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Blue Biotechnology, Renewable Energy, Unconventional Resources and Products as Emerging Frontiers at Sea

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1 INTRODUCTION

Marine Biotechnology, means diverse things to different people. Put simply, marine biotechnology, is the utilization of marine bioresources as the objective or source of biotechnological applications; marine resources are utilized to develop products or services; however, the marine environment can likewise be the beneficiary of biotechnology applications developed using terrestrial resources. As indicated by the Smithers Group (2015), global market for marine biotechnology can possibly reach $4.8 billion by 2020, rising to $6.4 billion by 2025. The United States leads the market with biggest share for marine biotechnology. Healthcare services or biotechnology constitutes biggest end-utilize section for marine bioresources. Europe is dominating one of the main areas adding to the development of this market. In Asia Pacific, China, India, South Korea and Japan, Thailand and Vietnam and Australia are expected to become significant markets for marine biotechnology within a reasonable time-frame, unfortunately Bangladesh is quite behind.

1.2 Emerging Blue Activities in Bangladesh

Emerging sea-based activities creating and applying a scope of science and technological advancements to explore the sea's all resources more securely and sustainably, or to make the seas cleaner and more secure and to ensure the abundance of their resources. The activities contrast extensively in their phase of improvement: some are generally cutting-edge while others are still in their initial stages (Table 1).

Table 1: Established and emerging sea-based sectors in Bangladesh.

Established	Emerging
Capture fisheries	Mariculture
Seafood processing	Marine Biotechnology
Marine trade, shipping and transportation	Sea renewable energy
Sea ports infrastructure & services	Offshore wind energy
Shipbuilding and repairing	Marine and seabed mining
Offshore oil and gas (shallow water)	Deep- water oil and gas
Marine manufacturing and construction	Maritime safety and surveillance
Maritime and coastal tourism	Marine unconventional products and services
Marine business services	Marine R&D and education
Sea salt production	Others

1.1.1 Marine Biotechnology

With regards to a worldwide financial downturn, Bangladesh is presently confronting intricate and troublesome difficulties, for example, the sustainable supply of food and energy, climate change and natural disaster, human health and wellbeing, high unemployment rate and old

populaces. Marine Biotechnology can make an imperative commitment towards addressing these societal challenges and in supporting monetary recuperation and development in Bangladesh (Figure 1).

1.1.2 Renewable energy

Despite the financial status, developing or developed, it is the worldwide pattern to advance renewable energy source, as a major aspect of energy security and additionally greenhouse gas emission reduction. Right now, renewable energy sources including solar energy have a low offer of the aggregate energy production (<2%) in Bangladesh (Islam and Khan 2017). The production of renewable energy from tides and waves, wind turbines situated in offshore regions, submarine geothermal assets and marine biomass could be suitable options for contributing to energy needs and environmental change mitigation goals. For Bangladesh, such renewable sources could help extend their energy portfolios and secure larger amounts of energy security.

1.1.3 Unconventional fishery products

Unlike other countries of the world, the unconventional fishery products in Bangladesh is profoundly encouraging. There is most likely that existing living resources, specifically mollusk (squids, oyster, mussel), seaweeds, marine echinoderms, marine micro algae and others can be utilized as a source of new fishery products that could straightforwardly consumed as nutritionally balanced marine food.

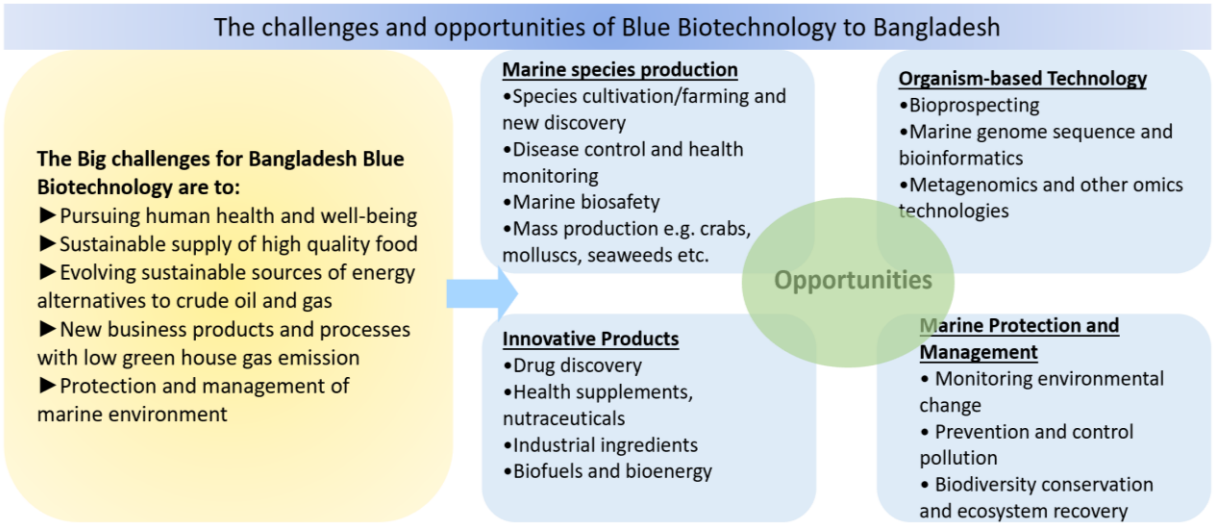

Figure 1: The grand challenges and evolving opportunities of blue biotechnology to Bangladesh.

1.1.4 Key role of the government and private sectors

The government of Bangladesh has a grand responsibility and a dynamic part in the blue economy, tending to existing issues and boundaries to enhance the overall blue development

potential and research center around its needs. The Initiative aims to encourage empowering crosscutting advancements;

- to make the best empowering condition for augmenting the improvement of marine biotechnology, renewable energy sources and unconventional fishery items;
- to create and maintain infrastructure to help a coordinated information and data base empowering industrial development and backup maritime governance;
- to build up a research to-approach system, specifically to help the marine strategy framework directive (MSFD) and marine spatial planning and administration;
- and to promote the interdisciplinary human capacities important to achieve the SDG 2030 goals and objectives.

The private sector has the duty to recognize and express the real statistical surveying needs. The government of Bangladesh looks for help and works together with several private sector stakeholders for the research and innovation (R&I) program.

1.1.5 International cooperation

There are huge challenges with respect to blue development explore, the greater part of which are worldwide (e.g. ocean acidification) and should be tended to by joint activity attempted at a worldwide level. Global collaboration in R&I for practical improvement and development of the marine and sea parts should be upgraded.

2 BLUE BIOTECHNOLOGY AND THE BLUE ECONOMY

2.1 The Blue biotechnology — an empowering technology

Blue is the shade of the seas and of the oceans and that is just why it defines the world of biotechnology that utilizes molecules and substances of marine origin, while other specific sectors defined by colors for example red for pharmaceuticals, white for industrial biotechnology, green for agricultural, yellow for environmental (Greco and Cinquegrani, 2016).

One of the significant uses of biotechnology in marine science is with respect to aquaculture. In any aquaculture industry the main point has dependably been to produce fish varieties that can become quicker, more beneficial, and greater with tastier flesh. Biotechnology in sustainable aquaculture and fisheries is profoundly effective to help the food security of Bangladesh (Figure 2). For instance, gene transfer technology was used to develop the growth of fish. In China, Zhang et al (1998), developed a gene containing promoter gene of antifreeze protein (AFP) and salmon growth hormone cDNA and was introduced into the red sea bream fish genome by electroporation technique and found good result. Another case of the utilization of biotechnology in aquaculture is the progress of DNA immunizations for aquaculture. Heppell et al. (1998) described that DNA vaccines are harmless, modest and proficient to be utilized as a part of aquaculture industry.

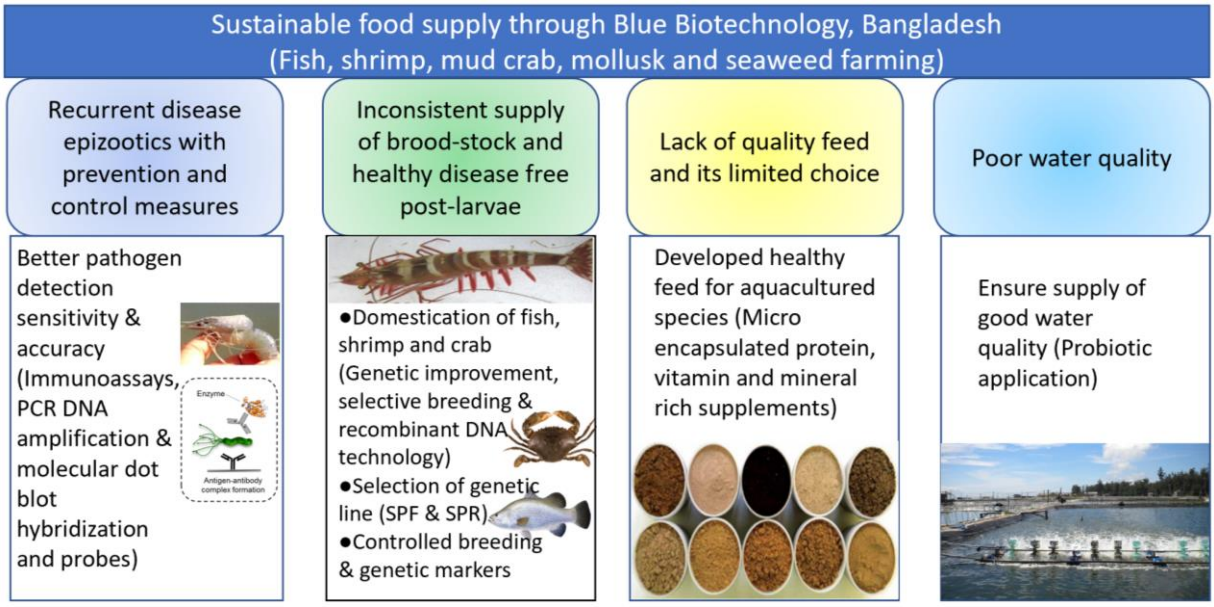

Figure 2: Sustainable food supply through blue biotechnology, Bangladesh.

A noteworthy issue in aquaculture is disease control. In many shrimps producing countries, *Vibrio* and *Aeromonas* are considered as the most well-known and significant infectious pathogens and causing mass mortality of penaeid shrimp larval stages (Lightner, 1996; Vaseeharan et al., 2005; AftabUddin et al., 2008). Use of monoclonal antibodies and DNA probes to new diagnostic strategies for pathogens has turned out to be extremely encouraging.

Another valuable utilization of molecular techniques is for stock assessment, genetic variation and evolutionary processes of aquaculture and wild fish and species recognizable proof which

remain uncertain issues in fishery management. To resolve those issues several molecular techniques such as mitochondrial DNA (mtDNA), Nuclear DNA (nDNA), DNA chips (microarrays), microsatellite DNA markers has become very promising (Olsen et al., 2000; Miller 2003; Liu and Cordes 2004; Hemmer-Hansen et al. 2014; Komoroske et al., 2017).

Another rising part in marine biotechnology is marine natural products (marine medication revelation). Trabectedin, a marine-derived anticancer medication was likewise endorsed to be utilized in Europe in 2007 (Molinski et al., 2009). A variety of bio-active compounds has been acquired from various marine organisms and are right now under investigation and in cutting edge phases of clinical trials (Montaser and Luesch, 2011; Blunt et al., 2014).

So, the blue biotechnology is a key empowering technology that backings the growth of nations blue economy. It is a multi-disciplinary, information and capital-intensive innovation that is applicable all through the value chain and navigate diverse segments. The initial steps of the chain depend on the discovery of new marine living beings, the isolation and characterization of interesting bioactive molecules and proteins, and to establishing protocols that developing potential business utilizations of these molecules. Until now the Bangladesh Blue Biotechnology sector is not existing compared to India, Japan, Malaysia, Thailand, EU and other developed country but have a good growth potentiality (Figure 3).

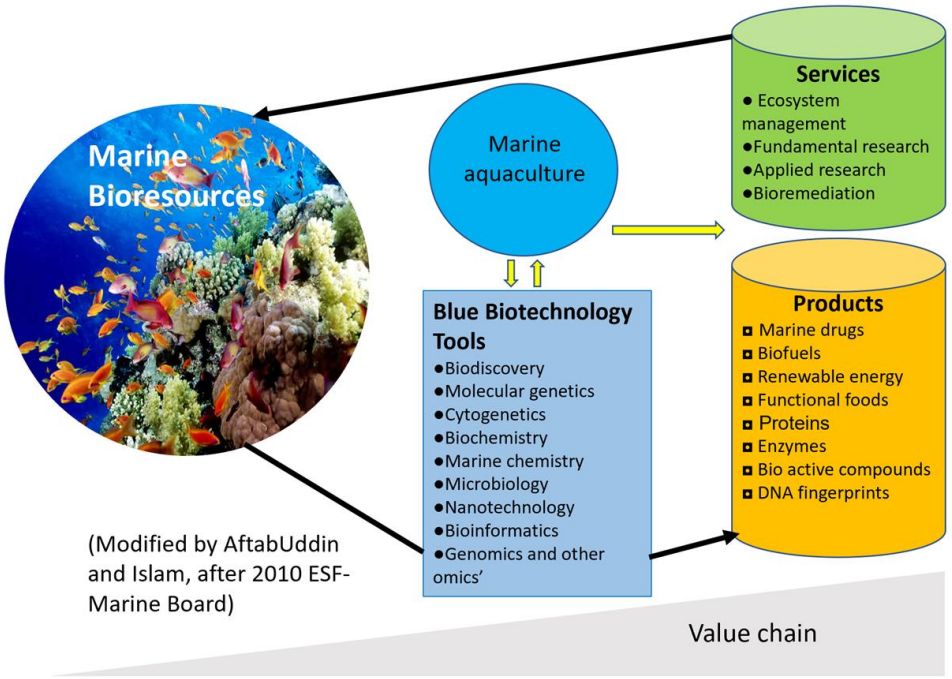

Figure 3: Possibility of blue biotechnology (resource-infrastructure-innovation) and the sorts of tools and technologies applied, resulting products and services. Source: slightly modified after 2010, ESF-European Science Foundation-Marine Board.

2.1.1 Blue biomass and its role of biosciences and contribution to the blue economy

Marine biomass starts from the wide-ranging marine biodiversity of the seas and contains numerous forms, e.g. entire fish, discards from open sea catching or processing, aquaculture items, macro and micro algae — both wild and developed, marine invertebrates and marine

microbes. The production and harvesting of available marine biomass is the beginning stage of extracting value from marine bioresources. The growth of Bangladesh's blue economy could be enhanced on the transformation of marine bioresources into food, medicine, animal feed and related bio-based items i.e. cosmetics, nutritional supplements, enzymes, agrichemicals etc. and is perceived as addressing to meet the Bangladesh future challenges for the 21st century (Figure 4).

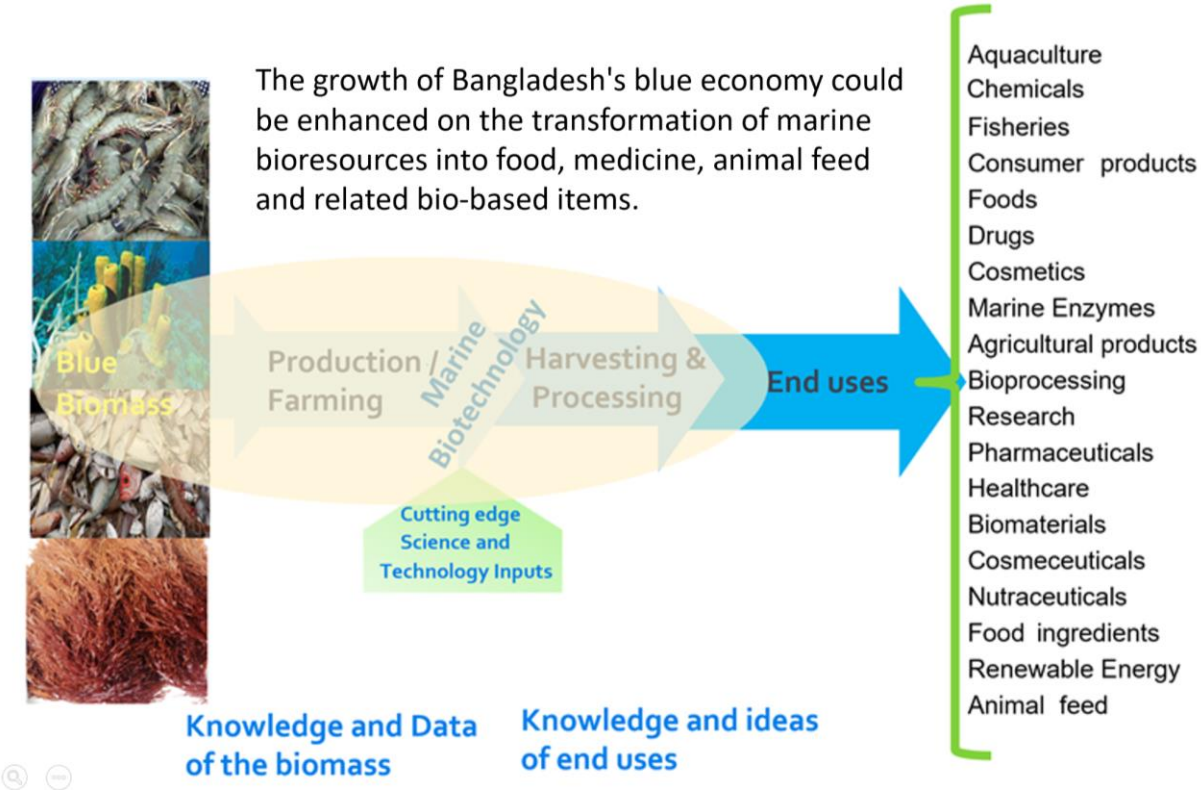

Figure 4: Transformation of Blue biomass into industry or process sectors.

2.1.2 Business activity and global markets for marine bioresources

The major opportunities to utilization of marine bioresources in business sectors are modern chemical compounds or enzymes, pharmaceuticals, foods, beautifiers, farming items etc. However, the emerging applications includes bioprocessing, ecological remediation and monitoring, genetics, marine bioactive substances, marine biomaterials, mariculture, fermentation engineering and enzyme engineering. Marine fish, sponges, tunicates, molluscs and bacteria are the main sources of potent bioactive compounds that shows various anti-tumor, anti-inflammatory, analgesia, immunomodulation, allergy, and anti-viral properties (Ebel and Jaspars 2015). As of March 2018, the US FDA has approved seven marine derived drugs for clinical use and a further 22 at various stages of pharmaceutical clinical trials (Mayer 2018).

Another growing business is nutraceutical products which is expected to be worth USD $578.23 billion by 2025 (Research and Markets, 2018). This market mainly constitutes functional foods and beverages, dietary supplements, sports drinks and medically formulated foods. The nutraceutical ingredients include pre-biotic and pro-biotic vitamins, minerals, fibers, proteins, omega 3 and structured lipids, amino acids and various other constituents. The global Omega-3 PUFA market is valued at 12.3 billion US$ in 2017 and will reach 19.00 billion

US$ by the end of 2025, growing at a CAGR of 5.6% during 2018-2025 (QY Research 2018). The Global Cephalosporin Market was valued at US $77,764 million in 2016 and is estimated to reach US $1,99,754 million by 2023 (Kaul & Srivastava 2017). The Cephalosporin was derived from the microscopic fungus *Cephalosporium acremonium* in 1945 and first sold in 1964 (Torok et al., 2009).

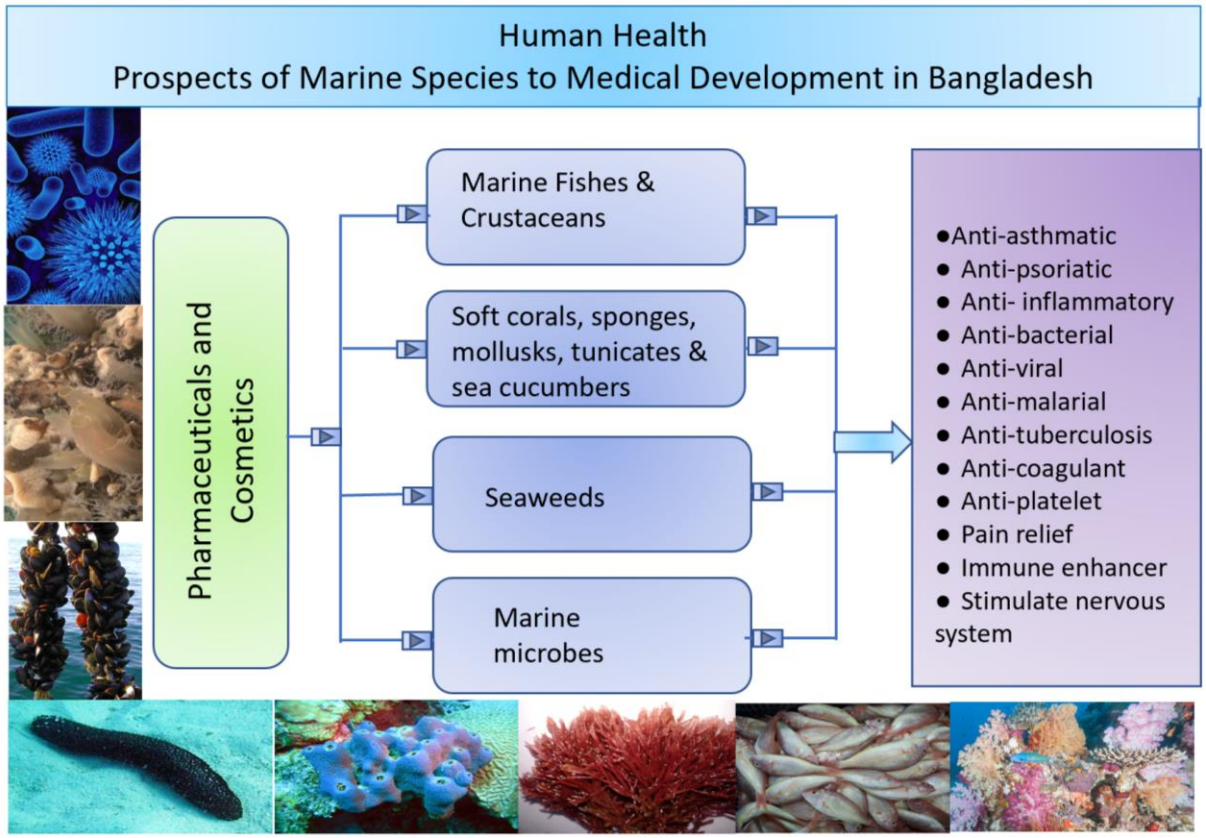

Figure 5: Prospects of marine bioresources to clinical development in Bangladesh.

Though, the anticipated high-development prospects for human wellbeing, food and biomaterials-related applications offer significant extension to make high-esteem products from Bangladesh marine bioresources. Marine biotechnology or blue biotechnology related research and innovation is not familiar by Bangladesh policy makers and the private entrepreneurs. The challenge of developing marine biotechnology capabilities has just been grasped by India and other neighboring countries, they have built up some intends to enhance their blue economy by expanding the utilization of their sea resources, unfortunately we are very behind it.

2.1.3 Exploration of the ocean environment

Even with the potential of the seas, the expenses of deep water exploration beyond the shallow coastal zone of the Bay of Bengal, is the main challenge of accessing those areas that remain undiscovered. Bangladesh's extensive coastal regions are home to numerous types of organisms, algae, fish, crustaceans and invertebrates, all of which offer convenience to marine bioresources for discovery type research. Seaweeds and fish are the vital sources of marine

biomass as of now utilized as a part of business applications, essentially as food and food ingredients. The consequences of different bioprospecting and discovery activities show the conceivable outcomes for a more extensive scope of utilizations for compounds derived from marine species.

Materials discarded during catching, harvesting, production and processing of marine species are exploited as human and animal food ingredients, composts, dietary supplements, biochemicals, proteins and lipids. More exploration and examination of known sources of bioproducts is expected to grow the conceivable scope of uses for such materials. However, marine exploration is largely dependent on collaborative research activity and technologies. To explore the Bangladesh marine environment, policy must be taken to i) target the sources of marine biomass; ii) accessing marine habitats; and iii) characterizing marine species, including their chemical and biological composition (Figure 6).

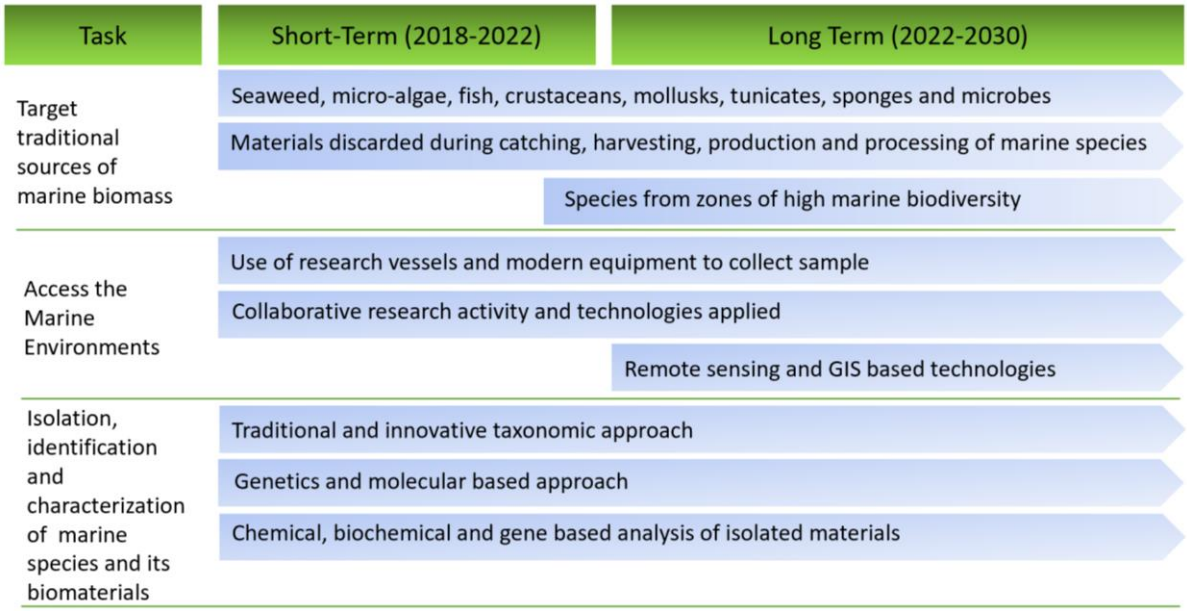

Figure 6: Marine exploration strategy for Bangladesh.

2.1.4 Marine Biomass production and processing

In Bangladesh, the culture of marine species is restricted to the production of finfish and shellfish, currently lesser extent to seaweed in coastal aquaculture activities. Offshore and deep-water aquaculture and integrated multi-trophic aquaculture (IMTA) are dynamic research themes. Changes in culturing processes are probably going to extend the utilization cultured biomass from food to take in non-food use and additionally develop new sources of feed. Marine biotechnology, including new breeding technology and genetics, is set to help more diverse and beneficial culturing of marine species. For instance, the global demand for marine lipids for use in functional foods, ingredients and in nutraceutical products, is growing and uses marine biotechnology to extract Omega-3 from fish, seaweeds and microalgal sources. The important components of the marine biomass production and processing in Bangladesh involve various tasks (Figure 6):

- Expanding the culture of biomass from marine resources, together with investigating the possibility to grow on coastal land and offshore aquaculture.
- Building up the controlled culture of marine biomass at sea and coast and creating strategies to culture marine living organisms which have not at present in culture.
- Decreasing the intricacy of the inventory network by incorporating biomass generation and refining, reducing energy demand and waste in processing marine biomass.
- Taking part in research to help the extension of cultured biomass production including measures to limit and relieve ecological effects; tending to waste management; upgrade biosecurity and the start of new production approaches like breeding, rearing, genetic manipulation, food and health status etc.

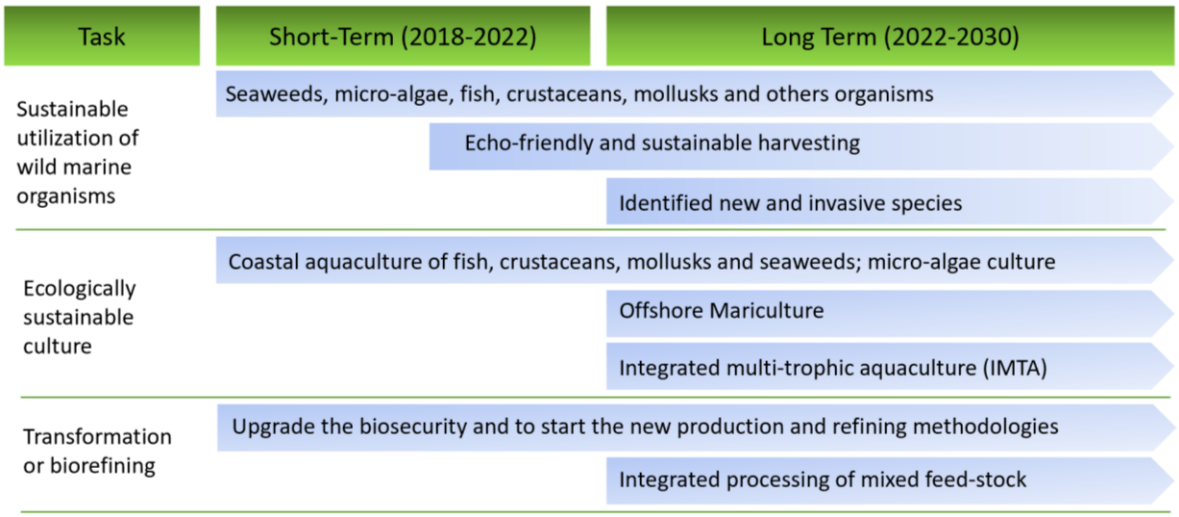

Figure 7: Policy can be taken for biomass production and process in Bangladesh.

2.1.5 Emerging market opportunities and challenges for product innovation and development

Currently, marine biomass is used as food and feed sectors in Bangladesh and none of them are used in the alternative sectors like pharmaceuticals and others. But there is a good prospect of application of novel marine derived compounds and its emerging market in the country like the health sector (new drug discovery). Even though the making new products from novel marine materials is often consideration, current accessible marine resources should not be ignored. With the growths in aquaculture sector in Bangladesh, the fish processing activities are going to increase. While processors plan to augment the recovery of the eatable segment of fish, absolutely, not all materials are completely utilized. The discarded portion can be termed as ‘co-product’ and this marine biomass is a ridiculous source of polysaccharides, lipids, proteins, pigments, flavors, polymers and other various chemical compounds. All of which can be used as product and process applications and the target markets for these materials are human and animal food, chemical substances, beauty care products, pharmaceuticals, public health and nourishment ingredients. For example, collagen and gelatin extracted from fish; algin, carrageenan and agars from seaweeds and algae; are generally utilized by the food

industry (Figure 8). Developing customized diets, integrated food production and processes Bangladesh could be taken various novel short term and long-term approaches (Figure 9).

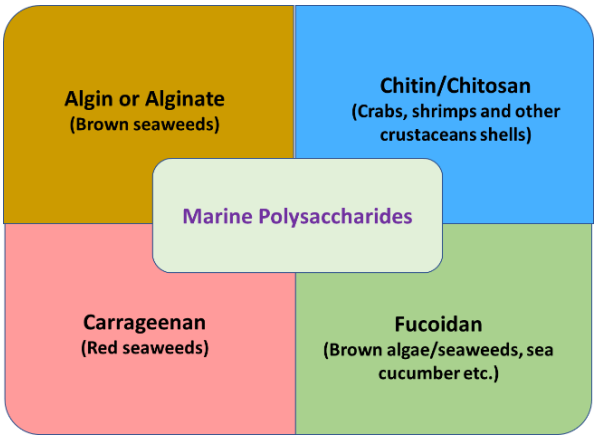

Figure 8: Various sources of marine polysaccharides for cosmeceutical, nutraceutical and pharmacological applications has been used.

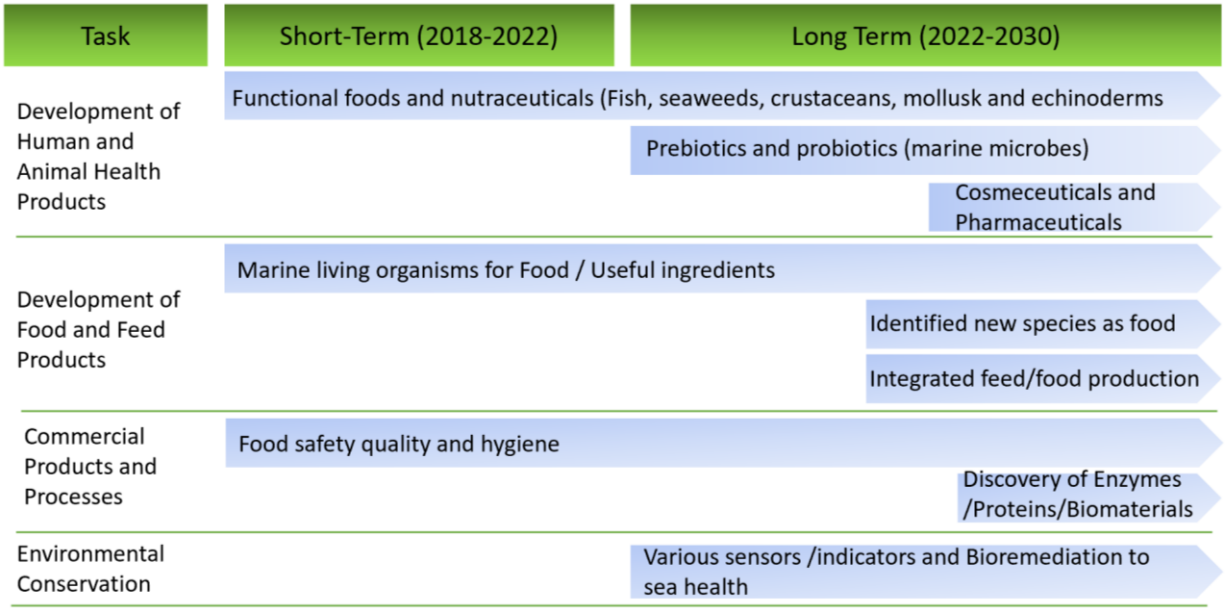

Figure 9: Marine product innovation and development strategy in Bangladesh.

2.1.6 Enabling technologies and infrastructure

Bangladesh marine biotechnology activity has no significant progress over the past decade, but there remains an intense need to build research and innovation capacity — in cooperation with the government research centers, marine science institutes and other private and non-government sectors to develop the science and innovation research foundation in this sector. Many tools and techniques applied in marine biotechnology are being utilized as a part of different sections of science and innovation technology such as radioactive testing lab, biotechnology lab at various universities. Collaborative multidisciplinary research ventures are an opportunity to access these offices/facilities. Building up a connection amongst researchers/specialists and the variety of end-clients is important to inspiring the advancement.

Assumptions regarding upgrading the accessible research framework to help product and process advancements must be met. Such frameworks include research vessels, exploration stages, labs, pilot plant, databases and archives and a variety of progressively complex systematic tools.

2.1.7 Policy initiatives, support and stimulation for blue biotechnology

For Bangladesh, policy relatives to marine biotechnology must have to include the marine fisheries, mariculture, marine food, health, natural resources and industrial application. Research activities can create information to advise the policy and strategy, which thus stimulates future development. State-of-the-art policy can stimulate collaboration between research organization and industry. The significance of such collaboration is essential in empowering marine biotechnology-based development. Information got from marine biotechnology research informs how the marine environment can be monitored and managed reasonably and realize its role in giving ecological facilities to the country as well as the world. Data acquired from the marine environment could help the decision makers to take initiatives in public and private sectors.

- Find approaches to extend the access toward marine bioresources for revelation purposes in Bangladesh marine waters.
- Create an extensive, set of policy research program to apply the information picked up from marine biotechnology research to advise public strategy, governance and regulation of sea environment and sea-originated items.
- Establish policy developments to advance marine biomass production and processing capabilities and to reduce barriers to the development of existing and new markets for marine-derived products (Figure 10)

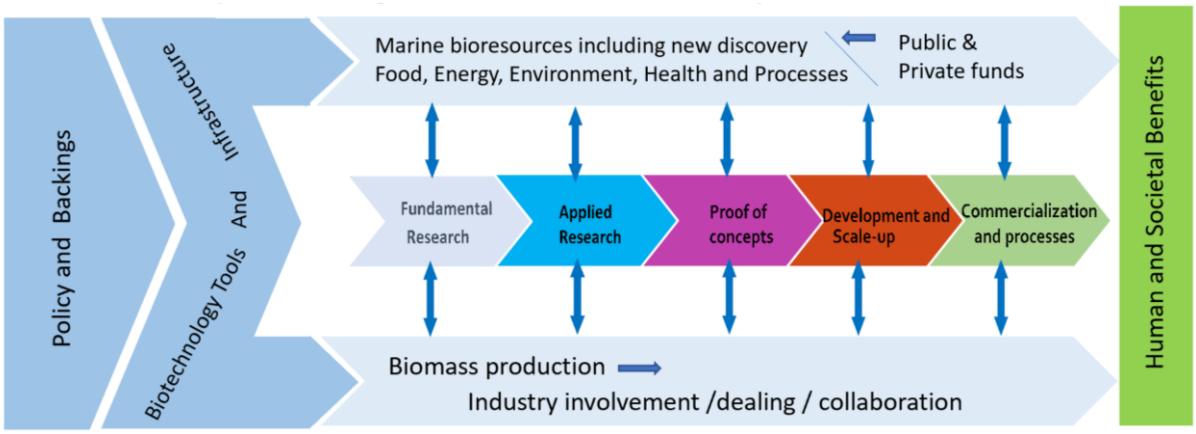

Figure 10: Activity connecting policy and research to support the product delivery and benefits to human and society.

3 RENEWABLE ENERGY

3.1 New Frontier for the Future of Renewables: Bangladesh

Growing economies of Bangladesh must upsurge its energy capacity and need clean, competitive generation technology to do so. Bangladesh is starving for energy for most recent couple of decades since its power generation is predominantly relied upon imported petroleum fuel and natural gas. The government of Bangladesh is trying to increase its electricity generation, yet grid electricity is not reachable in the remote areas of the country due to lack of infrastructure and longstanding distribution facilities.

Bangladesh is the new frontier for renewables. Renewable energy in Bangladesh alludes to the utilization of renewable energy to generate electricity in Bangladesh. To 'access the electricity for all' secure and pollution free clean electricity is crucial; but there isn't much option accessible for Bangladesh except for renewable energy. The current renewable energy comes from hydro power, solar, biogas and wind, however, tide and wave energy have good potential. Right now, renewable energy remains a little part of Bangladesh's energy producing portfolio. Introduced renewable energy production capacity is at present 437 MW, with the 230 MW Kaptai Hydro powerplant being the main grid associated renewable resources (Figure 11). The rest of the MWs incorporate off-grid establishments and solar based home system (Faijer and Arends, 2017).

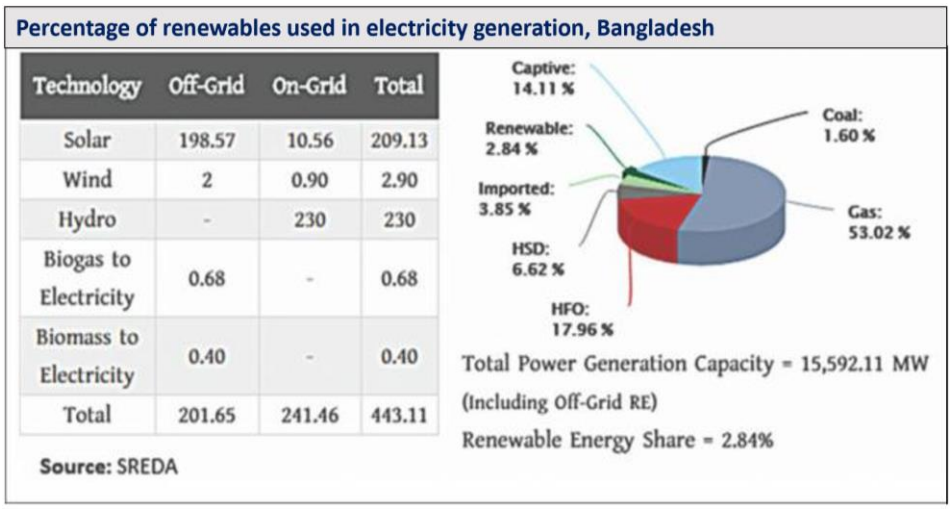

Figure 11: Energy generation in Bangladesh, (source SREDA 2017).

The long-haul wind stream, particularly in the islands and the southern coastal belt of Bangladesh is a great opportunity for the use of wind mills for generating electricity. In any case, amid the late spring and monsoon seasons (March to October) there can be low pressure regions and storm wind speeds 100 to 200 km/h can be normal. As of date, wind energy based physical implementations have been carried out mainly by Bangladesh Power Development Board (BPDB).

The tides at Chittagong Division are transcendently semidiurnal with a substantial variation in comparing to the seasons, the maximum high tide happening during the south-west monsoon. The average tidal range was found within 4-5 meter and the abundancy of the spring tide surpasses even 6 meters (Flemming and Bartoloma 2009). From different counts, it is foreseen

that there are various appropriate locales at Cox's Bazar, Maheshkhali, Kutubdia and different other places where fixed basins with pumping provisions may be built which would be a twofold activity scheme (Koppel 2007).

Bangladesh has promising conditions for wave energy particularly during the period starting from late March to early October. Maximum wave height of more than 2 meter with a flat out most extreme of 2.4 meter were recorded. The wave time periods varieed from 3 to 4 seconds for waves of around 0.5 meter and around 6 seconds for influxes of around 2 meter (Uqaili and Harijan 2011).

3.2 Offshore Wind Energy: Innovation frontier for technology, Industry, Market and Investment

Offshore wind is the world's most monetarily and innovatively created marine renewable energy subsector and is moving quick from being a specialty innovation into a mainstream provider of electricity. There are presently 18,814MW of introduced offshore wind capacity in 17 markets around the globe (GWEC 2017). At the end of 2017, almost 84% (15,780MW) of every single offshore establishment were situated in the waters off the shoreline of eleven European nations. The remaining 16% is found to a great extent in China, trailed by Vietnam, Japan, South Korea, the United States and Taiwan (GWEC 2017). The UK is the world's biggest offshore wind market and records for a little more than 36% of introduced capacity, trailed by Germany in the second biggest with 28.5%. China comes third in the worldwide offshore rankings with just over of 15% (Figure 12). Offshore wind market activity is currently focused in Asia.

Bangladesh started its first wind energy venture in 2005. There are two wind energy projects in Bangladesh, the Muhuri Dam wind power project and in Kutubdia Island. Muhuri Dam Project is the first grid connected wind energy production plant in Bangladesh. The assessed yearly electricity supply from this 4×225 kW wind plant is around 2 GWh. Kutubdia Island is Bangladesh's other wind battery hybrid venture situated in Chittagong. It produces 50×20 kW with assessed yearly generation of 2 Gwh (Faijer and Arends, 2017).

Ongoing Projects:

- Steps have been taken to introduce a 15 MW Wind Power Plant over the coastal districts of Bangladesh following multiyear Wind Resources Assessment in Muhuri Dam Area of Feni, Mognamaghat of Cox'sbazar, Parky Beach of Anwara in Chittagong, Kepupara of Borguna and Kuakata of Patuakhali. Wind Mapping is going ahead at Muhuri Dam zone of Feni and at Mognamaghat of Cox's bazar by Regen Powertech Ltd. of India.
- Installation of Wind Monitoring Stations at Inani Beach of Cox's bazar, Parky Beach of Anwara, Sitakundu of Chittagong and at Chandpur under USAID TA venture is in progress.
- 7.5 MW off Grid Wind-Solar Hybrid System with HFO/Diesel Based Engine Driven Generator in Hatiya Island, Noakhali.

Projects under Planning:

- BPDB has intended to execute 50-200 MW Wind Power Project at Parky Beach territory, Anawara in Chittagong on IPP basis.
- BPDB has likewise wanted to extend inshore wind energy plants along the coastline of beach front areas of Bangladesh.

The government of Bangladesh has set renewable energy (RE) improvement focuses for a few advance technologies for each year from 2015 to 2021, the "RE Development Targets". These targets require an extra 3,100 MW of renewable energy production ability to be introduced by 2021. The clear majority of the new capacity could come from solar powered (1,676 MW, or 54%) and wind (1,370 MW, or 44 %). There are likewise goals for biomass (47 MW), biogas (7 MW) and hydroelectricity (4 MW). Figure 13 demonstrates the renewable energy advancement targets for every innovation from 2015 to 2021.

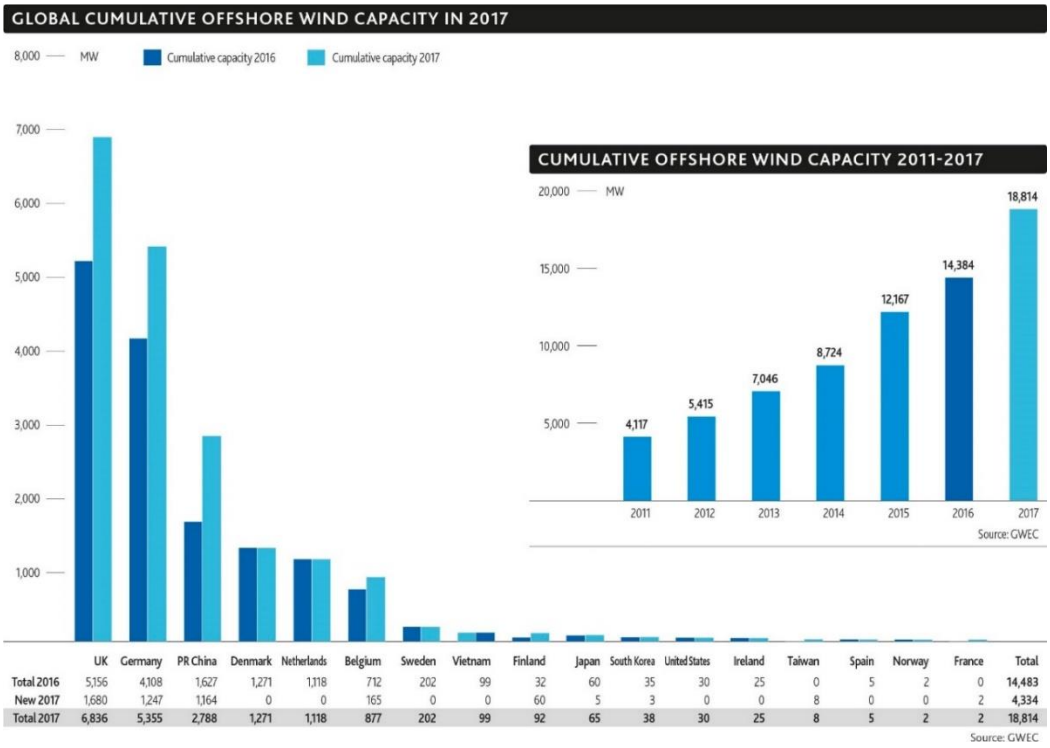

Figure 12: Global offshore wind energy production at the end of 2017. Source: GWEC 2017.

There are some national and international organizations that give financial directions or subsidizing to advancements in the energy sector in Bangladesh, concentrating on renewable energy. The Bangladesh Bank Refinancing Scheme for renewable energy is a rotating renegotiating system that gives credits at low interest to renewable energy and energy proficiency undertakings, for example, biogas, solar, bio-gas plants, SHS, solar irrigation systems and wind turbines. The highest quantity of loans for wind turbines is anyway insufficient to back a cutting edge expansive wind turbine (costs per turbine of a few million US$). Local and outside business banks have been the main lenders. In 2014, Local commercial banks loaned US$ 287.57 million to fund renewable energy ventures, 90 percent of the aggregate amount distributed by the rotating scheme. Foreign commercial banks loaned US$ 8.05 million to finance this sector, 3 percent of the aggregate amount distributed by the

revolving plan. However, some international organizations like World Bank 9WB), Asian Development Bank (ADB), Climate Investment Fund (CIF) and Scaling up Renewable Energy Program (SREP) is actively involved in both energy policy developments and investments in Bangladesh.

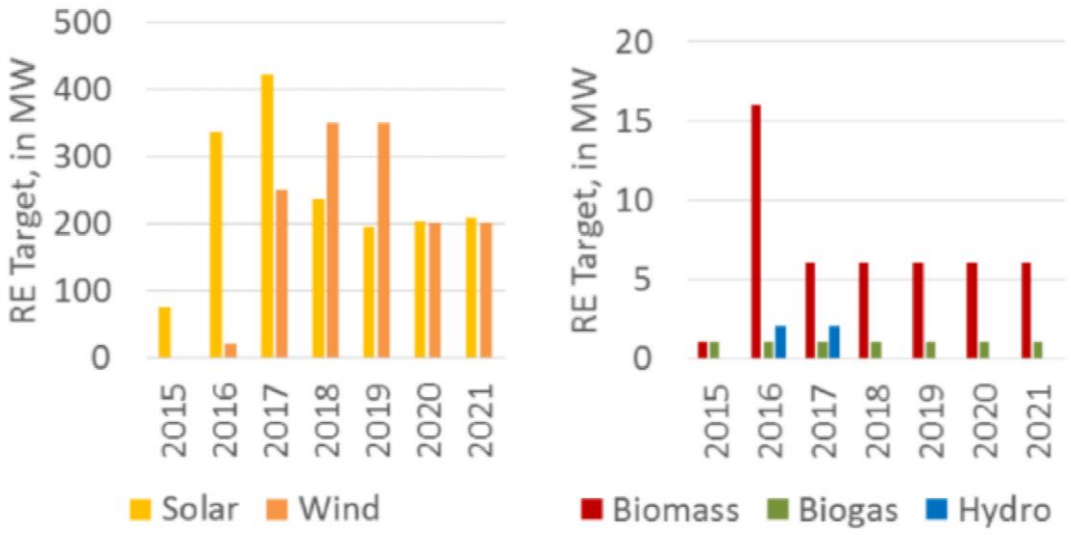

Figure 13: Renewable energy development targets from various sources (SREDA 2015)

3.3 Wind resources and uncertainties of wind energy

The sub-tropical atmosphere of Bangladesh, amid monsoon and cyclone seasons, Bangladesh is gone up against with a lot of precipitation and intermittently high wind speeds during the tropical storm season. The mean annual wind speeds in Bangladesh are not very much recorded and couple of information is accessible. The readily accessible information demonstrates that low wind speeds prevail on the Bangladeshi grounds. By inland wind speeds, no extensive information is promptly accessible relating to offshore wind speeds.

At present an operational wind mapping project is running with financial support by EC-LEDS (Enhancing Capacity for Low-Emission Development Strategy) which is a part of the USAID. This project comprises of 9 places where a two-year wind speed metering program is in advance at heights between 20 and 200 meters. The preliminary data of the project are still under prohibition with the Ministry of Power. Detailed results of the project are expected to become public in 2018. Figure 14 shows a rough map of the wind resources of Bangladesh to give an impression of the wind atmosphere, (available at: http://www.vortexfdc.com/assets/docs/vortex_3km_bangladesh_wind_map_resource.pdf).

No commercial scale offshore wind energy project has yet been decommissioned globally, however some single turbines and small projects have been decommissioned. There is a lot of uncertainty about the process. Usually, it is expected that turbines and change pieces will be removed with establishments cut off at a profundity beneath seabed which is probably not going to prompt revealing. Cables probably going to be pulled up, because of the reusing

esteem. Ecological checking will be directed after the decommissioning procedure. It might be that some wind projects will be repowered utilizing new establishments, cluster links and turbines, re-utilizing most transmission and grid connection.

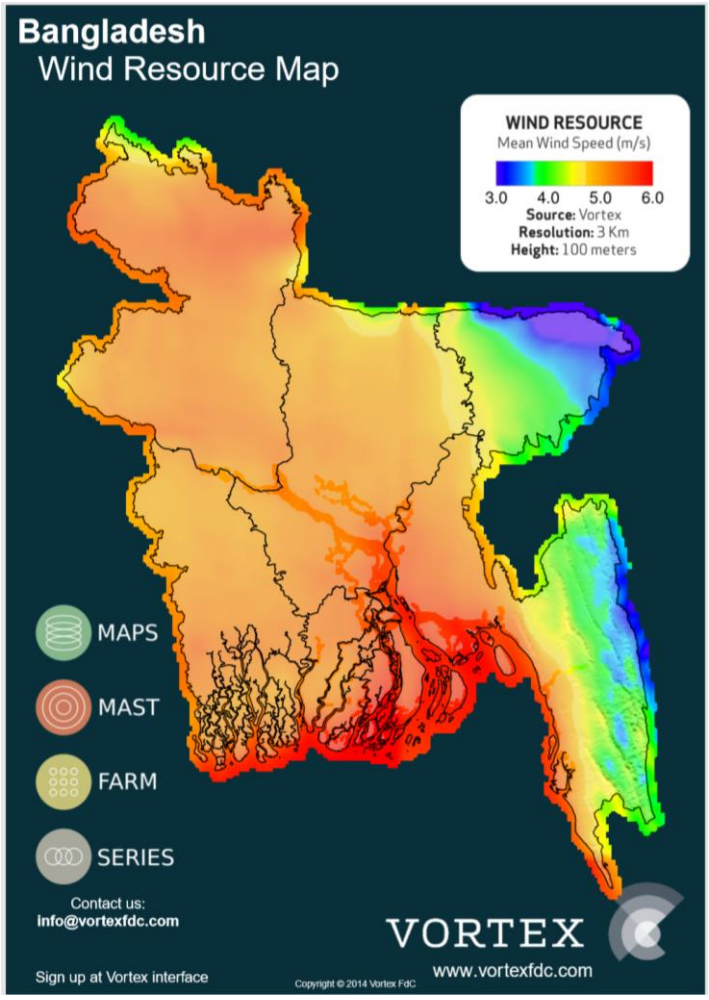

Figure 14: A rough map of the wind resources of Bangladesh.

3.4 Ocean Energy-Tide and Wave action

Tidal energy is foreseeable up to 100 years ahead of time (Alcorn, Dalton et al. 2014), making tidal energy interesting to grid operators by including more unsurprising and steady sources of renewable energy which has the result of pressing out the overall power supply from renewables. In tidal energy, there has been a general convergence of the innovations (Figure 15), with several developers testing full-scale prototypes and plans for commercial deployments. Limited availability of sites with insufficient high tidal ranges or flow velocities make the Bangladesh not appropriate for tide energy generation, moreover, a higher wave power resource is located near the St. Martin's Island, Bangladesh.

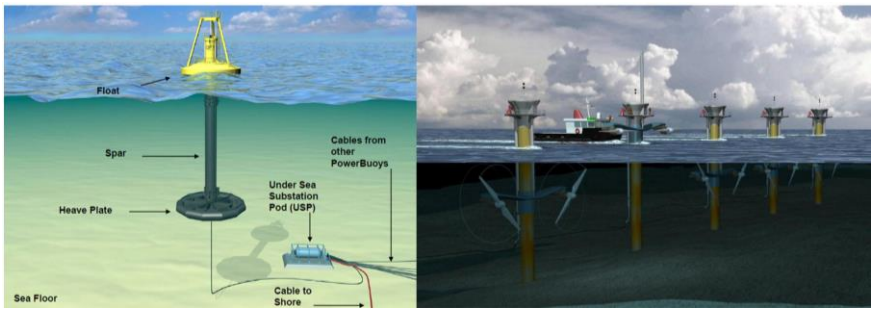

Figure 15: Tidal power generation

4 WHY ARE NON-CONVENTIONAL FISHERIES IMPORTANT?

Fisheries resources of Bangladesh has important role in food security, income and livelihoods for millions of people in Bangladesh. Particularly, fisheries often provide most affordable sources of animal protein for rural poor people. However, except hilsa fishery, capture fisheries' contribution to total fisheries production of Bangladesh is on decreasing trend. Though aquaculture has important role for enhanced fish production in Bangladesh, however extensive conversion of already decreased rice field into aquaculture pond many negatively affect rice production of the country. Further, scope for expansion of inland fisheries capture fisheries rather limited due to loss of habitat, population growth. Thus, it is important find alternative ways for enhance production to meet protein demand for increasing population of Bangladesh. In this context, fisheries resources of the Bay of Bengal hold promise. Though capture fisheries production in Bangladesh is increasing trend, however expert believe that increased fisheries production in Bangladesh is mainly related to increase fishing efforts rather than enhanced fisheries productivity. Further, harvestable fishery species in Bangladesh is limited to few species (e.g Hilsa, Bombay ducks), so if stock of these species collapse due to over-exploitation, it will cause negative impacts on the food security, employment and livelihoods of the millions of the people who are dependent on fishery resources for a livelihood option. Additionally, it is anticipated that climate change impacts will negatively affects the production of major commercial species harvesting from the Bay of Bengal (Fernandes et al. 2015). Thus, it is urgent to explore alternative harvestable species to compensate and or enhance fisheries production for ensuring food security and or enhancing income of coastal population

4.1 Potential unconventional fishery products in the Bay of Bengal

Unconventional fisheries are the species that are not considered as main target species when they are harvested, and mainstream population usually don't consume these species in traditional ways. Though unconventional fishery makes a rather small contribution to landings from capture fisheries relative to that of regular fishery of Bangladesh, in recent years, many artisanal fishers are involved in exploitation of non-conventional fishery species as their main occupation. Some of these fisheries can be considered as the unconventional fisheries those could be further harnessing in the blue economy context. These fisheries include squid, loligo, octopus, edible jellyfish, seaweeds, sea cucumber, sea turtle, lobster, mollusk species, small pelagic species and mangrove horse-shoe crab. Some of these species could directly be consumed by the consumers of the country; other could be exploited or cultured for export. At present, commercial trawlers usually catch non-conventional fishery species as by-catch. Unconventional fisheries remain under-utilized due to their unattractive appearance, color, texture, bones and small size. However, some species are used industrially for fishmeal production, though utilization of unconventional fishery species has potential for human consumption which could prevent post-harvest fishery losses (Hossain et al. 2017; Ahmed et al. 2007). Though non-conventional fishery species has economic potential, but the sector sectors failed to draw adequate attention both from academician and policy makers to explore these potentials.

4.2 Status and usage pattern of unconventional products in the Bay of Bengal

The table below presents an overview of the status and usage pattern of unconventional products.

Table 2: Marine unconventional fisheries items, their present status and recommended extraction practices

Important Unconventional fishery items	Exploitable species in Bangladesh marine waters	Current usage pattern and harvest technique	Recommended extraction practices	Reference
Seaweeds	*Caulerpa racemosa*, *Hypnea pannosa* *Enteromorpha* spp. *Gelidiella tenuissima* *Gelidium pusillum* *Sargassum* spp.	Extraction from nature use as vegetables, salad, main ingredients for soup, export items. Mostly collected from beach by hand.	Extraction from nature within sustainable limit. Culture practices should be introduced for exploitation	Zemke-White and Ohno, 1999
Mangrove horseshoe crab	*Carcinoscorpius rotundicauda*)	No extraction is reported	Extraction from natural source within sustainable limit	Vestbo et al. 2018
Lobstar	*Panulirus ornatus* Panulirus polyphagus *Panulirus* versicolor	Mainly collected from deep seas and rocky beach in the south-eastern coast. Mostly sale at local market as fresh or frozen some time exported. Dry specimens also sold as souvenirs. Usually harvested by bottom set gillnets, trawl nets and by diving.	Extraction from natural source within sustainable limit. Culture practices should be introduced for exploitation	Ahmed et al. 2007
Sepia	*Sepia haraonis* *Sepia intermis*	In recent years, these species are heavily exploited in the Cox's bazaar-Teknaf region. Became a delicacy for their thick and tender flesh, mainly consumed by tribal people and tourists. Also exported to south-east Asian region at lesser scale.Usually caught by light lures, traps, push nets, purse seins and hook and line.	Extraction from nature within sustainable limit.	Siddiqui et al. 2007
Octopus	*Octopus macropus* Octopus rugosus	The octopus fishery also became important for local consumption by the coastal people as well as export industries. This fishery has high demand in the south-east Asian countries, usually harvested in the sub-tidal habitats by trawl and spear, and on the intertidal reefs and rocky shore by hand or spear.	Extraction from nature within sustainable limit.	Siddiqui et al. 2007
Loligo	*Loliolus Hardwicke*, *Photololigo duvaucelii*	Recent years fishers involved in this fishery and became a profit oriented fishery. The species is marketed as fresh, frozen, dried or processed into cleaned mantle (whole hoods, rings). Captured by fishing techniques using light attraction.	Extraction from natural source within sustainable limit	Siddiqui et al. 2007
Oysters	*Crassostrea ariakensis*, *Crassostrea gigas*, *Crassostrea gryphoides*	Meat of oyster use as food, mainly by tribal people in Bangladesh, shell use for lime production. This fishery has market potential in south-east Asia.	Extraction from natural source with sustainable limit. Culture practices should be introduced for exploitation	Siddiqui et al. 2007

Important Unconventional fishery items	Exploitable species in Bangladesh marine waters	Current usage pattern and harvest technique	Recommended extraction practices	Reference
	Crassostrea virginica			
Edible Jellyfish	*Cephea cephea* *Catostylus mosaicus* *Crambione mastigophora* *Crambionella orsisi* *Lobonema smithii* *Rhizostoma pulmo* *Rhopilema hispidum* *Neopilema nomurai*	No extraction practice is reported in Bangladesh jellyfish industry. Its future looks promising due to the abundance of these jellyfish in Bay of Bengal waters, and the increasing Asian demand. Processed jellyfish, as a delicacy, have potential Japanese market.	Extraction from natural source	
Turtle	*Lepidochelys olivacea* Chelonia mydas Eretmochelys imbricate Caretta caretta Dermochelys coriacea	Local people indiscriminately porch turtle eggs for sale and consumption in the Cox's bazaar-Teknaf region. Turtle meat consume by tribal population.	Sea turtle farming (Green turtle) can be a promising ocean-based economic activity for Bangladesh	Sarker et al. 2018

4.2.1 Major barriers in exploitation of un-conventional fishery species

Exploitation of unconventional marine species could be an important driver for enhancing blue growth, but there are some challenges ahead to make these extractions ecologically, economically and socially sustainable. These barriers include limited knowledge about harvestable stock of these species. Until recently started exploratory survey by a research vessel, *Meenshandani*, there has been a long gap in the exploratory survey on fisheries stocks assessment. Some of these species may be under intense pressure of degradation. Thus, before starting commercial exploitation, it is important to set exploratory survey to the stock assessment of all major species these species to determine Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY). For certain species, there are lack of awareness and interest among the fishers and consumers. The mainstream consumers still are less interested about seafood particularly unconventional fishery items. Fishers and consumers are also reluctant because some of unconventional fishery items are prohibited by religious customs. Some other though not prohibited, but due to their appearance, lack of habit for consumption, less knowledge about nutrition value, social taboos, mainstream people usually do not consume. Lack of technological regarding exploitation and processing of unconventional fishery items is another impediment. Though the majority of these items have huge foreign demand. But fishers usually don't get appropriate supports from the government in terms of training on exploitation practices, knowledge about processing or foreign market. Thus, many fishers are not interested about some of these unconventional species. On the hand, inspired by huge profit and booming foreign market, some of the previously unconventional fishery species face risk of over-exploitation. To check this imbalance, appropriate legal framework is necessary. Though the legal coverage for coastal and marine living resources of Bangladesh is extensive; however specific rule for a number unconventional fishery species is missing. There is no provision of law regarding sustainable exploitation of cephalopod fish fishery in Bangladesh. Hundreds of fishers involve in this fishery using illegal gears such as current jal which could negatively affect the sustainability of this fishery.

4.2.2 Management approach of unconventional fishery species

Despite their importance as potential fisheries very little are known about their ecological status, potential harvest technology and utilization are not sufficiently studied and reported in the literature in Bangladesh context. Allowing commercial exploitation will require detailed knowledge of the abundance of the target species. For example, Size at sexual maturity is needed to know to set size limits to protect immature species, Identification of the areas where these species occur is needed to close fishing in some areas to protect a proportion of the population, to protect the habitat, Identification of the unit stock is needed to protect a proportion of each stock to ensure that individual stocks are not over fished. In this context, Bangladesh should actively develop a marine fisheries management plan to sustainable management marine conventional and unconventional fisheries. Development of a legal framework covering all unconventional fishery items is important before commercial exploitation these species starts. The Government should actively promote sustainable

exploitation and conservation of unconventional fisheries through providing training, awareness building and market development.

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