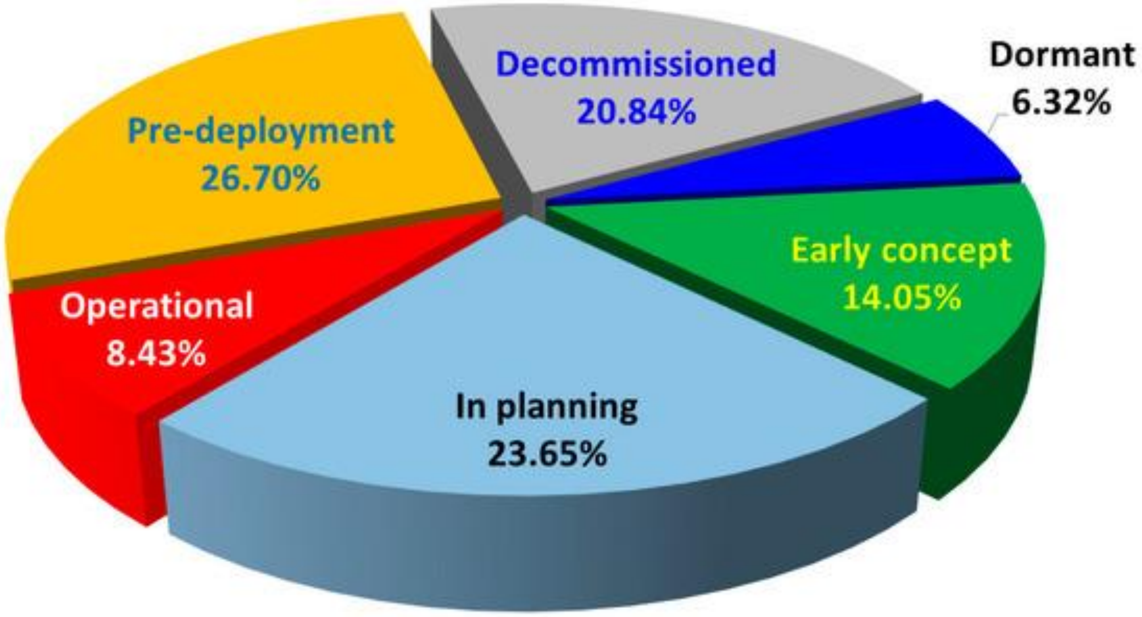
Keywords: Wave Energy Converters; Bouy; Pelamis; Transducers; Absorbers; Linear generator.

Global Status Of Development

Despite decades of development efforts, a large amount of the ocean's renewable energy sources are still untapped. In the last 10 years, the use of ocean energy sources has experienced significant growth globally. Since 2009, many devices have been deployed worldwide to capture the energy from currents, tidal ranges, thermal and salinity gradients, and waves. This progress is noticeable by the gradual increase in installed capacity in some continents, tidal ranges, thermal and salinity gradients, and waves. This progress is noticeable by the gradual increase in installed capacity in some continents, as shown below, demonstrating an expansion of marine energy in the world energy matrix. Globally, this growth has more than doubled from 244 MW in 2009 to 532 MW in 2018. However, more than 90% of this operating capacity is represented by two tidal barrages in La Rance, France and Sihwa Lake, South Korea.

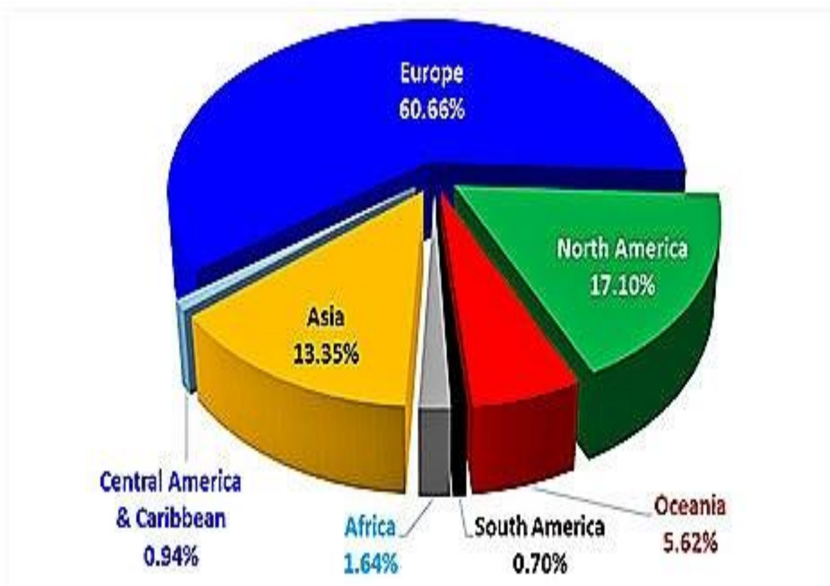


Marine energy: capacity installed by continents, according to the International Renewable Energy Agency (IRENA) (2019)

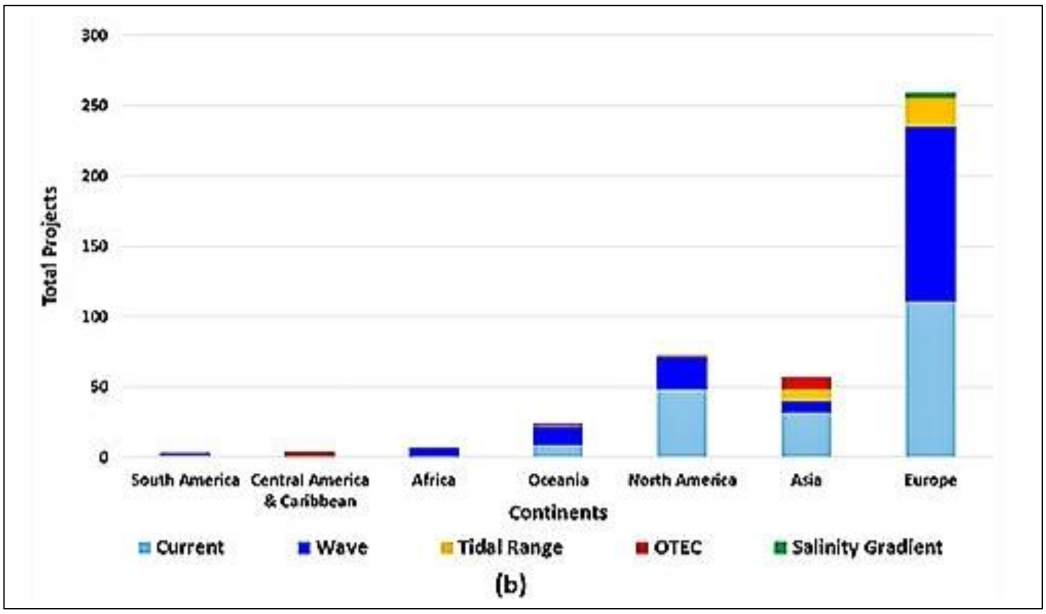


Global status of the ocean renewable energy projects

The following figure illustrates a summary of the global status of ocean renewable energy projects. Approximately half of the projects are in the "planning" and "pre-deployment" stages, and these projects are dominated by the current and wave energy and mostly located in Europe.Europe, Asia, North America, and Africa are the regions with operational projects. Asia may lead the future in OTEC technology having a larger number of "planning" and "pre-deployment" projects compared with other regions. These projects are mostly located on the eastern coast of Asia.

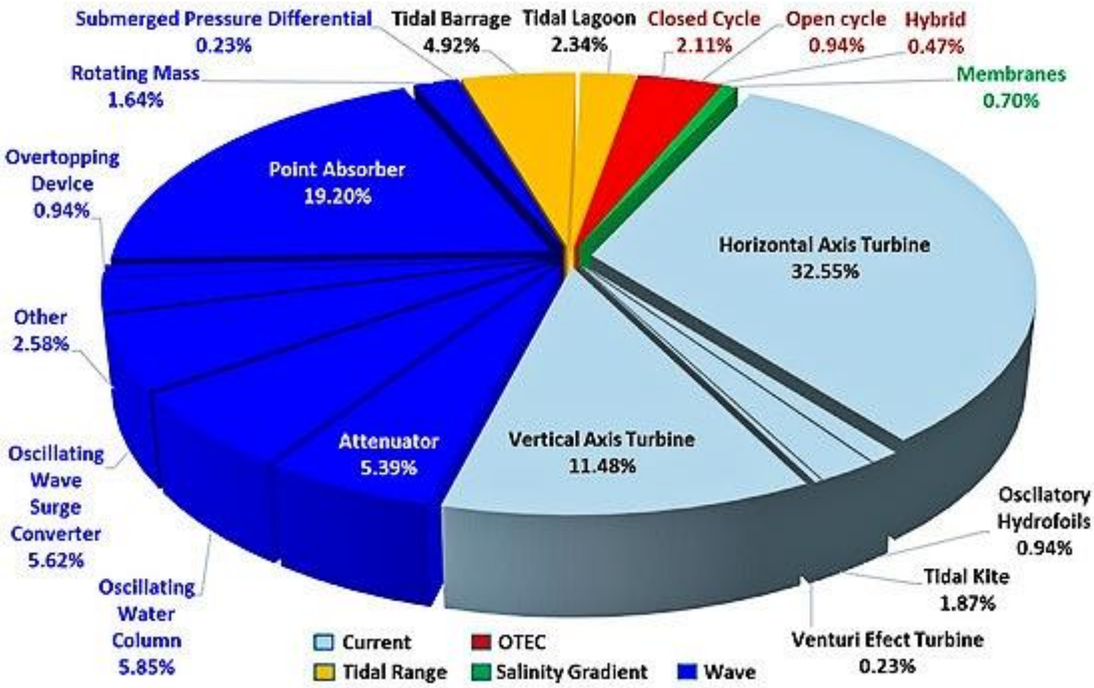


(a)



Distribution of the ocean renewable energy projects by (a) continent and (b) source for each continent

❖ Technology Distribution:



Technology distribution among projects.

The above Figure illustrates, and as was expected, the most employed technologies are current and wave energy technologies. Current energy technologies are closest to technological maturity showing a significant convergence with the use of horizontal axis turbines. Most projects use horizontal axis turbine technology, followed by vertical axis turbines, tidal kites, and oscillatory hydrofoils. On the other hand, more technology diversity can be observed for wave energy converters, partly due to the diversity of wave resources and the complexity of harnessing wave energy.

The wave energy technologies are dominated by point absorber devices followed by OWC, oscillating wave surge converters, attenuators, rotating masses, overtopping devices, and submerged pressure differential devices . The OTEC technologies are limited to the use of closed and open cycle and hybrid systems with a tendency of deploying the closed cycle method. Tidal range energy is traditionally harnessed using tidal barrages installed in the estuaries, but this method is associated with important environmental issues.

The use of tidal lagoons has been proposed and developed in the UK since 2008 as an alternative to reducing such environmental issues . The technology for extracting the salinity gradient energy is still in the conceptual stage of development, and its evolution is highly dependent on membrane enhancement, which will be responsible for 50% to 80% of the total cost.