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# Wave and Tidal Renewable Energy: Review

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## Abstract

Having immense and rapid development in technology, industrialization, modernization and with population growth, the whole world is in hunger for power and is searching for the power by all means. The want and searching of power is stronger than ever in this millennium. This power shortage which has worried the human generation along with the climate change has led us to the exploration of new renewable energy in the past few decades. Oceans, for their vast potential in producing green energy, have long been attracting leading Nations attention. The objective of this paper is to briefly overview the technology development of the ocean energy exploration, focusing on two main forms in which energy is contained in the sea wave and tide. There are many advantages when compared to the other green energy resources such as solar and wind energy, like higher power density, which can be more efficient when producing power. The wave and tidal energy are more consistency and predictable and non-hazardous and can be available throughout the days and years. The wave and tidal energy are quite new to our generation and the people are watching in an astonished way, though the scientists and researchers are however have new ideas and has improved this wave and tidal energy. This paper will enable us to have a thorough knowledge over the wave and tidal energy. A lot of research has been done and on progress for the improvement of utilization of the wave and tidal energy. Further this paper will help us to have new ideas and concept to produce power which may enlighten our planet to an extent.

**Keywords**: Renewable power resource, Marine energy, wave energy, tidal energy.

## Introduction
For recent years our civilization has changed and there is a great demand for power. This demand, as well as the growing concern over the global warming effect, has led to an increasing interest in the research and development of renewable green energies. The force of moving water, for last three centuries has played an important role in solving human's energy needs. Hydroelectricity dams built in rivers have powered hundreds of thousands of towns and cities all over the world. However, apart from rivers, there's yet another source of hydroelectric power waiting to be exploited. That is nothing but oceans, for they contain massive energy in forms of tides and waves, which is enough for meeting the total worldwide demand for power many times over [1]. It's like a beacon of hope in this energy hungry planet. Developing ocean energy has various advantages. Firstly, and most importantly, compared to other renewable technologies, the technology of ocean energy has a potential for competitive or even lower costs. EPRI studies indicate that [2] the high power density ($kW/m^2$ for currents and kW/m of wave crest length for wave) of the ocean energy resource results in relatively stronger energy conversion devices lower in capital cost than for other renewable technologies. The remoteness and, in some cases, hostile environment of ocean may result in higher implementation, operation and maintenance cost, but the overall cost efficiency of getting electricity can be comparable or even lower than that with other renewable technologies. Other benefits include:

a) Providing a new alternative of renewable energy source to satisfy the increasing power needs of modernization in an environmentally friendly manner.
b) Direct feeding of coastal cities with less transmission constraints. Since many large industrial cities are near the coast and coastal cities often have higher population density.
c) Avoiding the damage that may be caused by other energy technology like explosion and lethal radiation of nuclear power plant and growing threat of climate change worsened by fossil fuel-based power generation.
d) Mitigate the effects of increasing fossil fuel price.
e) Stimulating the development of new industry chain and creating more job opportunities. For these major benefits the marine energy can provide us with, a great deal of research has been carried out on ocean energy technology. To explore the advancement of technology, a brief general review of marine energy is first presented in the following section.

## Reviews
In the book "**NREL. US Climate change technology program technology options for the near and long term" [3]** the author says the security of supply issues are not the only concerning factors from an over-reliance on fossil fuels to meet energy demand. The $CO_2$ released into the atmosphere from burning fossil fuels restricts the earth from radiating the heat from the sun back into space, resulting in the rise in global temperature. This global issue known as the greenhouse effect causes dramatic climate change and, inevitability, a rise in sea level. The increased exploitation of

coal and nuclear energy to alleviate the oil dependence has resulted in acid rain and public concern over nuclear waste.

**Van Alphen K, Kunz HS, and Hekkert MP** in their paper "Policy measures to promote the widespread utilization of renewable energy technologies for electricity generation in the Maldives" describes the renewable energy technologies and says that they are indigenous and non polluting, and they can be dealt with both security of supply concerns and environmental issues. The development of renewable energy technologies is largely influenced by energy policy solar and wind energy technologies have gained the greatest attention recently and consequently have developed considerably. The main disadvantage of most renewable energy technologies are their intermittent availability and variation in energy intensity.

**Owen A, Trevor ML i**n their study "Tidal current energy: origins and challenges in Future energy" [5] describes about the formation of waves due to nature. Tidal energy is the energy dissipated by tidal movements, which derives directly from the gravitational and centrifugal forces between the earth, moon and sun.

**Mazumder R, Arima M.** in their research on "Tidal rhythmists and their implications. Earth–Science" [6] says that the tide is the regular rise and fall of the surface of the ocean is due to the gravitational force of the sun and moon on the earth and the centrifugal force produced by the rotation of the earth and moon about each other.

**Clark RH**. in his research "Elements of tidal-electric engineering." [7] and **Clarke JA et al** in his paper "Regulating the output characteristics of tidal current power stations to facilitate better base load matching over the lunar cycle"[8] has described about the gravitational force on the sea water. And **Boyle G** in "Renewable energy power for a sustainable future". [9] Describes about the effect of gravitational force on the sea water. The gravitational force of the moon, due to it being closer to the earth, is 2.2 times larger than the gravitational force of the sun. The tidal phenomenon occurs twice every 24 hours 50 minutes and 28 seconds. A bulge of water is created by the gravitational pull of the moon, which is greater on the side of the earth nearest the moon.

In parallel the rotation of the earth–moon system, producing a centrifugal force, causes another water bulge on the side of the earth furthest away from the moon illustrated in the figure-1. When a landmass lines up with this earth–moon system, the water around the landmass is at high tide. In contrast, when the landmass is at $90^0$ to the earth–moon system, the water around it is at low tide. Therefore, each landmass is exposed to two high tides and two low tides during each period of rotation of the earth [8]. Since the moon rotates around the earth, the timing of these tides at any point on the earth will vary, occurring approximately 50 minutes later each day [9]. The moon orbits the earth every 29.5 days, known as the lunar cycle [9]. Tides vary in size between spring tides and neap tides. Spring tides occur when the sun and moon line up with the earth, whether pulling on the same side of the earth or on opposite sides, resulting in very high spring tides. Neap tides occur when the sun and moon are at $90^0$ to each other, resulting in low neap tides. Tidal currents are experienced in coastal areas and in places where the sea bed forces the water to flow through narrow channels. These currents flow in two directions, one current is moving in the direction of the coast is known as the flood current and the other current receding from the coast is known as the ebb current. The current speed in both directions varies from zero to maximum. The zero current speed refers to the slack period, which occurs between the flood and ebb currents. The maximum current speed occurs halfway between the slack periods [9]. These tidal variations, both the rise and fall of the tide and the flood and ebb currents, can be utilised to generate electricity.

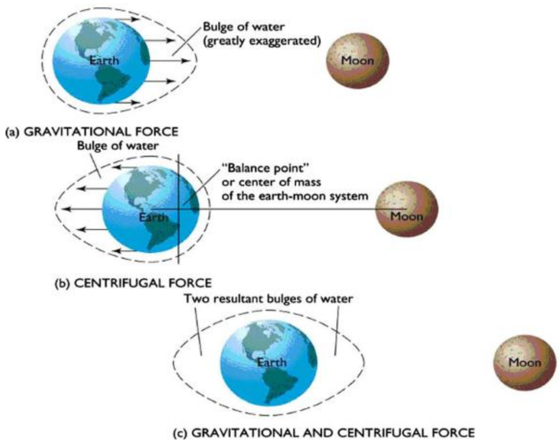


**Figure 1:** Gravitational and centrifugal force

In the book "The institute of engineering and technology, Tidal power" [10]. The principles of operation of Tidal barrages and how the potential energy of the tides is used are described. A tidal barrage is typically a dam, built across a bay or estuary that experiences a tidal range in excess of 5 metres [10]. Electricity generation from tidal barrages employs the same principles as hydroelectric generation, except that tidal currents flow in both directions. A typical tidal barrage consists of turbines, sluice gates, embankments and ship locks. The turbines that are used in tidal barrages are either unidirectional or bi-directional, and include bulb turbines, straflo or rim turbines and tubular turbines.

Tidal barrages can be classified into two types: 1.single-basin systems and 2.Double-basin systems.

### Single-Basin Tidal Barrages

Single-basin systems consist of one basin and require a barrage across a bay or estuary. There are three methods of operation for generating electricity within a single basin [11].

### Ebb Generation

The basin is filled with water through the sluice gates during the flood tide. At high tide, the sluice gates are closed, trapping the water in the basin. At this point extra water can be pumped into the basin at periods of low demand, typically at night when electricity is cheap. The turbine gates are kept closed until the tide has ebbed sufficiently to develop a substantial hydrostatic head across the barrage [12]. The water is let flow out through low-head turbines, generating electricity for several hours until the hydrostatic head has dropped to the minimum level at which the turbines can operate efficiently.

**Flood Generation**

During the flood tide the sluice gates and turbines are kept closed until a substantial hydrostatic head has developed across the barrage. Once the sufficient hydrostatic head is achieved, the turbine gates are opened allowing the water to flow through them into the basin. Flood generation is a less favourable method of generating electricity due to effects on shipping and the environment. These effects on shipping and the environment are caused by the average decrease in sea level within the basin.

**Two-Way Generation**

This method of operation utilises both flood and ebb phases of the tide to generate electricity. The sluice gates and turbines are kept closed until near the end of the flood cycle. After this point the water is allowed to flow through the turbines, generating electricity. When the minimum hydrostatic head for generating electricity is reached the sluice gates are then opened. At high tide, the sluice gates are closed and the water is trapped behind the barrage until a sufficient hydrostatic head is reached once again. Water is then allowed to flow through the turbines to generate in the ebb mode.

Two-way generation has the advantage of a reduced period of non-generation and a reduction in the cost of generators due to lower peak power [11].

**Double-Basin Tidal Barrages**

Double-basin systems consist of two basins. The main basin is basically the same as that of an ebb generation single-basin system. The difference between a double- basin system and a single-basin system is that a proportion of the electricity generated during the ebb phase is used to pump water into the second basin, allowing an element of storage; therefore this system can adjust the delivery of electricity to match consumer demands.

The major advantage double-basin systems have over single basin systems is the ability to deliver electricity at periods of high electricity demand. However, double-basin systems are unlikely to become feasible due to the inefficiencies of low-head turbines. High construction costs of double-basin systems due to the extra length of the barrage may also restrict the development of this system.

**Charlier R H. A Sleeper** in his research work “Tidal current power. Renew Sustain Energy” [13] have mentioned about the places where the tidal energy is utilized more. According to them the most desirable locations for harnessing the energy in tidal currents are generally sites where narrow straits occur between land masses or adjacent to headlands where large tidal currents develop. The major tidal currents are encountered in the following locations.

| | |
|---|---|
| Arctic Ocean | English Channel |
| Irish Sea | Skagerrak–Kattegat |
| Hebrides | Gulf of Mexico |
| Gulf of St Lawrence | Bay of Fundy |

| | |
|---|---|
| Amazon | Rio de la Plata |
| Straits of Magellan | Gibraltar |
| Messina | Sicily |

**Future Developments**

**Grabbe M et al**. in his review paper on "The Tidal Current Energy Resource in Norway" [14] and **Sathiamoorthy M, Probert SD** in **"**The integrated severn barrage complex harnessing tidal, wave and wind power" [15] has told about the future developments of tidal and wave energy. According to him tidal barrage technology is mature, reliable and has excellent potential. However, the high capital cost associated with the construction of a tidal barrage system is the biggest barrier restricting its development. The future development of tidal barrage systems depends specifically on an increase in the cost of electricity generated from conventional sources and on no alternative method of electricity generation is materialised in the meantime [15]. The major advantage this technology has over other renewable energy technologies is the fact that it is already available and reliable [15].

**Current Issues**

**Bahaj AS, Myers LE** in "Fundamentals applicable to the utilisation of marine current turbines for energy production" [16] has discussed about the current issues. The current issues restricting the development of tidal current turbines are installation challenges, maintenance, electricity transmission, loading conditions and environmental impacts.

The installation of tidal current turbines offers challenges some of which have been addressed from other off-shore energy technologies. These devices must be designed for ease and speed of installation.

Construction of foundations and installation during tidal currents will be challenging, with only a few minutes of slack time between tides. Some devices may require mooring systems which are subject to bio fouling and corrosion, affecting the survivability of the system. Several methods have been identified to prevent bio fouling and corrosion, particularly around seals, welds, bearing surfaces and electrical insulation materials. These methods include antifouling paints and the use of sonic and ultra-sonic systems.

Easy access to the turbine is required for maintenance. The use of a ship will be required for routine maintenance and repair of tidal current devices, making it hazardous and difficult. At the design stage, it is crucial to set out measures to reduce the frequency and difficulty of maintenance. There are several concepts proposed for ease of maintenance, most of which include the rising of the turbine above the water level to allow for maintenance from a platform or ship. Replacement of large parts will be a difficult operation requiring calm waters and good weather.

Electricity transmission is another issue and in some cases transmission to shore over longer distances may be required. If so the use of higher voltage transmission will be required. Generators should be developed to operate at higher voltages, preventing the need to install transformers at, or below, the sea surface. Tidal current energy resource is often in energy dense areas, where grid access is limited.

Upgrading the grid network may be required so that it doesn't restrict the amount of tidal generated electricity connected; this may be costly and cause public discontent.

In comparison to wind turbines, tidal current turbines generate a much larger thrust due to the density of seawater [16]. Resisting these large thrusts will involve the use of greater amounts of materials or stronger materials, which will result in greater capital costs. The fluctuations in the velocity of the flow around a tidal current turbine rotor can lead to several severe problems, such as blade vibrations, which may lead to fatigue failure. When designing a tidal current turbine turbulence levels must be taken into account to reduce its damaging effects.

The use of computer software to model the water flow and prototype testing will play an important part in blade design. The environmental impacts of tidal current devices are believed to be minimal in comparison to tidal barrages. The energetic conditions at which tidal turbines will be located are areas where marine species are not commonly found. Capturing the kinetic energy of the tidal flow has been identified as possibly the greatest environmental impact. This impact is also site specific and without appropriate assessments it is unknown how great an impact tidal current turbine may have on the surrounding environment.

## Discussion and Conclusion

**Fergal O Rourke** , **Fergal Boyle, Anthony Reynolds in** "Tidal energy update 2009" has discussed about tidal energy. Tidal energy is a clean and renewable source of energy and has the advantage of predictability over other renewable energy sources. There is great potential to generate large amounts of electricity from tidal energy technologies.

The large construction cost of tidal barrages is likely to restrict their development. However, with the probability of increased fossil fuel prices, tidal barrage schemes may prove to play a major part of worldwide electricity production. A considerable number of potential tidal barrage sites have been identified for large scale electricity generation, although only four tidal barrages have been constructed till date. Tidal barrages have several environmental impacts, such as effects on water quality and marine life. Tidal energy extraction using tidal barrages is mature and reliable with no major technical issues requiring resolution. Tidal current devices have lesser impact on the environment than tidal barrages. However the full extent of the environmental impacts is still unknown. As tidal current devices are still in an early stage of development, a lot of technical issues require resolution. Some of the main technology development issues identified are installation and maintenance, electricity transmission and loading conditions. All these issues will have to be fully resolved if tidal current energy is to be made a major source of electricity supply.

However, even though tidal energy is developing more quickly in most of the countries, financial supports for further development of tidal projects have not been materialised. Also, a robust resource assessment must be undertaken for all continents. Currently only a small minority of countries have conducted their own assessment of the potential for harnessing tidal energy within their waters.

Effective tidal energy policies are critical to the development of tidal energy. With such policies tidal energy can play a vital role in a sustainable energy future.

## References

[1] Pelc R, Fujita RM. Renewable energy from the ocean. Marine Policy 2002; 26 (6):471–9.

[2] US Committee on Science and Technology, Marine and Hydrokinetic Energy Technology: Finding The Path To Commercialization, 2010

[3] US, NREL. Climate change technology program, technology options: for the near and long term, DOE/PI-0002; 2005.

[4] Van Alphen K, Kunz HS, Hekkert MP. Policy measures to promote the widespread utilization of renewable energy technologies for electricity generation in the Maldives. Renew Sustain Energy Rev 2008;12(7):1959–73.

[5] Owen A, Trevor ML. Tidal current energy: origins and challenges. In: Future energy. Oxford: Elsevier; 2008. p. 111–28.

[6] Mazumder R, Arima M. Tidal rhythmites and their implications. Earth–Science Rev 2005; 69 (1–2):79–95.

[7] Clark RH. Elements of tidal-electric engineering. John Wiley and Sons; 2007.

[8] Clarke JA et al. Regulating the output characteristics of tidal current power stations to facilitate better base load matching over the lunar cycle. Renew Energy 2006; 31 (2):173–80.

[9] Boyle G. Renewable energy power for a sustainable future. 2nd. Berlin: Oxford University Press; 2004.

[10] The institute of engineering and technology, I. Tidal power; 2007.

[11] Bryden IG. Tidal energy Encyclopaedia of energy, vol. 6; 2004.

[12] Prandle D. Simple theory for designing tidal power schemes. Adv Water Resource 1984;7(1):21–7.

[13] Charlier RH. A ‘‘Sleeper” awakes: tidal current power. Renew Sustain Energy Rev 2003;7(6):515–29.

[14] Grabbe M et al. A Review of the Tidal Current Energy Resource in Norway. Renewable and Sustainable Energy Rev 2009;13(8):1898–909.

[15] Sathiamoorthy M, Probert SD. The integrated severn barrage complex: Harnessing tidal, wave and wind power. Applied Energy 1994;49 (1):17–46.

[16] Bahaj AS, Myers LE. Fundamentals applicable to the utilisation of marine current turbines for energy production. Renew Energy 2003; 28 (14): 2205–11.

[17] Tidal energy update 2009 Fergal O Rourke, Fergal Boyle, Anthony Reynolds Elseveir Applied Energy 87 (2010) 398–409.