Algal biofuel: A promising next-generation potential

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THE use of algae as biofuel is a relatively new technology, as compared to other biofuel resources. For production of biofuel, mass cultivation of algae or algaculture is carried out in various regions of the world. Many countries have implemented highly sophisticated techniques for enhancing mass-scale cultivation of algae.

Algae are a large group of primitive, mostly aquatic, photosynthetic chlorophyll-bearing plants, lacking specialized tissues and organs namely roots, stems, leaves, flowers etc. Algae can be broadly categorized into two groups: microalgae and macroalgae. Microalgae are very small (+/- 1 to 50 ìm) while macroalgae can reach sizes up to 60 m in length. Algae are usually found in damp places or bodies of water and thus are common in terrestrial as well as aquatic environments. Like plants, most algae require primarily three components to grow: sunlight, carbon-dioxide and water.

Microalgae, because of their growth rate and yields, are capable of producing a lot more oil than other energy crops. Some estimates suggest that microalgae strains are capable of producing up to 50,000 litres of oil per hectare a year. This could be converted into biodiesel by conventional processes and be used to fuel vehicles from jets to tractors. As per studies conducted on algae, it is observed that about 60 percent of their biomass can be converted into biofuel.

Microalgae, specifically, posses several attractive characteristics:

Impressive productivity: Microalgae can potentially produce 100 times more oil per acre than soybeans or any other terrestrial oil-producing crop.

Non-competitive with agriculture: Algae can be cultivated in large open ponds or in closed photobioreactors located on non-arable land in a variety of climates (including deserts).

There are two types of challenges to be overcome: (1) Engineering challenges such as making photobioreactors, raceway ponds and centrifuges more efficient and (2) Biological challenges such as increasing oil yields from algae, genetic engineering of algal strains and facilitating specific strains of algae to survive in habitats that are not natural to them.

Quick growth: Microalgae grow quickly. They commonly double in size every 24 hours. During the peak growth phase, some microalgae can double every three and one-half hours.

Flexible water quality: Marine water as well as wastewater can be used for mass cultivation of algae. Fresh water is not essential to grow algae.

Mitigation of CO2: Algae are capable fixing CO2 in the atmosphere, thus facilitating reduction of CO2 level. During photosynthesis, algae use solar energy to fix carbon dioxide (CO2) into biomass, so the water used to cultivate algae must be enriched with CO2. This requirement offers an opportunity to make productive use of the CO2 from power plants, biofuel facilities, and other sources.

Environment friendly: Algae biofuel is non-toxic, contains no sulfur, and is highly biodegradable, thus reducing the chances of environmental pollution. Moreover, in case there is spillage of algal-based biofuel in water sources, there are no significant adverse effects on the ecosystem.

Broad product portfolio: The lipids produced by algae can be used to produce a wide range of biofuels, and the remaining biomass residue has a variety of useful applications. These are combust to generate heat, use in anaerobic digesters to produce methane, use as a fermentation feedstock in the production of ethanol and use in value-added byproducts, such as animal feed.

One of the key reasons algae are considered as feedstock for oil is their high yields. Algae are the only bio-feedstock that can replace all of our current and future petro-fuel consumption. It will be very difficult for the first generation biodiesel feedstock such as soy or palm to produce enough oil to replace even a small fraction of petro-oil needs without displacing large percentages of arable land meant for food crops.

Typical yields in US gallons of biodiesel per acre:

Plant	Biodiesel Yield(Gal per acre)
Algae	5000 and higher
Palm Oil	500
Rapeseed	100
Soy	60-100

Source: The Department of Energy (DoE), USA

According to the Department of Energy, USA, the world's use of gasoline and diesel is about 1300 billion gallons per year. Studies revealed that algae have the ability to produce about 5000 gallons of biodiesel/acre. Moreover, about 1.5 billion hectares of non-forested land is available worldwide that is not being used for agriculture. A simple calculation shows that in order for algae biodiesel to completely replace all transportation fuels, it will require about 80 million hectares of land (less than 5%), which sounds achievable. Crops such as palm would require close to a billion hectares for the same result, a daunting and almost impossible task.

PHOTO: COURTESY THE WRITER

Large scale algae production

The US Navy recently took delivery of 90,000 litres of a new type of biofuel, produced from algae. The successful test flight by a Super Hornet jet fighter using the algae biofuel is a milestone in the US biofuels programme.

In 2008 the British government-backed Carbon Trust launched an £8m Algae Biofuels Challenge, which focused on accelerating the development and commercial production of microalgae biofuels for use in aviation and road transport by 2020. 11 British Universities took up the challenge.

In the USA the Energy Independence and Security Act declared that America should produce 36 billion gallons of biofuels by 2022. President Barack Obama has allocated £530m ($800m) for biofuels research.

Many large companies, such as Aquaflow Bionomic, Cellana, Exxon-Mobil, Solazyme etc are also investing heavily into bio algae research. At present worldwide around 200 companies are conducting the research in wide range of technical sectors to lowering the production cost for commercialising the algal biofuel.

Mary Rosenthal, the Executive Director of the Algal Biomass Organisation said "We're right at the cusp of commercializing and making fuel from algae. There are companies making thousands of gallons of biofuel now, but in several years - maybe by 2015 - we should be at millions of gallons."

The biggest bottleneck today for algae to become a mainstream biofuel feedstock is the higher production cost.

Algae Fuel Production Cost:

Fuel	Cost($/gal)
Fossil gasoline/diesel	2.0(Based on prices between June and September, 2010)
Non-algal biofuel	2.25-2.75
Algae biodiesel	6-18

Source: Oilgae Estimates

Key challenges: The real challenge facing the algae industry is the high cost of fuel production from algae. The high cost is owing to the following difficulties:

- Difficulty in optimal strain selection
- Contamination management in open cultivation environments and in waste water/sewage
- High capital and operating costs of photobioreactors
- High cost of harvesting
- High cost of biomass gasification

There are two types of challenges to be overcome with respect to processes: (1) Engineering challenges such as making photobioreactors, raceway ponds and centrifuges more efficient and (2) Biological challenges such as increasing oil yields from algae, genetic engineering of algal strains and facilitating specific strains of algae to survive in habitats that are not natural to them. It is expected that many engineering challenges could be solved within the next 2-3 years.

Now it is difficult to predict when the biological challenges will be overcome, though good progress is being made on aspects such as genetic engineering of algae strains. Experts predict that experiments on overcoming the biological challenges could take more than five years (beyond 2015). Then it would be possible to commercialise the algae fuel at competitive cost. If the scientists are able to reduce cost, in near future, algae biofuel may be the alternative fuel that can replace the fossil fuel, which causes global warming by releasing the greenhouse gases that often degrade the environment.

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Policy responses for adaptation to climate change

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POLICY options for meeting the challenges of climate change are basically divided into policies for mitigation and adaptation. Policy responses for mitigation intend to reduce the greenhouse gases (GHGs) in order to avoid the anthropogenic causes of climate change. On the other hand, adaptation policies are necessary to cope with the adverse impacts, which will occur despite the best efforts to mitigate the causes. The very nature of climate change exacerbates the inequities in terms of contribution to the causes and the sufferings from the consequences. Causal liability shifts the burden to the industrialised countries to take entire responsibility for mitigation and adaptation.

In terms of mitigation, aggregated emission limits should be set by the developed countries to avoid dangerous climate change and from the adaptation perspective, the developed countries should take entire responsibility of responding to the climate vulnerability and to prevent further deterioration. Therefore, pro-active and re-active policy interventions are required for the response. In terms of re-active policy, developed countries should act to correct the past wrongful behavior under the principles of corrective justice since they are responsible for causing the vulnerability. Against this backdrop, required technological and financial resources for adaptation should be provided, based on proportional contribution to climate change and respective capacity of the states.

Least developed countries, which are the most vulnerable, should utilise the support available from global community and also the domestic resources through adopting appropriate policy frameworks to protect their own citizens. Therefore, it becomes realistic to speculate the policy responses for adaptation of the least developed countries like Bangladesh. Hence, policy responses for adaptation to climate change is to be considered as priority issue to prepare for the bracing.

However, climate change is an issue that is inherently global in nature, and the dynamics of the climate system are globally integrated. Therefore, an integrated international policy framework is needed to ensure the coordinated efforts.

To date the international climate change regime is designed to respond to mitigation and adaptation requirements adopting two international treaties -- the 1992 United Nations Framework Convention on Climate Change (UNFCCC) or the Convention and 1997 Kyoto Protocol along with institutional frameworks developed there under. Article 3 of the Convention provided the basic principles that include equity, common but differentiated responsibility, respective capacity, precautionary principle, special consideration to vulnerable parties and sustainable development. These principles provided the ethical and legal grounds for advancing and forming the future climate governance regime.

In terms of adaptation to slow onset events including climate induced migration, and disaster risk reduction as sudden onset issue, policy approaches should be anticipatory to reduce loss and damage along with reactionary approaches on rehabilitation measures with insurance, compensation and other related mechanisms.

Occurrence of cyclones has increased in the Bangladesh coastal areas due to climate change.

However, the existing climate policies are basically focused on mitigation, and adaptation has only recently been given priority equal to mitigation. Cancun Decisions [COP 16] prioritised adaptation with same degree of mitigation. Instead of mitigation framework, strengthening the adaptation mechanisms under Cancun Decisions, however, raises concerns over failure in stabilisation of GHGs concentrations. Worth mentioning, a number of provisions in the UNFCCC and Kyoto Protocol address adaptation, taking into account the reality of mitigation as a means of real solution to climate change.

However, ongoing climate negotiations are moving towards designing the architecture of climate governance regime for the post 2012 period and hence it is worthy to examine the existing mechanisms' response to adaptation and to look at the scope and challenges for future policy frameworks.

Initially, it is quite important to understand the critical aspects of the term adaptation and its related terminologies within context of definitions available. IPCC Third Assessment Report defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation." However, this definition remains away from suggesting the institutionalised responsive measures. So, adaptation along with the terminologies of vulnerability and resilience require to be defined clearly within UNFCCC.

Existing frameworks lack the institutionalised approaches on adaptation measures to climate vulnerability and proactive measures for resilience to potential impacts. Therefore, adaptation policy frameworks will be reactionary and anticipatory. Reactionary measures are taken after the impacts of climate change occur, whereas anticipatory is planning ahead. However, climate impacts relate to complex and wide-ranging issues and involve decisions that affect social, environmental and economic issues. Therefore, prior to taking adaptation measures, it requires macro and micro level assessment of needs and existing knowledge and capacity.

Overall, the response to adaptation requires good governance, strong institutional arrangements and capacity with financial and technological supports. The chronological linkage at the international, regional, national and local levels is the prerequisite to ensure coordinated and effective response to climate change.

Institutional arrangement with the compliance and monitoring mechanisms from local to global level is the big challenge for framing adaptation policy. In the national context, macro level measures include poverty reduction, improved infrastructure, healthcare, awareness and education and the micro level measures such as building dams against sea level rise, water purification and agricultural changes demand the integrated and coordinated efforts.

Moreover, regional issues, for instance transboundary water, requires special policy frameworks bilaterally or regionally and then on the global policy frameworks which would coordinate all the measures taken from local to global level for adaptation. Climate induced migration/displacement and associated socio-economic disruptions also go far beyond territorial limits and capacity, which is one of the biggest challenges since it relates to loss of homes, livelihoods and culture. Therefore, the coordination and integration among the international, regional, national and local level institutions can provide an effective adaptation policy framework.

Cancun Decisions called for the new or strengthened mechanisms for mitigation and adaptation including required finance and technology transfer. As such, committees are suggested to be formed on adaptation, finance and technology transfer to work and adopt an instrument in COP 17. Parties are invited to enhance action on adaptation taking into account the specific national and regional development priorities, objectives and circumstances assessing the impact, vulnerability, including the financial needs, as well as economic, social and environmental evaluation of adaptation options. Work programme suggested for climate risk insurance facility to address impacts associated with severe weather events and the rehabilitation measures associated with slow onset events. The very little context on migration found in the Cancun Decisions is also to be decided in COP 17.

In terms of adaptation to slow onset events including climate induced migration, and disaster risk reduction as sudden onset issue, policy approaches should be anticipatory to reduce loss and damage along with reactionary approaches on rehabilitation measures with insurance, compensation and other related mechanisms. Climate change impact and vulnerability bring up the serious legal question of liability for the damage caused, based on proportional contribution to climate change. Loss and damage involved with climate change and related mechanisms are suggested into Cancun Decision, however, to be adopted in COP 18. But the assessment of loss and damage related to climate change and compensation mechanisms demand separate approaches, which is important and integral part of adaptation frameworks.

On the other hand, the efforts taken by Bangladesh, as a least developed country, are appreciated by global community since it has completed NAPA in 2005 and adopted Strategy and Action Plan, 2008 along with financial mechanisms including trust fund and resilience fund. The Trust Fund formed with domestic resources is already providing finance for implementing some of the projects without adopting legal framework with appropriate institutional arrangements. It is strongly suggested that, prior to taking broader initiatives, to assess the causes and consequences of climate impacts and the existing capacity of intuitions from micro to macro level, there should be adopted a broader policy framework on climate change, particularly on adaptation in Bangladesh.

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