The Potential and Challenges of Microalgae Biofuel Production

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Biofuels

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Intro

Climate change, thanks to human-induced greenhouse gasses (GHG) is heating up the Earth's temperatures (NASA, 2017). Microalgae-based biofuels, with its abundant, eco-friendly potential, can provide an alternative to fossil fuels and other biofuels in mitigating climate change while supporting the global economy (Milano et al., 2016). I will analyze the need, processes, along with benefits and concerns of microalgae biofuel production. Lastly, I will provide recommendations to address the challenges facing microalgae biofuels.

The Case for Microalgae Biofuels

Climate change is a major concern among our generation (World Economic Forum [WEF] 2017a), as 97% of scientists agree human extraction of fossil fuels is the leading cause of global warming (NASA, 2017). Gross Domestic Product (GDP) would fall 5% yearly without climate action (Stern, 2007). Meanwhile, reducing carbon emissions to 350 parts per million (ppm) would mitigate the worst effects of climate change (Hansen et al., 2008). Extreme weather events (intense rainfall, heatwaves, & wildfires), a byproduct of human-induced climate change, is increasing, creating more infrastructure failure (Government of Canada, 2015). Climate change is also creating financial losses in the US at USD $240 billion annually while growing to USD $360 billion within a decade (Watson, McCarthy & Hisas, 2017).

Meanwhile, global population will reach 9.8 billion by 2050 (WEF, 2017b), as the rise of the middle class from emerging markets (Ernst & Young, 2017) will further strain natural resources, requiring a low carbon alternative to fossil fuels. Microalgae bioenergy can provide critical solutions to these concerns in developing a clean energy global economy.

What Is Microalgae and Processes of Production?

Microalgae are single-cell photosynthetic microorganisms which live in fresh or saltwater environments that convert algae biomass, sunshine, and water (Demirbas, & Demirbas, 2010). Algae can feed off large amounts of carbon dioxide and use photosynthesis to produce more algae supply (Singh, Olson, & Nigam, 2011).

To create microalgae biofuel four stages are required; Refining (cultivation); harvesting; extraction; and conversion (Milano et al., 2016).

Refining microalgae are done through closed or open systems. Closed systems require photobioreactors to control the local environment from specific conditions (weather, carbon dioxide) while growing single strain algae in more significant quantities (Milano et al., 2016). Open pond systems, use wastewater from treatment & industrial plants, allowing nutrients to mix with microalgae. Open ponds are an inexpensive way to create large commercial amounts of biofuel. However, microalgae are vulnerable to environmental conditions which can cut productivity (Milano et al., 2016). Hybrid photobioreactors combine both closed & open refining processes to reduce contamination (closed) and provide nutrients (open system) to microalgae (Milano et al., 2016).

After refining, harvesting occurs with bulk harvesting, as the bulk culture is split from the biomass (Milano et al., 2016). Biomass is then thickened by procedures like filtration and gentrification (Milano et al., 2016). Microalgae biomass is then extracted for conversion preparation. Dehydration (costly, but efficient) and sun drying (less expensive, more time consuming & requires more area) are common extraction methods (Milano et al., 2016). After extraction, biomass can be converted through either thermochemical, biochemical or chemical conversion. Types of biomass & economic considerations factor into how microalgae biomass is converted (Milano et al., 2016). Once converted and depending on the type of biomass, its used in different biofuel formats, including bioethanol, biodiesel, biohydrogen, and biogas (Jones & Mayfield, 2012).

<u>Advantages of Microalgae Biofuels Production</u>

Algae can feed on substantial amounts of carbon dioxide (CO_2) and sequester CO_2 (Sing et al., 2011). Photosynthesis then converts biomass in helping to create bountiful quantities of clean energy (Singh et al., 2011). The potential of microalgae growing bigger yields other than oilseed crops used for biofuels (Singh, & Gu, 2010) creates abundant opportunities for a clean energy global economy.

Microalgae biofuels do not have the same concerns, as first generation (1G) or second generation (2G) biofuels. Microalgae do not compete against food or land or need ample water and fertilizer inputs as 1G biofuels require (Singh et al., 2011) which limit GHG reductions. Microalgae can also reduce possible pollution, by cutting phosphorus and nitrogen use from wastewater (Singh et al., 2011). Second generation (2G) biofuel has minimum conversion rates, with a limited land efficiency which make 2G biofuels an economic challenge (Milano et al., 2016). Microalgae, on the other hand, can grow in areas where conventional biofuels aren't produced in, including desert land, oceans, and lakes, (Miller, 2010).

Microalgae biomass can provide a versatile platform for diverse type of biofuels needed in the marketplace, including Ethanol, biodiesel, biogas, and biohydrogen (Miller, 2010). Creating an original set of biofuels will help to grow the global algae biofuel market, anticipated at USD $10.73 billion by 2025 (Grand View Research, 2017).

Challenges of Microalgae Biofuels production

Microalgae biofuels face some environmental and economic concerns which could hamper development.

Environmentally, low energy efficiency ratio's (EER's) based on life cycle analysis (LCA) suggest microalgae biofuels have a more inferior EER, in comparison to oil-based feedstocks, including soyoil (Lam & Lee, 2012). Although chemical/inorganic fertilizers are the source of phosphorus and nitrogen used in reducing culture contamination, LCA analysis suggests using chemical fertilizers create half of the GHG emissions and energy used in microalgae biofuel production (Lam & Lee, 2012). Therefore, use of chemical fertilizers in cultivation is both unsustainable and energy inefficient.

Reducing economic costs remain a concern for microalgae production. Using artificial lights in the photosynthesis process, have unreasonable prices (Singh & Gu, 2010). Harvesting costs also contribute a substantial portion of all microalgae biofuel production costs, at 20-30% (Milano et al., 2016). Getting production costs down will be essential in attracting private sector investment and making microalgae biofuel more commercially viable.

Recommendations in Enhancing Microalgae Biofuel Development

Taking care of environmental and economic concerns of microalgae biofuel production will help to ensure its future success.

To reduce nutrient and inorganic fertilizer concerns, using both recycled wastewater and recycled nutrients from agricultural waste can create a positive environmental impact on production (Jones & Mayfield, 2012). Hybrid photobioreactors, to improve mixing intensity between carbon dioxide, nutrients, and microalgae, would reduce inputs and address energy efficiency concerns (Lam & Lee, 2012).

On the economic side, collaboration between, public, private and non-government sectors to enhance research & development (R&D), while scaling microalgae biofuel commercially, is beneficial. The US Navy lead by example 2011, by conducting a test of 20,000 gallons of algae biofuel on a non-active warship, which was a 50-50 mix of regular petroleum fuels (Casey, 2011).

Oil companies & chemical companies are becoming partners in developing microalgae biofuel. Exxon Mobil, BP, and Amoco invested over USD $600 million in the early 2010's in helping to scale production with other microalgae companies (Singh & Gu, 2010). Algenol Biofuels & Dow Chemical teamed to demonstrate an algae ethanol plant in 2009 (Hamilton, 2009). More collaboration between governments oil companies, non-governmental organizations and start-up enterprises are needed to make microalgae biofuels commercially feasible and become a replacement for fossil fuels in the future.

Conclusion

Increased risks from human-induced climate change and the rise of the emerging market middle class, provide an excellent opportunity for microalgae-based biofuels as a clean energy source. The process involves refining(cultivation), harvesting, extraction, and conversion to ensure the microalgae biomass is ready to become bioenergy. Advantages of using microalgae biofuels include potentially significant yields, no competition for land or food while producing in areas other biofuels can't. Microalgae is very versatile and can provide ethanol, biogas, biohydrogen, and biodiesel. Challenges with microalgae biofuel production include low energy efficiency rates compared to oil-based feedstocks, high inorganic nutrient use, and steep production costs. Using wastewater and nutrients from agricultural waste, along with hybrid bioreactors would help ease energy efficiency and environmental production concerns. Collaboration between private, government and non-governmental sectors would help support R&D, commercially scale microalgae biofuels and reduce costs.

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