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Exploring Availability of Seaweed for Biofuel Production in Bangladesh

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ABSTRACT

This paper aims to explore whether seaweeds from the Bay of Bengal are available for commercial biofuel production. Seaweeds provide various ecosystem services from marine ecosystems that can be utilized as food, cosmetics, fertilizers, industrial chemical, or biofuel. Other than diversified usefulness, seaweeds could be used in a running vehicle. It can be used as an alternative source of non-renewable energy along with a high potential to produce environment friendly fuel for the next generations. Developed countries are utilizing seaweeds as essential resources of biofuel with advanced technology, machinery, and skilled manpower. From the physiography of the ocean of Bangladesh, it can be found that seaweeds have a high potential to produce biofuel from the coast and offshore areas. Among different types of seaweeds, biofuel can be produced from lipid & fatty acid, carbohydrate, or protein in them. Therefore, a sustainable SWOT analysis has been conducted to explore the availability and potential of seaweeds for biofuel production. To produce biofuel in Bangladesh due to the lack of investment, advanced technology, well-equipped machinery, and skilled manpower are still in shade. However, if investment and technical equipment are embraced for producing raw material (such as specific species of seaweeds) for the biofuel production those could be exported to the nearest market.

Keywords: Seaweed, Biofuel availability, NIB, Biofuel production, SWOT analysis, and Marine ecosystem.

INTRODUCTION:

Seaweeds are the kind of macroalgae or microalgae, which grow in every ocean. Being located in the tropical area in Indian Ocean, where more than 732 varieties of seaweed species are found (Ganesan *et al.*, 2019). Bangladesh is surrounded by the Bay of Bengal in the south, which is a part of the Indian Ocean, has a coastline of 710 km along his southern portion. It is rich in various forms of seaweeds (around 200 variety of species) having huge nutritious elements (i.e., lipid, protein and carbohydrate) (Ahmed, 2019; Sarkar *et al.*, 2016; Nehal, 2014).

Seaweeds can also be used as food, production of fertilizers, cosmetics, medicine, chemical or bio-fuel (Balina *et al.*, 2017). Ironically, bioenergy or a form of green energy can be produced with the effective utilization of macroalgae (Michalak, 2018). Produc-

tions of bio-energy from seaweeds are becoming popular day by day in the Asian countries. Seaweeds of this region can be used as a new and alternative source of energy that can enhance solar energy conservation and environment friendly fuel production for various vehicles in near future (Hamouda, 2015).

Biofuels can be defined in different ways based on the types of processing, use of technology, types of feed stocks or their level of development (Fig 1) (Dragone, 2010). This paper mainly investigates present availability and status for commercial production of biofuels in the Bay of Bengal.

Problem Statement

Bangladesh has a coastline of 710 kms and oceanic territory of 1,07,000 sq.kms., which is almost 1.4 times greater than the terrestrial area of the country

(Ahmed, 2019; The Territorial Waters and Maritime Zones Act, 1974).

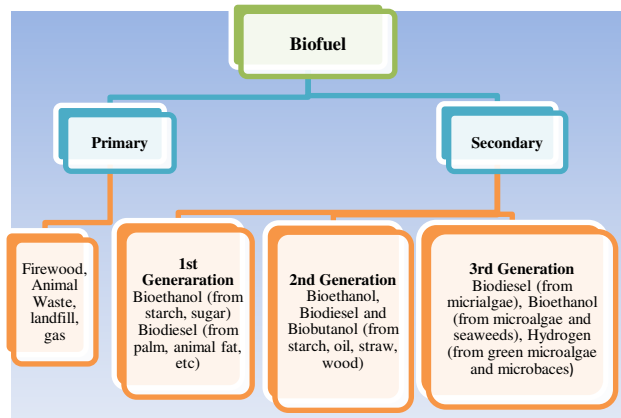


Fig1: Classification of biofuels (Adopted from Dragone *et al.*, 2010).

The tropical climate and habitable marine environment make the oceanic area so resourceful. There are also varieties of seaweeds found along with other oceanic resources in the region. However, there is lack of research as well as development to make productive use of the seaweeds found in the bay areas of Bangladesh. So, it is urgently needed to identify the types of seaweeds found through research. On the other hand, because of increasing trend of interest in alternative sources of cleaner energy their research on bio-fuel production has been increased. So, research on available seaweeds in Bangladesh along with potentials of bio-fuel production from seaweeds is very much needed.

MATERIAL AND METHODS:

Bio-fuel production and utilization on commercial basis is a comparatively new concept. Most of the countries are yet to find the viability and commercial production capacity of bio-fuel as an alternative source of energy. Human rely on fossil fuel for energy consumption that is not finite. So, scientists and experts have been looking for other sources of energy such as hydroelectricity, renewable energy, petroleum through hydraulic fracturing, or nuclear energy etc. We try to explore whether marine resources available in the Bay of Bengal have potential as an alternative source of energy of our own. So, to conduct this research a qualitative research approach has been applied. Data and information had been collected from secondary sources. Data was collected from sources from web of science, Scopus, Academia, etc. (using keywords). A total of 36 available articles were reviewed by using keywords to find out core information related to this paper. More- UniversePG | www.universepg.com

over, interview of five experts and scientists from various levels had been conducted. Then sustainable SWOT analysis has been conducted after reviewing literatures and taking interviews of the expert's SWOT analysis has been utilized as a very effective tool to get findings from SWOT matrix for sustainable production and consumption of any natural resource (Metzer *et al.*, 2012). Finally, findings and representation was data has been based on available papers and expert review.

Relationship of Seaweeds with Biofuel

At the time of global dependency of petroleum and concern on adverse impact of burning fossils fuels such as coal or petroleum on environment, biofuel can be great sources of environment friendly biofuel of second or third generation of bio-energy. It can be generated from different types of seaweeds. Furthermore, biofuel needs almost no modification and non-toxic bio-refinery process. Biofuel has potential demand in the emerging market because of its environment friendly nature (Rocca *et al.*, 2015). Other reasons for the use of biofuel can be (Rajkumar *et al.*, 2014):

- a) It is a non-terrestrial marine source of green energy.
- b) It emits less CO², which is good for environment.
- c) It could be a cultivable green energy.
- d) Increasing level of sea/oceanic water, additional type of seaweed could be found.
- e) Over whelming CO² from the environment could be suctioned by biofuel.

Furthermore, three major nutrients from seaweeds are responsible to convert seaweeds into biofuel. Nutrients are Lipid (such as triglycerides, hydrocarbons), Carbohydrates and Proteins (Ruiz *et al.*, 2013). Types of fuel production from nutrients in seaweeds are (Darzains *et al.*, 2010):

- a) Biodiesel and Green diesel can be produced from Lipid/Oil.
- b) Bioethanol can be produced from Carbohydrates.
- c) Biomethane and Biohydrogen can be produced from Proteins.

Pioneer Countries in Biofuel Production Using Marine Algae

USA has become the market leader successfully through the utilization of their land, technology, skills and proper management (Fig 2) (Statistics, 2017;

Lundquist *et al.*, 2010). The country has been the world’s largest producer of biodiesel since 2015, bioethanol since 2016 and the 3rd largest producer of biogas (Uddin *et al.*, 2017; Bilan *et al.*, 2017). In addition, they have the most skilled scientists, manpower to conduct research, development and maximum utilization of available seaweeds in the USA for biofuel production. Few decades ago, operation and maintenance costs were significant for the cultivation of seaweeds in the USA (Burg *et al.* 2016). It is found that profitability can be ensured if selling price of seaweed had increased. Selling price from the bio-fuel would be higher because of higher costs (i.e., installation cost, raw material cost, production cost, harvesting cost, labor cost, transportation cost, maintenance cost, insurance and other costs) related to location of the production site, availability of essential elements for seaweed production. For the case of USA, selling price of sea weeds has to be increased by 300% when the average production cost

was \$1747/metric ton equivalent to \$1.747/liter in 2016 (ibid). It was mentioned that estimated break even fuel ethanol selling price (BFESP) using seaweeds was \$0.58/liter which was three times higher than 2010, however, the production cost of ethanol was calculated as \$0.93/liter after the minimal reduction in transportation and labor costs and maximize productivity by increasing production scale in 2017 in USA (Soleymani & Rosentrater, 2017). After calculating the percentage of the bioethanol production cost using the average production cost of 2016 and estimated cost of 2017 shown above, 40-43% (approx.) cost of bioethanol production from seaweeds would be reduced in the USA. However, factors related to production cost of biofuel using seaweeds can be varied from country to country. Again, bio-diesel price was equivalent to diesel when vegetable oil price declined and the production costs of biodiesel reduced in 2018 (US bio-fuel market update, 2018).

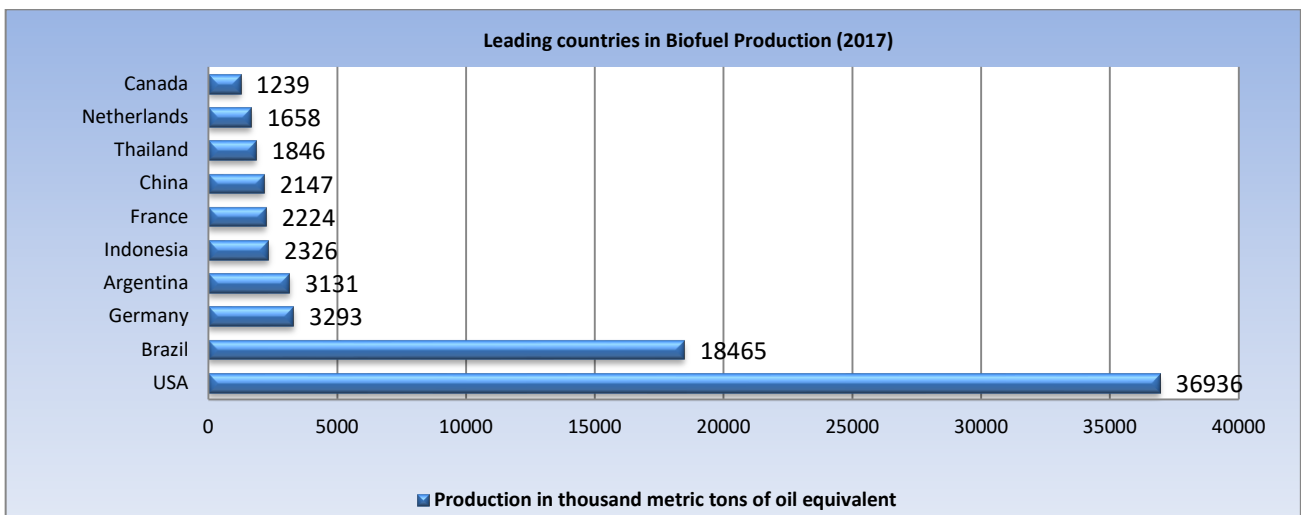


Fig 2: Leading countries in biofuel production in 2017 (Statistics, 2017).

Another pioneer country for biofuel production from marine algae is Brazil, who established the world’s first industrial biofuel plant for producing biofuel from seaweeds in the Northeastern State of Pernambuco since 2013. Brazil and the United States produce 62% of world’s demand of bioethanol with the advanced technology and different plants (Ozcimen & Inan, 2015). In last decade, commercial cultivation had been implanted in coastal areas on the southern and south eastern coasts of Brazil, which was ranked the 2nd largest producer of both biodiesel and bioethanol in 2015 (Bilan, 2017; Trivedi *et al.*, 2015). Furthermore, Germany did research on offshore cultivation of brown seaweed for food and fuel production (Buschmann *et al.*, 2017). Germany was

the 3rd largest producer of biodiesel in 2015 and 2nd largest producer of biogas in the same year (Bilan *et al.*, 2017). Argentina ranked 5th largest producer of bio-diesel in 2015 (ibid). In addition, France ranked as 4th largest producer of biodiesel in 2015 and Canada ranked 5th largest producer of bioethanol in 2016. Japan, China, Korea, Taiwan, Philippines, Malaysia, Indonesia and Thailand are cultivating seaweeds at present. Around 221 species of seaweeds are found in the South-East Asia, which is commercially important not only for biofuel production but also for food and other consumptive purposes (Ahmed, & Taparhudee, 2010). China ranked as 4th largest producer of bioethanol in 2016 and held the largest shares of biogas (Bilan, 2017).

Pioneer Countries of Biofuel Production

A number of projects were successfully implemented biofuel production. **Table 1** shows some of the projects related to biofuel production around the world. Different types of projects were taken as a part of innovation of green energy for future generation. However, most of them are now slowed down due to the excessive cost, potential scope of commercialization, insufficient investment for global market and potential negative impact on environment. As projects were under considerations or in pipeline, financial

data related to raw materials, machineries, construction and others are not available. Moreover, most of the statistical data are not available due to the privacy policy of the companies and competition in global market. In addition, other countries are in the process of research and experiments to innovate new methods for cost-effective biofuel production for future generation to save environment. Some of the available project’s summary run by pioneered countries is shown in **Table 1**.

Table 1: Project summary of biofuel production from algae.

Country Name	Type of Biofuel	Project Name	Name of seaweed
USA Columbus, New Mexico) ¹	Photosynthetic algal biomass production, green crude oil	Sapphire Energy, Inc. (SEI)(2012-14)	Micro Algae <i>Athrospira Sp.</i> and <i>Desmodesmus armatus</i> (a relative of <i>Scenedesmus</i>)-for biomass production and oil extraction
Germany ²	Biodiesel and kerosene	AUFWIND (2013-ongoing)	Micro Algae <i>Chlorophyta</i> (green algae), <i>cyanobacteria</i> (blue green algae)
Scotland ³		MacroFuel (The Scottish Association of Marine Science)(2016-19)	Macro Algae
European Union Project			
Netherlands ⁴		FUEL4ME (FUTURE European League 4 Microalgal Energy)(2013-16)	Micro Algae <i>Phaeodactylum tricornutum</i> and <i>Nannochloropsis oceanica</i>
Ireland ⁵	Bioethanol	DEMA Direct Ethanol from MicroAlgae (2012-17)	Micro Algae <i>Cyanobacteria</i> (blue green algae)

A total of 200 species of seaweeds (red, brown, green) are used in food and pharmaceutical industry in Tamil Nadu Coast line but some wasted are used as the raw material for biodiesel production because they have hydrocarbon as an essential ingredient to produce biodiesel (Sharmila *et al.*, 2012). In AUFWIND Project, Germany, they are highly optimistic about the manipulation of microalgae named Chlorophyta (green algae) and Cyanobacteria (blue green algae) for the production of bio-diesel and kerosene because they contain lipid more than 40% (Grob-

elaar, 2016). AquaFUELS under EU Project identified 72 algae where 34 algae are for biomass production, 32 algae are for biodiesel production, 10 algae are for bioethanol and 9 algae are for biohydrogen. Australia had some selected plant for the production of biodiesel where they were used to export biodiesel. On the other hand, some of them were closed due to the imposition of excise. Some selected production plant of Australia is shown in **Table 2** till 2017 (Farrell, 2017).

Table 2: Selected production facilities of biodiesel in Australia (ML)-2017.

Biodiesel Plant	Location	Capacity	Production Start
Macquarie Oil	Tasmania	15	2008
Ecotech biodiesel	Queensland	30	2006
Biodiesel Industry Australia (BIA)	New South Wales	20	2003
Australian Renewable Fuel (ARF) Largs Bay	South Australia	45	2006-16
Australian Renewable Fuels (ARF) Picton	Western Australia	45	2006-16
Australian Renewable Fuels (ARF) Barnawartha	Victoria	60	2006-16
Smorgon Fuels Biomax Plant	Victoria	100	2005(closed)
Territory Biofuels	Northern Territory	140	Closed in 2009

(Source: Adopted from Farrell, 2017)

From the **Table 2** shown, it is clear that most projects were shut down. Reasons for that were for higher production cost even though sufficient investment was implemented for operation and maintenance. However, research and development of bio-fuel production projects also need to run by skilled scientists in future for the innovative production of green energies. Some competitive projects are still in global market with the utilization of technology and some are successful enough. Cost effective methodologies and distinguished area requirements can gear up for mass production of macro algae.

Potential Seaweeds for Biofuel in Bangladesh

Around 200 species seaweeds are found in St. Martin, Cox’s Bazar, Sundarbans and northeast part of the Bay of Bengal, while some are found near Cox’s Bazar and the Sundarbans (Benglapedia, 2021; NIB, 2018; Billah *et al.*,2018). Seaweed’s cultivation can

be easy in Bangladesh because of having accessible and tropical coastal area. In 2010, 133 species of seaweeds were found and among them 8 were commercially important (Ahmed & Taparhudee, 2010). In 2016, 193 seaweed species of 94 genera were found belonging three divisions (such as Chlorophyta-Green Algae, Phaeophyta-Brown Algae, Rhodophyta-Red Algae). Among them 19 species of 14 genera was economically important (Billah *et al.*, 2018). Again in 2016, 95 red, 47 green and 60 brown algae respectively were found from St. Martin Island. Coastal communities can be benefitted from the aquaculture in different ways. However, usefulness of the available seaweeds in the coastal areas of Bangladesh had been found in various scholarly words, which are given below (**Table 3**) (Sarkar *et al.*, 2016).

Table 3: Use of available seaweeds of Bangladesh (Source: Adopted from Islam &Haroon, 2016).

Use	Name of Seaweeds	Species Diversity
Edible	<i>Cladophora prolifera, Caulerpa sp., Codium geppii, Dictyota atomaria, Dictyopteris australis, Gracilaria sp., Hypnea musciformis, Hydroclathrus sp., Halymenia sp., Padina sp., Ulva lactuca</i>	11
Industrial (agar, alginate)	<i>Gracilaria spinuligera, Sargassum sp.</i>	2
Agriculture (animal feed and fertilizer)	<i>Cladophora sp., Codium geppii, Dictyota atomaria, Gracilaria sp.,Hydroclathrus sp., Hypnea sp., Halimeda sp., Halymenia sp, Padina spp, Sargassum sp., Ulva lactuca</i>	11
Biofuel	<i>Caulerpa species, Caulerpa taxifolia, Codium geppii, Ulva lactuca (Green Algae) Sargassum species (Brown Algae)</i>	5

Available seaweeds can be used as medicine, agriculture, in industry and for green energy production other than only consuming as food. Thirty-seven types of seaweeds along with species are found in Bangladesh mentioned in **Table 3**. Ramification of nutrients based on elements (ex. water, chemical) helping to breeding them. In 2018, it is found that 37 seaweed taxa were present in northern and southern portion of St. Martin, among them 11 were under Chlorophyceae, 14 were under Phaeophyceae; 12 were under Rhodophyceae (Billah *et al.*, 2018). In 2018, around sixty varieties of seaweeds had been found in the Sundarbans, hence, about one hundred fifty-five varieties of seaweed species among them were found in the Cox’s Bazar (Razia, 2018).

Mr. Shykh Seraj, renowned Agricultural Development Activist in Bangladesh, has recently mentioned about potentialities of available seaweeds in an article ‘The ample opportunities of Blue Economy in

Bangladesh” on a Bangla Newspaper named “Bangladesh Pratidin” on 12 May, 2018 (Siraj, 2018):

“Around 25000 sq. kilometer from 147 Upazillas of 19 Districts, can create a new way of production of algae for agriculture or blue economy. These algae can be used as food, raw material of medicine and other industries. He also mentioned about the research of seaweeds in Cox’s Bazar. He is optimist about employment generation as well as revenue generation by exporting the seaweed in different ways.”

During face-to-face conversation on 7 November 2018, Prof. Dr. Mohammad Almujaaddade Alfasane, Department of Botany, University of Dhaka, mentioned about the 100 % possibility of production of biofuel from seaweed in Bangladesh. Biofuel can be produced from the algae such as *Enteromorpha, Laminaira digitata, Hypnea and Sargassium* (Brown and Green). Additionally, *Caulerpa* and *Ulva Sp.* could be used to produce biofuel if Lipid/Oil, Car-

bohydrates or Proteins is found in them. If Macro Algae are produced in seawater, production cost will be higher. On the contrary, if microalgae are produced in fresh water, production cost will be cheaper. He mentioned that cost effectiveness must be ensured. Higher production cost for purchasing machineries and hiring efficient workers from overseas has to be kept under consideration. He mentioned that the production of biofuel in Bangladesh could be possible within next decade from available seaweeds or algae if coastline of Bangladesh is used for the production.

Comparison of Available Seaweeds for the Commercial Production with Different Biofuels in Bangladesh

Based on the availability of nutrients in seaweeds, different varieties of biofuel can be created. Nutrients rich in the following macroalgae can be used to produce biofuel through available lipid, carbohydrate and proteins. Types of macroalgae are shown in **Table 4** to differentiate the species abundant in necessary nutrients (Rajkumar *et al.*, 2014).

Table 4: Types of Macro Algae to produce specific type of biofuel (Source: Rajkumar *et al.*, 2014).

Macro Algae	Biofuel Production
<i>Ulva, Enteromorpha, Monostroma, Laminaria, Alaria, Sargassum, Padina, Porphyra, Rhodymenia, Gracilaria</i>	Biodiesel
<i>Laminaria sp., Gracilaria Sp., Sargassam Sp., Ulva Sp.</i>	Biomethane
<i>Gelidium Sp., Ulva Sp., Kappaphycus alvarezii</i>	Bioethanol
<i>Gelidium amansii, Laminaria japonica</i>	Biohydrogen

Macro Algae from **Table 4** are used and have been used to produce specific types of biofuels. But biofuel production varies from countries to countries for the availability of raw materials, land, investment, machineries and skilled manpower. To produce potential biofuel with available seaweeds in Bangladesh are (Sarkar *et al.*, 2106; Rakjumar *et al.*, 2014; Darzains *et al.*, 2010; Ahmed & Taparhudee, 2010):

- a) Green Algae- *Enteromorpha, Ulva, Bryopsis, Caulerpa, Codium, Halimeda* and *Acetabularia*
- b) Red Algae- *Derbesia, Liagora, Galaxaura, Euthora, Gelidiella, Gelidium, Jania, Amphiroa, Melobesia, Kyalinia, Hypnea, Gracilaria, Catenella, Champia, Chrysomenia, Halymenia* and *Caloglossa*.
- c) Brown Algae- *Ectocarpus, Giffordia, Dictyota, Dictyopteris, Padina, Colpomenia, Hydroclathrus, Rosenvingea* and *Sargassum*

(*Ulva, Enteromorpha, Sargassum, Padina, Gracilaria*), Biomethane (*Laminaria sp., Gracilaria sp., Sargassam sp., Ulva sp.*), Bioethanol (*Gelidium sp., Ulva sp.*) and Biohydrogen (*Gelidium amansii, Laminaria japonica*) can be produced using these algae in Bangladesh. There is a global trend of alternative energy production and utilization because of reducing dirty fossil fuel or coal production. So, alternative sources of energy such as wind, bio-fuel, solar or hydropower are becoming popular. However, the exact number of seaweeds from the ocean is still unknown in many regions. On the other hand, this resource is not exempt from natural disaster as well. So, commercial production needs huge investment in the oceanic or terrestrial brackish water territory. In the **Table 5** SWOT matrixes identifies four major strengths, weaknesses, threats and opportunities of bio-fuel production from seaweeds of the Bay of Bengal region.

Comparing Macro Algae in **Table 4** and available seaweeds in Bangladesh, it is found that Biodiesel

Table 5: SWOT Matrix.

Strength	Weakness
<ul style="list-style-type: none"> • Bangladesh is rich in various types of seaweeds. • Tropical weather makes it available and more oceanic spaces seaweed production region. • Huge human who could be transformed into human capital with accessibility to cultivate seaweeds to produce biofuel. • Government of Bangladesh has already formed 	<ul style="list-style-type: none"> • There is lack of skilled manpower that knows about biofuel production from seaweed variety. • Lack of investment opportunities and change in government policies. • Lack of infrastructure and immature bio-refinery process for harvesting seaweeds that could be used as biofuel production.

taskforce to do research and development of seaweeds.	<ul style="list-style-type: none"> • There is lack of data on whole species and number of seaweeds of Bangladesh.
Opportunity <ul style="list-style-type: none"> • Global concern about global warming and climate change needs alternative source of energy. • International recognition of longest continuous sea beach. • Potential international and local market. • Higher demand in Asian countries. 	Threat <ul style="list-style-type: none"> • Shade in global market of biofuel. • Foreign investments or donation might undermine local expertise or local bio-refinery process. • Might not be cost effective. • Competitive to other renewable energy. • International policies might change over time.

FINDINGS:

Bangladesh can be one of the beneficiaries to revenue generation of biofuel production through available seaweeds. Eight available seaweeds are found in Bangladesh, which can be used to produce Biodiesel, Bioethanol, Biomethane and Biohydrogen. According to the experts, higher production costs have to be minimized through strategic plan for operation and maintenance. For instance, USA has been the market leader using strategic planning even though having higher transportation cost than Brazil (Bilan, 2017). It is found that production cost of biofuel can be minimized using by the processing and maintenance cost of microalgae than macroalgae (Jhing *et al.*, 2016). However, production cost of biofuel will vary from country to country according to the conversion methods. China, India and Australia are contributing for the preservation of environment by producing biofuel through the low carbon development

movement since 2016. However, various steps can be initiated for the biofuel production in Bangladesh (Kibria *et al.*, 2018). Saudi Arabia is also using algae for the production of biofuel and bio-fertilizer in Al Ahsa oasis by trying to contribute to low carbon emission movement (Semary *et al.*, 2018). In addition, researchers and scientists from developed and developing countries need to come forward to undergoing multiple long-term experiments for the technical and economic feasibility for the production of biofuel from seaweeds (Jacob *et al.*, 2016). Moreover, mass production of biofuel can be ensured if advanced technology or substitute of it can be introduced to balance higher production cost (Soleymani, & Rosentrater, 2017). **Table 5** depicts sustainable SWOT analysis framework for producing bio-fuels from seaweeds (Metzer *et al.*, 2012). Therefore, from **Table 6** it could be found that skilled manpower and investing more on this industry could create experts.

Table 6: Sustainability SWOT Findings.

Strength to reduce weakness <ol style="list-style-type: none"> 1. Human capital can be created for bio-fuel production from seaweed, by training and educating. 2. Local and foreign investments could be fostered with effective government; and research on commercial production of seaweed for bio fuel production is also highly needed. 3. Institute formed by Bangladesh of Government (NIB) could establish real-world seaweed information containing database; and develop local infrastructure as well as bio-refinery processing system for biofuel production. 	Strength to minimize threat <ol style="list-style-type: none"> 1. Foreign investments or aid could be encouraged to reduce impact of climate change in the vulnerable zones of Bangladesh by establishing biofuel production. 2. Huge variety of tropical seaweeds would compete international market if it could be produced and served in local market. 3. Cheaper production cost with advanced local technology and infrastructure could be cost-effective and sustainable.
Opportunity to reduce weakness <ol style="list-style-type: none"> 1. Global concern about climate change could assist developing low laying country like Bangladesh to invest more on biofuel production. 2. Technology or infrastructure transfer from developed countries could develop local production process. 3. International recognition of the Bay of Bengal coastal areas could burgeon the production of biofuel. 	Opportunity to decrease threat <ol style="list-style-type: none"> 1. Foreign investments or aids must be utilized to develop local expertise, manpower and database. 2. Both national and international market should embrace supporting financial instruments. 3. Well-developed international liaisons could bring opportunity for grabbing international market of bio-fuel produced from Bangladesh like other industries.

Present concern on climate change and adverse impact of fossil fuel burning could be remedied by utilizing renewable energy or bio-fuel energy. Furthermore, foreign assistance and investments could be

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utilized in Bangladesh because the coastal resources of the Bay of Bengal are well recognized worldwide as a resourceful zone. Though there are lacks of research and development in the field, inclusive and potential importance of biofuel production could help local improvement and fulfill international market demand by supplying biofuel produced in the Bay of Bengal or in the coastal areas of the bay.

CONCLUSION:

Marine algae are a potential resource of food, pharmaceutical industry as well as green energy. Due to the higher production and maintenance cost, many projects were slowed down. However, some developed countries are successful in global market of biofuel. Developed and Pioneer countries are expecting to overcome challenges related to the reduction of biofuel production costs using seaweeds. Hopefully biofuel can be produced in Bangladesh using seaweeds within coming decades through the implementation of advanced technology and substitute production methods.

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CONFLICTS OF INTEREST:

The authors of this article declare that no potential conflict of interest lies to publish this research paper.

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