Harnessing Un-retrieved Wave Energy-Sustainable Approach Towards Blue Economy: Bangladesh-Perspective

Abu Hasan Rony[1]

Abstract

Bangladesh has sustained solid economic growth since the last decade. The revolution in agriculture, manufacturing of readymade garments and many other industries are the main contributors for this. As such the power demand also increased exponentially in recent years. According to the Bangladesh Power Development Board, the maximum generation of power was 9479MW in June 2017 which was 4130MW in 2007. The energy demand is skyrocketed and the government is having a tough time keeping pace with it. At this stage, maintaining availability and affordability are the prime concerns for policymakers. The mounting pressure sometimes leads us to take wrong steps such as adopting cheap and dirty energy solutions. Aligning country's energy policy with international requirements, alternatives fuel, and Renewable Energy (RE) options are given consideration at present. All renewables such as Solar Photo Voltaic (SPV), ocean energy and wind energy require equal importance on the basis of their potentials. Recently, there have been significant improvements in the RE sector, especially Solar Photo Voltaic (SPV). But, it is necessary to look for diversified clean energy sources for a greener future. The necessary for a holistic approach and how the blue economic approach of Bangladesh could be made more meaningful are emphasised in this paper. Moreover, how the ocean energy in the Bay of Bengal such as wave, tidal and wind can be made more feasible for sustainable yield. This paper reveals the potential for exploring wave energy to meeting energy demand, especially for coastal community and a brief focus on recent energy policy of Bangladesh, infrastructure, logistics requirements and progress made in wave energy throughout the world.

Keywords: Renewable Energy, Wave Energy, Blue Economy, Sustainability, Diversification.

Introduction

For any nation to maintain growth, the wellbeing of citizens, eradication of poverty and uniform development of the societies, it is the availability, access, and security of energy are among all those matters most. Increasing global population and booming industrialisation are causing the dependency of fossil fuel to rise exponentially.

The anthropogenic pressure on climate, causing radiative forcing, is irreversibly damaging the climate since the last few decades.

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[1]*Chief Engineer (Marine), MEO Class 1, Singapore*

International Panel on Climate Change (IPCC) states, in the case of Business-As-Usual (BAU) scenario as much as 50 per cent biodiversity will be lost by 2050. The extreme events like floods, cyclone, wildfire, and drought are caused by the effect of climate change which is threatening human existence on earth. However, realising the adversity of climate change, the global community is more committed to a green energy solution than ever before. In the Paris Climate Change Agreement (COP21) and United Nations Sustainable Development Goal (SDG), every nation has specific targets on cutting down Greenhouse Gas (GHG) emissions.

The potential of Renewable Energy (RE) for powering our homes, cities, and industries are huge. 90 minutes of the solar energy that hits the earth surface is sufficient for powering the entire world for one year, IEA (2011). As a secondary source of solar energy, oceans have great potential as energy sources. Wave Energy, Ocean Thermal Energy Conversion (OTEC), and tidal energy are abundant in the oceans. These sources are mostly untapped and ignored. Despite having 710 kilometres of long coastline and access to the Bay of Bengal (BoB), the potential ocean energy resources were unnoticed by the policymakers till recently. In 2012 and 2014, respectively, Bangladesh won huge sea area from Myanmar and India after a long dispute and that victories have created increasing interest to the policymakers for embracing the blue economy. This paper reveals the potentials, possibilities, requirements, socio-technical aspects and a brief world outlook for harnessing the huge amount of wave energy available on the coastline of Bangladesh and in the BoB. A holistic approach towards a sustainable yield of ocean energy sources could be the solution to future electricity demand.

Wave Energy

Wave is the secondary source of solar energy which is abundant, free and sustainable. The kinetic energy content in the wave energy is around 1000 times more than the wind. (Ocean Energy Council 2017). About 1 per cent of the energy radiated from the sun reached the earth

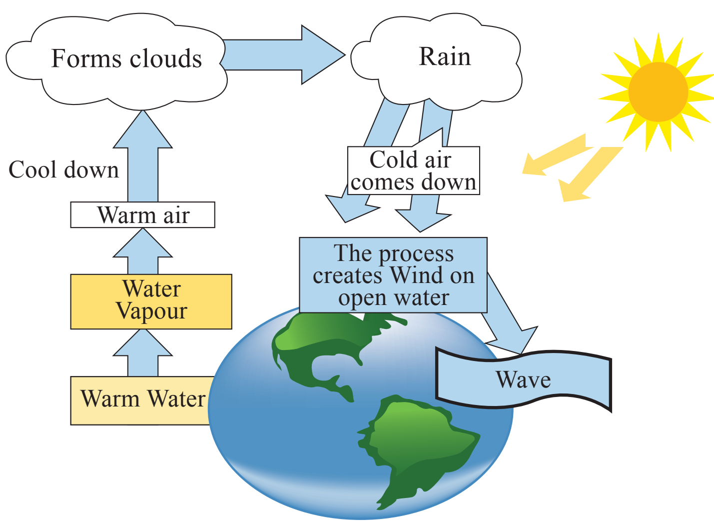

Figure 1: Creation of waves, Source: Author (Adapted from NOAA)

and is being used for creating waves. Long-period waves tend to be larger and stronger and short-period waves are smaller and contain less energy.

Waves are mainly the product of wind. Wind's interaction on the surface of the ocean creates waves on earth. As the earth is affected by unequal heat energy from the sun, the state of the air differentiates between different regions. Warm air expands and rises up while cold air condenses and sinks, hence resulting in the flow of air and forms wind. The wind carries warm water mists evaporated by the heat of the sun which forms clouds and later comes down as rainfall. The creation of different motion of wind on the surface of water produces waves of different motion and magnitude (Figure 1). As much as 95 per cent of the energy in waves is located between the surface and ¼ th of the wavelength. The best wave condition for

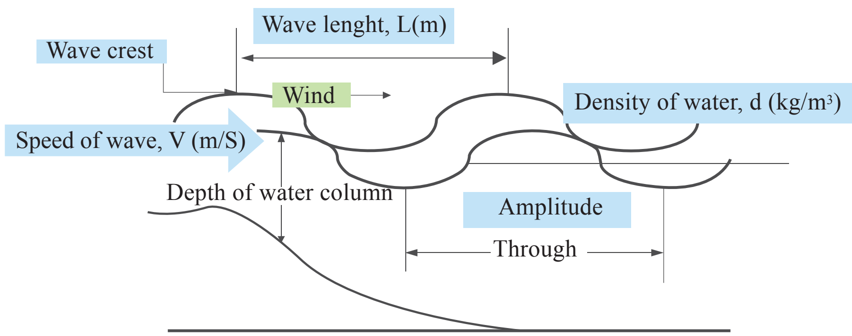

Figure 2: Factors affecting wave energy output, Source: Adapted from Aboobacker, (2016).

exploration is at high- medium altitude and in the deep water at more than 40m of water depth, and wave power density is about 60-70Kw/m in those places, International Renewable Energy Agency (IRENA, 2014).

Wind speed over the water surface determines the strength of the waves. Stronger the wind, the larger the wave is. In figure 2, the influencing factors of the wave energy on the earth

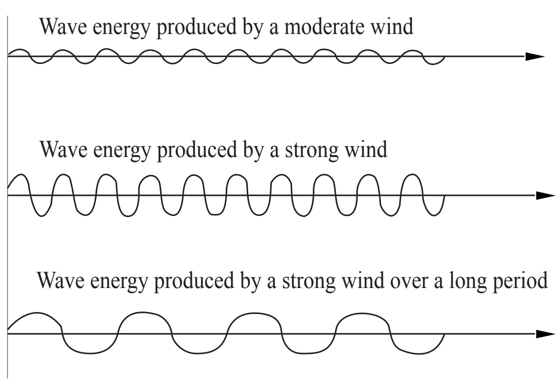

Figure 3: Characteristics of the wave, Source: Adapted from Boyle, 2012. p.363-404

surface are represented such as wave height, wavelength, the density of water and the depth of water. Also, Aboobacker (2016) states that ocean waves are not consistent and largely depend on wind duration (or how long the wind blows), and fetch, which is the distance over water that the wind blows in a single direction.

In figure 3, if the wind speed is slow, only small waves result, regardless of wind duration or fetch. If the wind speed is significant but it only blows for a few minutes, no large waves will result even if the wind speed is strong and fetch is unlimited. Also, if strong winds blow for a long period of time but over a short fetch, no large waves form. Large waves only form when all three factors contribute together (NOAA, 2002).

Energy transport of a harmonic wave can be measured as -

$$\mathbf{p_{Energy} = (\rho g^2 H^2 T)/32\pi \ (Wm^{-1})},$$

where, ρ is the density of water, g is the gravitational acceleration, H is the wave height (metres) and T is the wave period (in seconds). According to Boyle (2016), another important factor to consider for the establishment of wave energy is the location of instalment. The devices situated offshore can produce more energy than nearshore devices, as power density in the deep water is more than the shallower water.

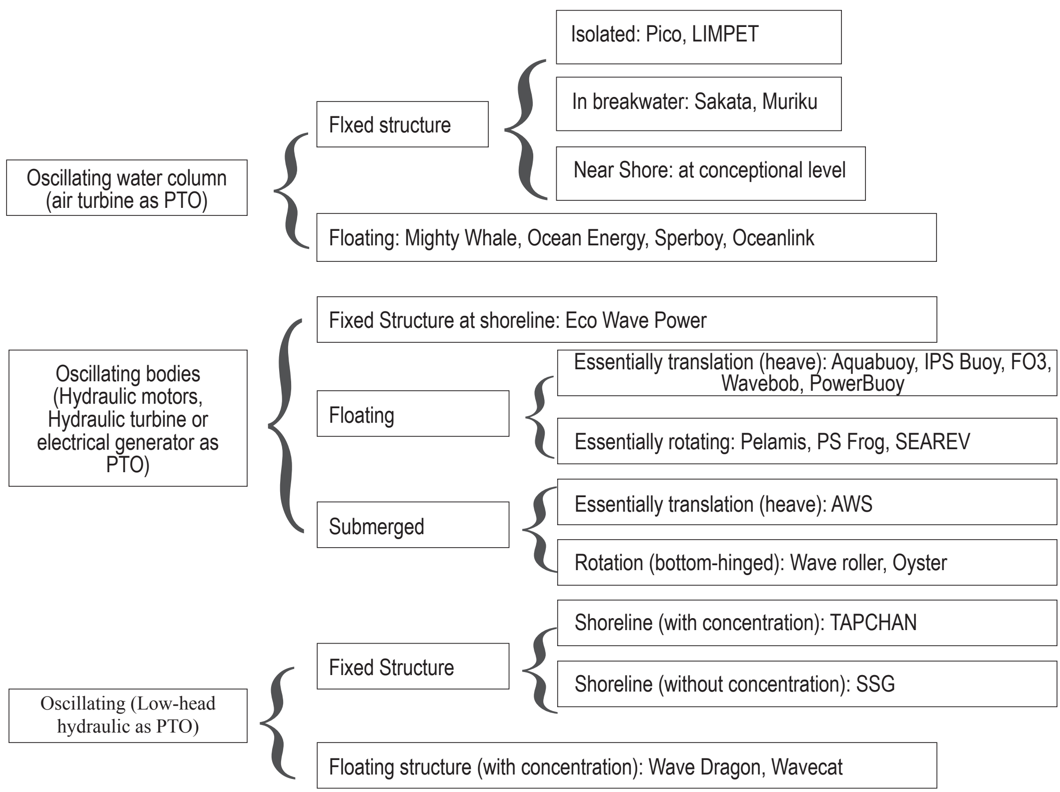

Figure 4: Types of wave energy converters,
Source: IRENA, 2014, Based on Pérez and Iglesias, (2012)

Wave Energy Converters

The available Wave Energy Converters (WEC's) are being classified on their employment and characteristics of places where the energy is extracted. With the available technology, three types of wave motions which can be converted into energy, such as horizontal front and back, horizontal side to side and vertical up and down motion can be extracted to energy (Kempener & Neumann, 2014). The WEC's are classified into three main categories, such as, Oscillating Water Column (OWC), Oscillating bodies (OB) and Overtopping which are then subdivided depending on their installation. The categorisation of WEC's is best described in figure 4.

Most of the WEC's are simple and have less moving parts which incur less maintenance. The principal parts of these technologies involve- the prime movers or power generation, foundation and securing arrangement with the seabed, Power Take Off (PTO) devices and the control systems for optimal performance of the installation. Some of the prominent WEC's are namely- Green Wave & Wavegen Limpet (Scotland/UK), Oceanix (Australia), Ocean Energy Buoy (Ireland), Pelamis, Wavestar, Oyster, Wave dragon (Denmark) and Wave cat (Spain). However, not all the converters are suitable efficient use in all condition of wave intensity.

Exploring Wave Energy Potential in Bangladesh

Geographically, Bangladesh is blessed with the vast shoreline of the BoB which can be a solution for RE for the coastal community and for the remote islands as described by Haque (2014). There are many sites available for wave energy production. Among them the south west of Cox's Bazar, Moheskhali island, Kutubdia island, Sandwip island and the Hiron point are the most suitable and potential wave energy sites in Bangladesh (CORDIS, 1995). The wave height in Bangladesh coastal area is about 1 to 2 metres, depending on the seasons.

The annual average of the wave power density is about (8-15) KWm-1 in the BoB (Boyle, 2012, p. 363-404) which is considered as a low concentration of energy. Saint Martin, Kutubdia and Sandwip Islands are the potential places where OWC's could be installed where power density is optimal for cost-effective operation. The average concentration wave energy is high between May to October for a single wave based on everyday data of wave height, as represented in figure 7. The most suitable wave energy devices for Bangladesh are OWC's and Pelamis device. OWC's are having a simple construction, required less maintenance, equipped with

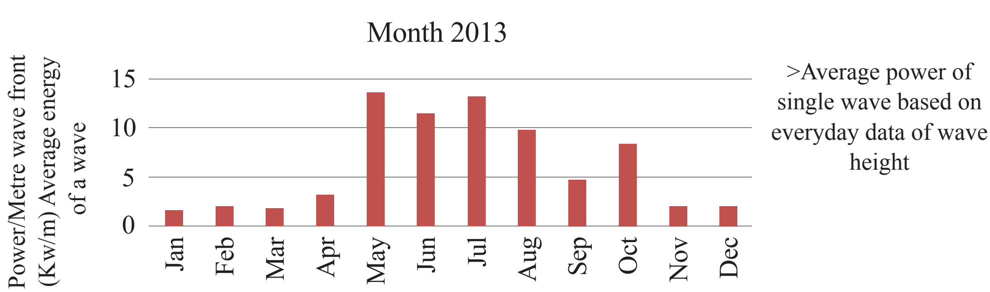

Figure 5: Average wave power, 2013, Source: (Haque, 2014)

wells turbines which rotate in any direction of air flow. For Pelamis device, low environmental impact, low cost, work at any direction of the wave, Shah Md. Salimullah etal., (2016).

The detail wave power assessment and compatibility study for integration with other ocean energy enhances reliability and integration with two or more energy resources on the same platform reduces the Capital Expenditure (CAPEX) and Operating Expenditure (OPEX) for per unit energy output.

Recent Energy Policy of Bangladesh

The total power generation of Bangladesh is about 15500MW and the share of RE is just about 2.8 per cent, illustrated in figure 9, of the total power generation of the country and over 50 per cent is gas. In 2008, the Renewable Energy Policy (REP) was enacted and a target was set. According to REP, by 2020 as much as 10 per cent share of total energy generation will be from renewable energy, Sustainable and Renewable Energy Development Authority (SREDA, 2017).

The Solar Home System, Domestic Biogas Programme, Solar Irrigation Programme, Solar Mini and Micro Grid System, Biogas based power Projects and Biomass-based Power Projects receive significant loan facility to promote to the end users. Recently, Solar energy has been promoted significantly by the government (figure 8). Table 1 represents the present status of RE in Bangladesh. It is time to think about the wave energy potential and includes it in the national REP for future strategy. A significant share of RE can be provided from wave which is comparatively simple and consistent than other sources.

The extended maritime boundary, in figure 10, opens a treasure for Bangladesh to explore natural resources on the surface, in water, on the ocean floor and under the seabed. The mean average power available in the Bay of Bengal region is represented in figure 11. From both figures, 10 and 11, it can be comprehended that a moderate intensity of wave energy can be

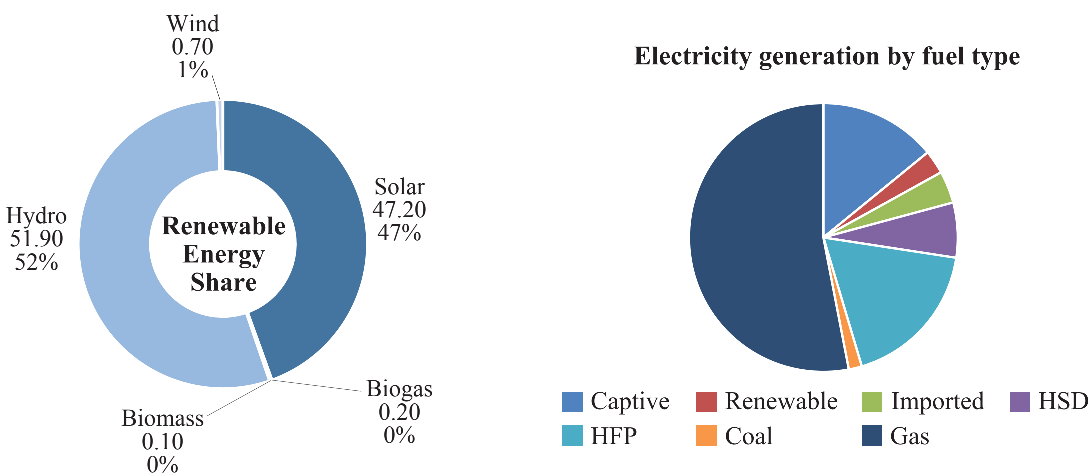

Figure 6: Electricity generation by fuel type, Source: SREDA

utilised for powering the energy-hungry nation in the extended and redefined maritime boundary of Bangladesh. However, wave energy did not receive sufficient attention from the policymakers.

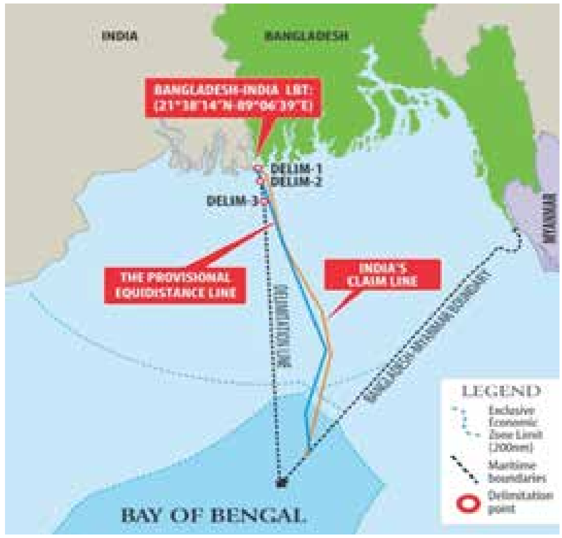

Figure 7: Reclaimed sea area of Bangladesh (Source: The Daily Star, July 08, 2014),

Building Expertise

Human elements are as important as technology in energy management and should be treated equally (Kitada & Ölçer, 2015). It is of utmost importance to ensure quality education and research on energy. Knowledge about the sustainable use of ocean energy is also important for citizens as well as policymakers. In 2013, Bangladesh established Bangabandhu Sheikh Mujibur Rahman Maritime University (BSMRMU) to enhance education for promoting maritime education in the country which has begun its journey in 2016. Besides, many public and private universities are providing education on oceanography, electrical and electronic engineering department for providing education of ocean energy to some extent. However, to build quality experts in this field, more funding on quality maritime education and research is required for capacity building for the future.

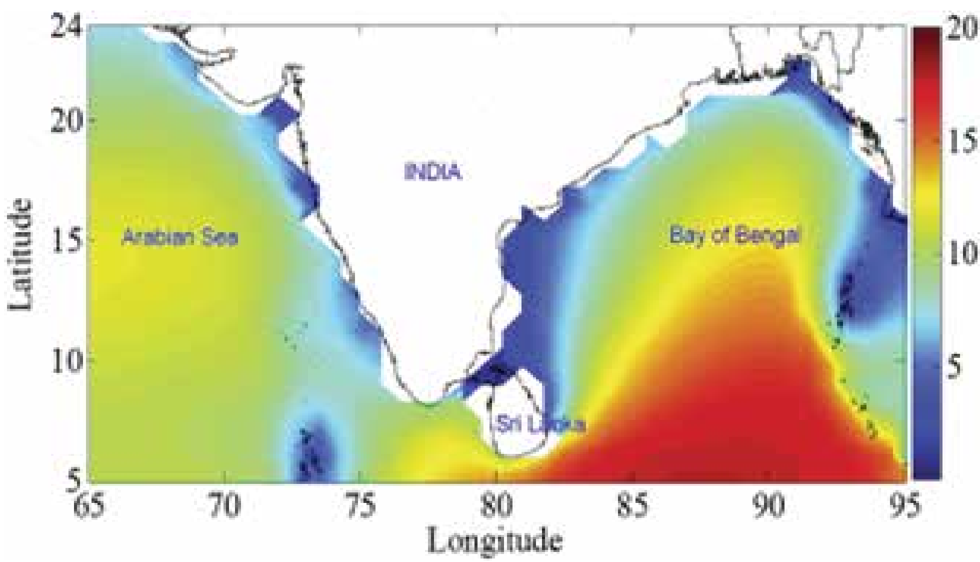

Figure 8: Mean Ave wave power-BoB(Source: Sanil Kumar &Anoop, 2014)

Dealing with Renewable Energy in Bangladesh

Bangladesh has very limited natural resources. The limited reserve of natural gas is not sufficient to meet local consumption. In December 2009, after ratifying REP, the Bangladesh Government established Bangladesh's only RE authority SREDA, Power Division, under the Ministry of Power. The SREDA deals with energy management in the country and now has an ambitious target of producing 2000MW of electricity from renewable sources by 2021. However, the policy of SREDA is so far lacking in diverseness in exploiting all sorts of natural resources.

Availability and Affordability of Technology

About 100 pilot projects based on wave energy are ongoing in the different parts of the world. As technology gets maturity, simultaneously, the extraction of wave energy will be cheaper with research and innovation. However, now it is expensive compared to other sources. The

Table 1: Comparison of the cost of energy sources, (Source: Ocean Energy Council, 2017)

Energy Sources	Cost of production
Fossil fuel	3.58 Cents/KWh
Wind	4.5 Cents/KWh
Wave	7.5 Cents/KWh
Coal	2.6 Cents/KWh
Combined cycle natural gas	3.0 Cents/KWh

production cost also varies depending on the intensity of energy in waves, distance from the shoreline and geographical location of the farm (Ocean Energy Council, 2017).

Figures in table 2 do not conclude that availing wave energy will be most expensive. Considering all concerning aspects such as environmental impact, OPEX, CAPEX, Levelized Cost of Energy (LCOE) and Social cost of Energy (SCOE), the unit price will be considerably reduced which will make it suitable for deployment.

Development of Infrastructure

In Bangladesh, many coastal area and islands are still not connected with the national electrical grid. Prior to setting up any RE farm, it is necessary to bring all remote areas under the distribution network. The infrastructures for a wave farm are required for electricity generation, supply grid infrastructure, connection, port facilities and mooring where the wave energy converters are stationed in deep water. Sometimes, it needs more complicated installations as it requires substation, long distance underwater cabling and maintenance station (Kempener & Neumann, 2014). Boyle (2012) describes that as the intensity of wave varies, great care must be taken to connect with the small power grid and varying output can be accommodated by the dump load to eliminate fluctuation in demand.

Logistics of Wave Energy

Wave energy needs a similar supply chain as oil and gas (Kempener & Neumann, 2014). A wind farm can be integrated into any forms of offshore energy installation. So, the wave and ocean current harnessing devices could be fixed into the same platform for wave energy, Manasseh SA. et. al. (2017). This helps to improve PTO systems and connections which allows multi arrays of systems well connected to each other in the same grid. The direct use of wave power from the plant can be arranged, but it is recommended to connect it with the electricity grid as varying wave power, phase factor, transmission loss and power factor correction should be considered as influencing factor (Freris & Infield, 2008).However, there is a huge lack in cohesion and supply chain for the development of wave energy technology (Kempener & Neumann, 2014).

Analysing LCOE and SCOE of the Wave Energy

For pre-assessment and feasibility study, it is important to calculate the LCOE, the net present value of all cost of the sources over the lifetime divided by the output energy by the source, which is the first thing to consider and forecast.

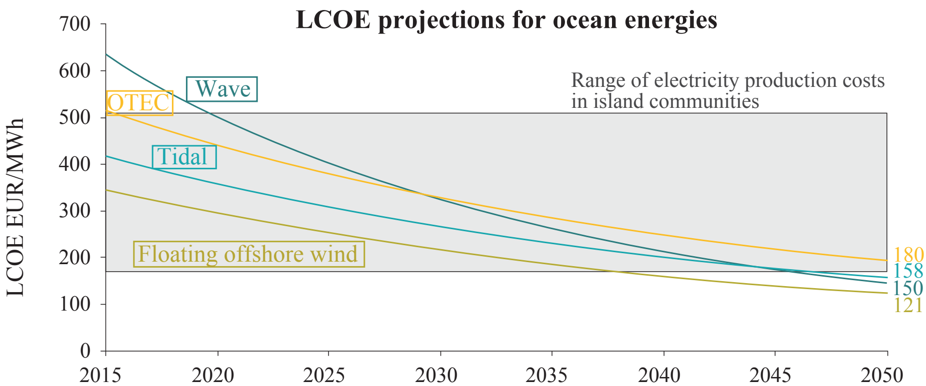

Figure 9: LCOE Projection for ocean energies, (Source: arena.gov.au)

The LCOE is a very important factor and it depends on capital cost, operational cost, maintenance cost and cost of fuel used. LCOE decreases, when installed capacity of the wave energy reduces, Penesis et. al. (2016). Figure 12 forecasts the LCOE over time till 2050 which also shows great potential for wave energy use beyond 2030. At present, LCOE for wave energy is about EUR 330-630/MWh, which will come down to EUR 113-226/MWh in near future (Kempener & Neumann, 2014).

The environmental cost of providing that energy to society also needs to be considerd, which is termed as SCOE. The SCOE requires an environmental assessment to perform on the site and beyond, effect on biodiversity in the life span, energy use, storage and at last the recycling or beyond insurance cost ensuring the minimal adverse impact on the public health and environment. For some energy sources, such as coal and fossil fuel, the environmental impact and the SCOE are huge as the adverse impact on public health and climate change.

The Forerunners of Wave Energy

In IPCC's assessment in 2007, it has been estimated that the wave energy could be deployed by 2 per cent of 800,000 Km coast of the world where power density is above 30KW/m. According to geographical location and power density of wave energy, Australia, UK, Ireland, Chile, USA, New Zealand and South Africa have the most favourable condition for wave energy exploration with a power density of 40- 60KW/m. Among them, the United Kingdom is in the most suitable position for harnessing wave energy as it lies end of long fetch of. It is estimated that around 15-20 per cent of the UK's energy demand could be met by wave energy, Boyle, (2012). World first wave energy converter was established in Isle of Islay, Scotland which was a 5 MW plant, Ocean Energy Council, (2017). More than 100 pilot projects exist all over the world (Kempener & Neumann, 2014). Below table shows leading wave energy producers in the world.

Table 2: Top wave energy potential countries and their current production
(Data gathered from Australian Energy Council, Marine Renewable Canada, Australian Renewable Energy Agency, www.energy.gov, World ocean review, Wave Power: AENews, Ernst and Young Associes)

No	Country	Wave Energy Potential (TWh/Year)	Current Power Production from Wave	Recent Investment
1	Australia	2760TWh/year	1.25MW	AUD43Mil/3MW
2	USA	2640TWh/year	0.06MW	USD64 Millions (Oregon)/1.5MW
3	Canada	1863TWh/year	0.759MW	None
4	South Korea		0.5MW	0.3MW
5	UK	350TWh/year	1MW	40MW
6	China		0.5MW	2.8MW
7	Japan	19TW/year	0.15MW	350MW
8	All Europe	2830TWh/year	2.25MW	85.6MW
9	Global	11400TWh/year, (1700TWh/Year-sustainable-production)	Around 4MW	Around 411MW

Table 2 represents the leading producers of wave energy and also their efforts and strategy for the future. Basically, in the current situation, it is difficult to name one particular country as the leader in wave energy. Australia, USA, Canada, South Korea, UK, China, Sweden and many other European countries are showing huge interests in wave energy. Thanks to the COP21 and other environmental regulations, UK, Australia and Japan are taking big leaps towards wave energy for a sustainable solution to cut their GHG emission. As such now it is time for Bangladesh to start exploring this area.

An Apple-to-Apple Comparison

The wave energy density along the Bay of Bengal coast of India and Bangladesh are similar. Thus, initiatives which were taken by the Indian Government in this respect could be an inspiration for Bangladesh. A multi-resonant OWC has been installed in a breakwater utilising a wells turbine (axial flow, unidirectional) situated at Trivandrum coast in India (Figure 14). As shown in figure 14, wave strikes on the harbour wall situated in the breakwater, which makes air to escape from the top of the wells turbine and drives the electrical generator. The wells turbine is of 2 metres in diameter and capable of driving 150KW generator.

The power density in the Indian coast is about 5 to 10KWm-1 and output of the plant varies significantly, between April to November it is 75KW and December to March about 25KW. The two units of power conversion systems are incorporated in the systems as both of them

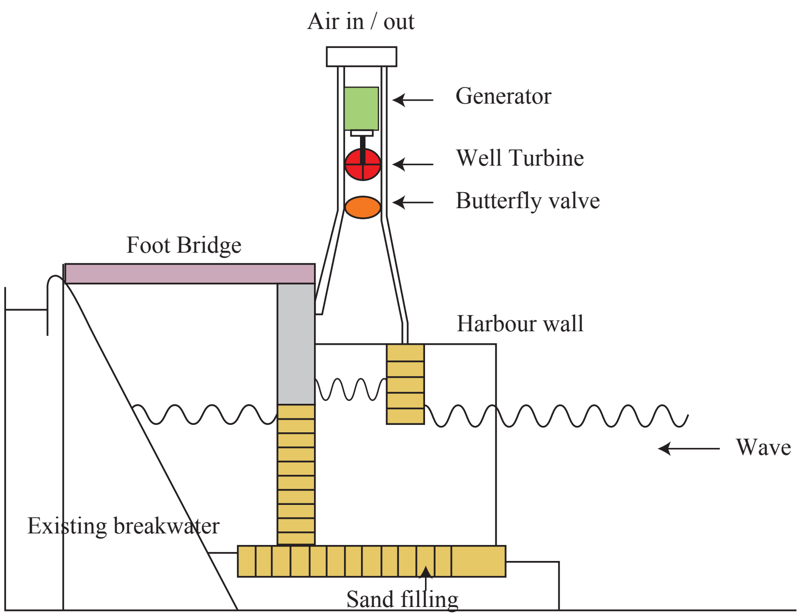

Figure 10: Cross-sectional view of Indian breakwater OWC, Source: Boyle, 2012.p.363-404

could be operated at a peak energy density period. A plan has been taken by the Indian Government that many more such devices are to be installed along the Indian coastline considering the potential of the energy source (Boyle, 2012).

Recommendations

Transition to wave energy is much desirable from Bangladesh perspective. Wave power can save coastlines from breaking waves and adverse coastal erosion as the array of wave energy devices could significantly reduce the wave height (Shields & Payne, 2014, page no. 9-12).

The offshore renewable energy farm could be a great habitat for marine species and protected zone for fisheries. Considering the positive impacts, wave energy can be a lucrative solution to electricity shortage.

Ocean literacy has to be enhanced among students and individuals through education and knowledge about our blue planet, life underwater, coastal management, fisheries management and ocean energy. More funds need to be allocated for R & D on the ocean in various public and private educational institutions in the country.

Besides REP, the government should enact Ocean Energy Policy for better protection of the ocean, detail energy mapping, and sustainable ocean management. Bangladesh Government's policymaking needs to be directed towards renewable energy future and investment have to be made on research for local solutions and promoting climate literacy and innovation in the early stage of education. Such a system will provide a greener solution while reducing the carbon dioxide emission and meeting the requirements of SDG 7 and COP21 goals and targets. All public and private sectors could be the potential participants for the green energy exploitation to power up economic development through collaboration and mutual partnership.

The shoreline of Bangladesh could be utilised for the exploration of ocean energy for powering the coastal population and remote islands mostly the poor community of the coastal are still deprived of electricity supply. The Isolated islands, such as Saint Martine Island, Andar Char, Dublar Char, Nijhum Dwip and many more islands could get their power supply from renewable sources. Development of smart grid system integrating all power sources could be a feasible solution in this case. An expert's assessment and research on sustainable ocean energy yield and holistic marine spatial planning are required at this stage.

Conclusion

A huge population is still out of the electricity supply network, mostly living in rural and coastal areas. Paradoxically, Bangladesh has registered tremendous growth during the last ten years, Gross Domestic Product (GDP) stayed over 7 per cent for the past few years. To keep the momentum of the development she needs to ensure sustainable and affordable energy for all citizens. Looking for diverse sources while reducing the carbon footprint is the key issue here. Recently, gaining access to the continental shelf of the BoB has created a great opportunity for exploration of resources on the water, sub-surface and seabed. Extensive research on wave energy resource modelling and mapping are now extremely important for boosting Bangladesh's recent drive to the blue economy. As we can see the wave energy is getting momentum and increasingly becoming a focal point as the alternative source of energy in many countries. With respect to geographical condition and wave energy potential, the most suitable wave energy devices for Bangladesh are OWC's and Pelamis device which need to be explored. The wave energy may not seem to be cost-effective alone at present, however, in a holistic approach, wave energy including the wind and tidal energy can create huge difference and positive impact on the development of Bangladesh.

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