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Microalgae biofuels production: A systematic review on socioeconomic prospects of microalgae biofuels and policy implications

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A B S T R A C T

There is currently no sustainable reliance on liquid fossil fuels worldwide, which ensures that future fiscal, environmental and social stability requires alternative renewable sources of liquid fuel. In order to satisfy the worldwide demand for liquid fuel, microalgae production is needed on a commodity scale; however, there are significant challenges in ensuring that production is economical and durable. This paper aims to examine microalgae' economic and cost advantages in greater depth and evaluate how vital biofuel policy support is for microalgae. A systematic analysis outlined the obstacles facing traditional biofuels to achieve these targets and proposed microalgae biofuels' economic opportunities. Provided that the policy was a primary determinant of the biofuel industry's development, these economic studies' findings were then included in the debate on existing policy support for biofuels and biofuels' potential microalgae play an essential role in the policy background.

1. Introduction

The protection of fossil fuel supply is jeopardized by rising demands due to population growth and uncertainty in regions producing fossil fuels (Dasan et al., 2019; Gavrilescu and Chisti, 2005). Gas-powered and electric substitutes (e.g., liquefied petroleum gas and natural gas) require expensive customer investment in new cars or improvements to current vehicles (Karatzos et al., 2014). Therefore, the production of biofuels that can be easily replaced by existing vehicles (Celikten et al., 2010) is a critical component of global transport fuel demand. While biofuels currently account for just a small percentage of 1.9 percent of global transport fuel consumption, trends have indicated a threefold rise over the next 20 years (Carson, 2014). The main driver of this growth is expected to be increasing support for the policy. This focuses on constructive government policy that has helped grow the biofuel industries of Brazil and the (US) (Goldemberg and Guardabassi, 2009). From a neoclassical economic point of view, this production promotion is likely to increase the supply of biofuels, lower prices of goods, and ceteris paribus. However, most current organic feedstock is based on terrestrial agriculture, which raises the cost of opportunity by allocating food crops and capital. These biofuel feedstock's external prices would counteract the market change's benefits, resulting in less economically favourable outcomes (Dasan et al., 2019).

Microalgae species with higher lipid content material are appropriate feedstock for manufacturing renewable energy such as jet fuel, biodiesel, and biogasoline. However, those with more significant protein and carbohydrate fraction are excellent candidates for meal supplements, human nutritional products, cosmetics, aquafeed and animal feed. More than one technology has been recommended to make use of biomass for renewable energy. However, they can all be categorized into thermochemical and biochemical conversions (Gollakota et al., 2018). Thermochemical procedures target liquid fuel by applying greater temperatures, pressures, and oxygen deprivation to various biomass feedstocks. Processes such as pyrolysis, gasification, liquefaction, and combustion are underneath this class (Teymouri, 2017). Since life cycle assessment (LCA) has validated the dewatering stage as one of the most energy-intensive strategies in the algal-biofuel refineries (Davis et al., 2014; Handler et al., 2014), the large variety of up-to-date research has targeted the hydrothermal processing of wet algal biomass to dispose of the high priced dewatering step. Hydrothermal Liquefaction (HTL) that can convert biomass to bio-crude has won perfect attention. The bio-crude yield and its factors drastically rely on the temperature and residence time (Patel et al., 2016).

Increasing literature has suggested that microalgae, the latest feedstock for biofuels, would alleviate problems that have plagued their biofuels counterparts, particularly in their effect on food allocation and resources (Chisti, 2008). The microalgae biofuels controversy has been heavily dominated by research and engineering disciplines (Rodionova et al., 2017). While this helps to examine improvements in production technologies, a more thorough economic assessment must be carried out to determine the need for policy action and the resulting ramifications, especially in the presence of externalities, by undertaking an economic analysis of the production and use of biofuel microalgae.

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This study's results can be used to advise on how to reframe the approach for this new transport fuel technology in Malaysia.

2. Methodology

2.1. Literature search

One potential method of implementing qualitative analysis to text data is illustrated by the methodology presented in this manuscript. Numerous distinct phases are defined in the planning and exploring microalgae biofuels production in version 9 of ATLAS.ti (Taofeeq et al., 2020). A review was carried out first of all. The literature scanning allowed the authors to define the analytical structures used to process and analyze the data. The research sources used for the search were Taylor and Francis, Emerald, Springer, and Elsevier. Simultaneously, the predominant keywords were Microalgae, Conventional Biofuels, Biofuels Production, and Microalgae Biofuels' Economic Prospects. While the usage of this level of granularity of the database (aggregator and publisher level) resulted in a certain degree of correlation between the two domain tiers, this offered confirmation of the aggregate searches performed to collect all applicable material in the literature (Bastas and Liyanage, 2018). Only peer-reviewed journal articles, books, and conference proceedings were included in the analysis to ensure the academic fields' inclusion under the scrutiny of the most credible materials and publications of exceptional managerial effect (Moshood et al., 2021a; Thornhill et al., 2009). They contained only articles written in the English language.

The Kyoto Protocol's adoption in 2002 was recognized as a remarkable achievement in global sustainability, with the bulk of sustainability integration research in line with the research objective of this analysis adopting this global initiative (Moshood et al., 2020a; Rajeev et al., 2017). Based on these main achievements in the fields of efficiency, global sustainability, microalgae, biofuels production, algae fuel manufacturing, sustainability, the quest date for this analysis was set from 1999 to 2021.

Only journal articles, books, and conference proceedings were included in the analysis to ensure the academic fields' inclusion under the scrutiny of the most credible materials and publications of exceptional managerial effect (Thornhill et al., 2009). They contained only articles written in the English language. The approach outlined in this paper shows one possible way of applying qualitative research to text results. In preparing and exploring microalgae, biofuels production, algae fuel manufacturing, sustainability, various separate stages are described (Moshood et al.,2021a). Each stage of the evaluation phase is organized around the sections of processes, findings, and discussion, allowing the reader to understand further how the data are evaluated and follow the process's implications and the resulting data. The 341 papers Identified were screened (Identified through database searching, 341 papers), Screening (Post Removal of Duplicates, 226 papers remain), Eligibility (Post-Abstract Review, 192 papers remain), and validated for Included (Post-Full-Text Review, 181 papers were used). Duplicates have been excluded as part of this process, eligibility has been verified from abstracts, and the complete content of outstanding papers has been checked in the context of the study issues for the final judgment regarding the microalgae, biofuels production, algae fuel manufacturing areas under examination (Shamseer et al., 2015). As per the systematic literature review protocol for this study, the 181 papers were screened and verified as valid.

Duplicates have been excluded as part of this process, eligibility has been verified from abstracts, and the complete content of outstanding papers has been checked in the context of the study issues for the final judgment regarding the microalgae, biofuels production, algae fuel manufacturing, and sustainability areas under examination (Moshood et al., 2021a; Shamseer et al., 2015). As per the systematic literature review protocol for this study, the 181 papers were screened and verified as valid.

2.2. Literature consideration

To save, identify, and interpret this research proof, the ATLAS.ti 9 software package is suitable. One benefit of using the software ATLAS.ti 9 was that for keywords, patterns, relationship charts, and other analysis features, easy access to quotations is possible. The ATLAS.ti 9 software was first used for auto-code invention during the primary research process. All areas of the information organization in which software has been applied were defined and labelled as quotes. These quotations were grouped into a different registry for review, and the quotations were analyzed periodically using the research process. All papers were read repeatedly and clarified, driven by the research subject, to identify recurrent trends and ideas (Moshood et al., 2020c; Paulus and Bennett, 2017a). In order to achieve three kinds of reports, the collected materials were planned. 1) Overall report: the papers obtained are initially explained by their research backgrounds to describe the literature assessment's overall intent. 2) Detailed description: This study's primary focus is on microalgae biofuels production in the manufacturing sector. Seven primary word forms discussed above distribute the obtained posts. The relevant items shall control a comprehensive report on the products obtained, such as the testing goals, strategies, and productivities, the significance of microalgae biofuels production 3) Lastly, an interaction review is a further argument on microalgae biofuels production in the manufacturing sector research for integrated design through multiple papers that were carried out (Chang and Hsieh, 2020; Moshood et al., 2020a).

2.3. A systematic review using ATLAS.ti 9 software

This section conserves the organization of the technique section-each phase of the research process is addressed. The use of ATLAS.ti 9 software (quotation, families, and network) would probably mean little for those not familiar with the software. By comparison, Weisheng Lu and Yuan (2011) used and clarified machines' terminology to allow readers to take stock. The researchers described this overview and what features were used to evaluate the methodological approach and software and version (quotes, codes, and system hierarchy with memos). The definition of quotes and the relationship between quotes and codes have been explicitly articulated (Paulus and Bennett, 2017a). The researcher explained briefly how the software was used to inform unknown people about the efficiency of data processing software (Moshood et al., 2020a). One benefit of using the software ATLAS.ti 9 was keywords, topics, relationship charts, and other analysis features, as easy access to quotations as possible. In ATLAS.ti 9 applications, Fig. 1 represents a network view demonstrating how the data codes are related to the five major themes arising from the microalgae biofuels production, Biofuels, Food/Feed, Biochemical, Landfill Management, and Water Treatment. In this case, the authors suggested that the data was generated using the network function of ATLAS.ti 9.

Open coding: Upon initial analysis of text results, the researcher will recognize several words, sentences, and other words of interest related to this article or field of interest with the open coding feature of the ATLAS.ti 9 software package. A "quotation" is labelled with Open Coding and uses the same wording to produce a message from the same passage. It is not uncommon to come to a point where we will have more than a couple of pages of codes as we begin developing codes with fresh ideas (Friese et al., 2018). At that point, to find the correlations and classify them into classes based on their common properties, we may research the codes. Researchers may also consider the codes' dimensions that reflect the property's position within a continuum or set (Moshood et al., 2021a). The name of the category can vary from the codes to help communicate its width, and, if appropriate, we may even create sub-categories from the codes and then apply them to the categories (Soratto et al., 2020). Open coding is usually the initial stage of qualitative data analysis. We may do gravitational coding and selective coding after finishing open coding, depending on the technique we use.

Fig. 1. Atlas.ti network view on usages and products of microalgae.

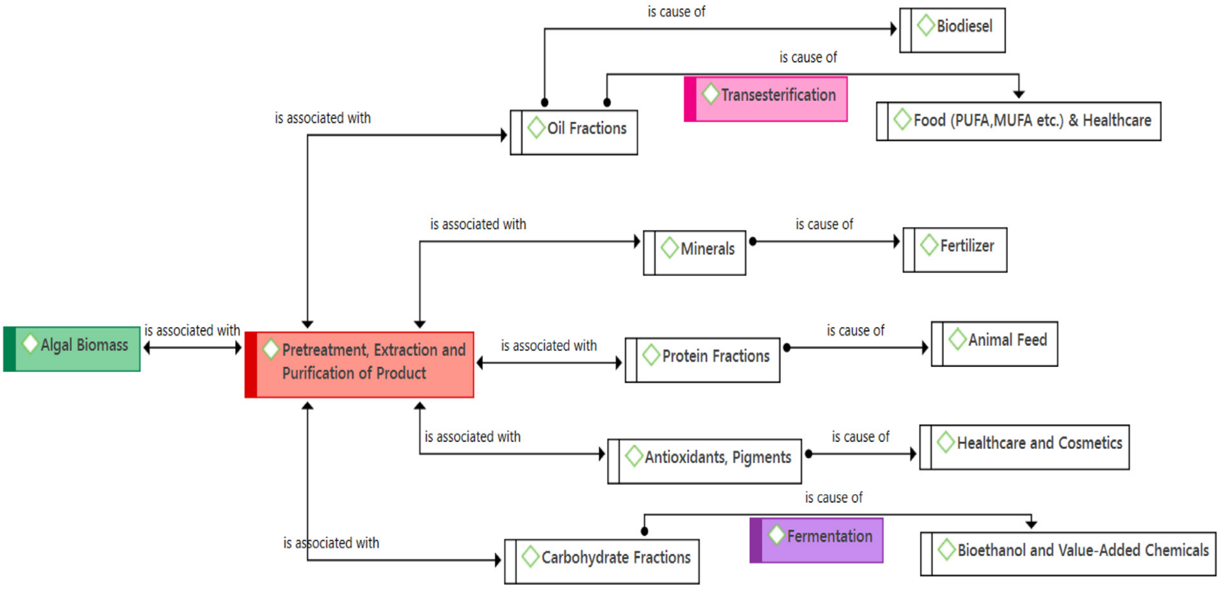

Fig. 2.. Microalga biorefinery processing system.

At the later stage of the study, such coding enables one to create models in an inductive process. The required information for mathematics is shown in Figs. 1 and 2.

Data Analysis: After developing the code structure, the principal researcher had a simple overview of the data. The codes used to view and reread the data have been refined several times. The next move was to organize the codes to a cohesive pattern concerning the research issue. It's like creating a plotline where a portion of the plot is made up of the theme. Fourteen code groups were formed to review the case study data and summarize five subject areas that serve as the first themes (see Fig. 1). Figs. 1 and 2 illustrate how the codes surrounding work-related problems were further discussed in the theme creation process. The network feature ATLAS.ti 9 software was used for this. Codes that all contributed to the Biofuels, Food/Feed, Biochemical, Landfill Management, and Water Treatment were drawn into a network and connected to each other. This is not an automatic method (Soratto et al., 2020). The software creates no connections or names the links. The software only provides the researcher with space for conceptual thought. This occurs as the networks arrange the nodes, think of meaningful connections, and name those connections. For example, the above network (Figs. 1 and 2) indicates that oils created from microalgae have both physic and chemical traits comparable to oils found in the vegetable and, consequently, view as credible raw resources to manufacture biofuel.

Microalgae provide higher productiveness of oils than palm and viable oil sources through the most elevated productiveness in manufacturing structures. Current reviews verify the microalgae plant, which is sustainable and capable of accomplished international needs for flammable fuels. Microalgae can serve as feedstock to manufacture value-added products (such as food, fine chemicals, cosmetics, and pharmaceutical) and bulk commodities (e.g., biofuels and oleochemicals) in a bio-refinery. In addition to photoautotrophic growth (where energy derived from light is transformed to chemical energy through photosynthetic reactions), microalgae can additionally be grown heterotrophically (where biological mixtures can recycle as a supply of energy and carbon) or mixotrophically (where both organic compounds and CO_2 are utilized, with photosynthesis as the primary source of energy) (Chojnacka, 2004; Abel, 2017).

Figure two has illustrated the viable domains of utility and available outputs through microalgae. The previous investigation has indicated that it was feasible to turn microalgae biomass into profitable products (Musa et al., 2019). This would be a central question in trying the biofuel agenda for micro-algae. Microalgae are the alternative source of green energy in a nation with exhausting energy supplies and increased energy demands, which are necessary if technical discoveries are to be used to keep them safe. The bio-refinery method is the processing of biomass into a sustainable and spectrum of marketable products. In this procedure, microalgae-based biofuels' monetary viability is based on co-production by great-value products (Musa et al., 2019).

3. Global energy challenge

A rising global population has seen an ever-increasing demand for significant natural resources (fresh water and food) and fuel over the past half a century. Increased global industrialization has led to a widespread dependency on petroleum products in recent years (Tsita and Pilavachi, 2013). It is estimated that 80% of the world's primary energy consumption is derived from fossil fuels, with 58% being used in the transport industry (Escobar et al., 2009). With this reliance unlikely to decrease in the near future and our fossil fuel stocks begin to decline, the urgency for alternate renewable energy options is rising (Menegazzo and Fonseca, 2019). The development of productive and safe renewable energy industries has seen technical developments in recent decades: hydro-electric, wind and solar (photovoltaic) industries are now seen worldwide, all of which can produce vast quantities of sustainable electricity suitable for human consumption (Diesendorf, 2019; Menegazzo and Fonseca, 2019).

The inability to store these forms of energy currently prevents these sources from meeting all of our energy needs, especially the need for a mobile energy source. This illustrates the need for a transportable liquid fuel to be produced to be tailored to the existing infrastructure. The production of fuel from sustainable biomass supplies (i.e., biofuels; Nigam and Singh 2011) will offer an alternative approach to fossil-derived fuels, enhancing the renewable energy sector's ability to provide social, economic, and environmental benefits (Chia et al., 2018). A government/nation/economy with greater fuel protection will be provided by creating a competitive fuel industry. Brazil's new prominence as a major global economy can be seen as a case study to illustrate the benefits of mainly being energy-independent from fossil fuels, an effort sparked by the 1970s global energy crisis (Chia et al., 2018; Robbins, 2011).

Besides economic benefits, biofuels provide environmental advantages as they break the carbon loop, are carbon-neutral and provide the opportunity to further decarbonize our society by moving internationally, culminating in the Paris agreement (Secretariat, 2015). The Paris Agreement's clean energy goals were to lower yearly greenhouse gas emissions with the goal "to keep the average global temperature well below 2 °C above pre-industrial level" (Doshi, 2017a). Government mandates are being carried out to meet those goals; for example, India expects to be regulated by 20% for biofuel (ethanol) mixture by 2020 (currently 5 percent; Doshi 2017a). Increasing stability would lead to global consumer demand for biofuels that are readily available and allow biofuels to be exchanged as commodities. Social and environmental consequences impair any biofuel production process's viability to this degree (Doshi, 2017a; Fairley, 2011; Robbins, 2011).

3.1. *Sustainability and energy diligence*

A variety of valuable and useful goods for consumer welfare include personal care products, health products, agrochemicals, and transportation fuels. Chemical technology and chemical companies offer services (Zaimes, 2017). However, producing such goods is followed by producing immense amounts of waste and several unhealthy pollutants from the air, water, and soil. Resource consumption and anthropogenic impacts are progressively becoming aware of the longstanding effects on global ecological systems and the natural biogeochemical cycle, leading to human existence. Reported environment review results from the millennium ecosystem assessment (MEA) (Qi et al., 2020). The impacts and substantial impacts of environmental changes on human and ecological well-being on the environment are apparent in an international partnership, which has seen a quicker and more extensive transition in habitats during the second half of the 20th century to anthropogenic resource depletion and unsustainable capital use than during any era in human history (Zaimes, 2017). Rockström et al. (2009) measured the earth's transgression of environmental limits for climate change, ecology, nitrogen cycle equilibrium, and rapidly exceeding global fresh-water, land-use, acidity, ocean, and global phosphorous cycle balance. Traditional approaches for chemical process design have focused primarily on seeking the right economics relative to physical restrictions, namely the fulfillment of thermodynamic limits for heat and material balance (Kılkış, 2019; Moey et al., 2020).

However, the worries about reducing fossil oil supplies increased compliance with regulations. The consequent movement for environmentally sustainable process design because manufacturers see a decreased environmental footprint as one of the product design priorities. Market leaders have started to understand that a move towards sustainable planning can mitigate industrial production's effect on the environment and is also necessary for their companies' long-term growth and profitability (Suzuki et al., 2017). The new area of science and engineering for sustainable development provides tools to identify, calculate and reconcile constraints on energy, human needs, and maximize global and human benefits. The idea of sustainable development is multifaceted; it encompasses the human enterprise's whole, dealing with and, as such, deeply interdisciplinary, cultural, social, political, and economic problems (Xu and Chen, 2020). The great challenge for the chemical sector in producing new chemical processes is integrating environmental and sustainability aims and conventional design priorities. The rapid production of biofuels as a potentially stable and safer alternative for traditional fuels is a unique chemical industry challenge. Simultaneously, environmental and green externalities beyond the standard process architecture need consideration (Cai et al., 2019).

4. Microalgae

The word "algae" refers to a wide variety of anatomy and chemical processes of species that is very diverse. Microalgae, often known as algae, can be unicellular or multicellular (Branco-Vieira et al., 2020). Algae are photoautotrophic mainly and dependent on photosynthesis to survive. Photosynthesis allows algae to consume energy from the sun to mix water with carbon dioxide (CO_2) to create algal biomass

(Chia et al., 2018). Their energy consumption mechanisms are similar to terrestrial plants, but algae's anatomy in terrestrial plants is uncomplicated. Microalgae comprise two purposeful agencies, which are: heterotrophic and phototrophic. Phototrophic is the algae that use sunlight and CO_2 through photosynthesis, while heterotrophic is the algae that require carbon-based for their development (Barbera et al., 2018). Equally, heterotrophic algae and phototrophic algae additionally need water and nutrients for their growth. The benefit of microalgae related to global biomass and its great deal in photosynthetic effectivity resulted in growth rates that extend CO_2 mitigation (Biller, 2013; Brennan and Owende, 2010; Hajar et al., 2017; Wang et al., 2008).

It ought to be brought into the record that only photosynthetic active radioactivity can be used when talking about the duration of fundamental carbohydrate manufacturing. During the decades, demand from industry has powered the mass culture of algae. In the medicinal, nutraceutical, feedstock and fertilizer, food, and biofuels sector, algal biomass components were found to be extremely valuable (Hajar et al., 2017). In the aquatic and fresh-water habitats worldwide, algae are included. Microalgae are present in all marine settings and can barely be observed without using a microscope, even where the crops are rich in color. They are especially interested in the industry as they can easily be grown within a comparatively short period in a laboratory, photobiological, or terrestrial pond environment (Branco-Vieira et al., 2020).

4.1. Applications

When grown in mass culture, microalgae have many commercial applications. Early on, rotators, fish, and animal feed or feed additives were grown to microalgae (Vignesh et al., 2020). However, high polysaccharides, fermentation products, and fertilizers, and, most importantly, nutraceutical, pharmaceutical, and biofuels are seen to be generated by microalgae. Microalgae cultivation can vary by commodity because each microalga's optimal processing properties are different (Muhammad et al., 2021). Algae-derived biofuels are of particular concern. This interest stem from the awareness of the increasingly inefficient use of fossil fuels such as oil and gas. Besides, fossil fuel burning contributes to the release into the atmosphere of toxic greenhouse gasses. These greenhouse gasses pose imminent risks to fauna's health and may contribute over time to negative climate changes (Chai et al., 2020).

Scale cultivation of microalgae is appealing to biofuel production because it is ecologically sustainable, gives fossil fuel relief, and does not harm food crops. CO_2, methane, nitrous oxide, and fluorinated gasses are the most significant greenhouse gasses listed by the Environmental Protection Agency (Volk, 2010). Of the four-carbon dioxide emissions, 76 percent of all gasses are the highest global pollution rate. The fossil oil and manufacturing processes account for 65 percent. In 1900, fewer than 1000 million tons of carbon were released (Curley, 2011; Ramseur and Leggett, 2019). This figure increased to around 9.500 million tons in 2010 and continues to grow. In the last 40 years, surprisingly, 90 percent of the rise occurred. Today, fossil fuels are somewhat different and are in high demand, leading to increased fuel costs. Another way to satisfy gasoline demands is by using biofuels to reduce fuel cost (Agrawal et al., 2020). Using a transesterification reaction, turning algae-derived oil into functional biodiesel is simple. Transesterification is the conversion process between an ester and an alcohol functional group with an organic functional group. In order to create glycerol and methyl esters, the triglycerides react with alcohol. As biodiesel, methyl esters are used. In this method, ethanol is the popular alcohol used (Menegazzo and Fonseca, 2019).

5. Conventional biofuels: an overview

It is essential to identify the type of biofuels specifically. A general concept is a fuel that can be sub-categorized as primary and secondary biofuels from renewable biomass supplies (Stöcker, 2008). Primary biofuels produce electricity in the natural biomass from modifying chemical energy (e.g., firewood). Secondary biofuels are known to be primary biofuels refined before the fuel manufacture and can be further categorized according to feedstock and technology. The three kinds include (advanced) biofuels of the first and second generation (Malins et al., 2020; Nigam and Singh, 2011). Biofuel classifications as shown in Table 1.

Biofuels are derived from a feedstock of various types of derivatives of carbohydrates and lipids. According to the convention, biofuels are separated according to feedstock (Larson, 2008). In traditional biofuels use, the feedstock is from plants. First-generation biofuels use raw materials dependent on food crops to produce fuel. These include ethanol from sugar cane and corn-based biofuel, biodiesel from palm oil, rapeseed oil, and soybean oils-based biofuel (Fernández-Escobar et al., 2014; Gasparatos et al., 2013). Around 37 percent of corn and vegetable oil production from the US and European production is allocated to the respective biofuel (Groth and Bentzen, 2013). Brazil and the United States manufacture 90 percent of the global ethanol for gasoline, and Germany only supplies half of the worldwide biodiesel (Doshi, 2017a; Martinot et al., 2005).

Second-generation biofuels use feedstock from non-edible crops to produce energy such as ethanol (Ramirez et al., 2015). Different biomass forms include sugarcane bagasse (Kosinkova et al., 2015), firewood, bamboo, woodchip industry for bio petrol, and jatropha6 biodiesel production (Carriquiry et al., 2011). Many commercial crops have been produced, but biofuels' big-scale production concerns remain unresolved (Chisti, 2013; Mata et al., 2010). Over-fertilization of land cultivates it without using it for food and heat. Besides, these recent results suggest that yield per area is low and that more biofuel is uneconomical. The current emphasis is on exploiting microorganisms' natural metabolic mechanism to create a viable, alternate feedstock; microalgae is a good illustration (Chisti, 2013; Doshi, 2017a; Ziolkowska, 2020).

In general, third-generation biofuel feedstock is microscopic biomasses that can be produced in regulated, artificial environments and are less dependent on limited resources such as food crops, arable land, and water (Dragone et al., 2010; Nigam and Singh, 2011). Besides, microalgae cultivation will use waste stream nutrients such as urban wastewater and power plant carbon emissions. It is possible to refine microalgae to generate both biodiesel and ethanol. Given the technology's fuel production capacity, an increasing number of studies are exploring microalgae biofuel developments (Azad et al., 2015) that suggest the opportunity to fulfill current and future fuel demands (Chisti, 2007) while preventing economic problems that endanger conventional biofuels (Usmani, 2020).

5.1. Feasibility of conventional biofuels

Traditional biofuels are typically characterized by higher processing costs and thus uncompetitive market prices in studies that have measured the financial feasibility of producing biofuels relative to fossil fuels (Demirbas et al., 2016). For example, Hill et al. (2006) report that soybean biodiesel was about 20 percent more costly to produce in 2005 than diesel's wholesale price. In contrast, ethanol production was around 5 percent more expensive than the price of wholesale gasoline. Increases in fossil fuel costs (up to 30 percent) have made it easier to make these biofuels more affordable since 2005, but markets have largely held in favor of fossil fuels (Demirbas et al., 2016; Doshi, 2017a).

Government support, however, has allowed some varieties to join the commodity fuel market by mixing mandates and tax credit programs, with sugar cane ethanol being a prime example in Brazil (Goldemberg and Guardabassi, 2009). Market or output-based costs are not captured by the possible non-market advantages associated with bio-

Table 1.
Biofuel classifications.

Primary	Secondary	Secondary	Secondary
Direct combustion of firewood, wood chips, Pellets, animal waste, forest and residues, landfills gas.	1st generation Substrate: Seeds, grains, or sugars. Products: Bioethanol or butanol by fermentation of starch (wheat, barely, corn, potato) or (sugars (sugarcane, sugar beet. etc.) Biodiesel by transesterification of plant oils (rapeseed, soybeans, sunflower, palm, coconut, jatropha used cooking oil animal fat, etc.)	2nd generation Substrate: Lignocellulosic biomass Products: Bioethanol or butanol enzymatic hydrolysis. Methanol, Fischer Tropsch gasoline and diesel, mixed alcohol, dimethyl ether, and green diesel by thermochemical processes. Biomethane by anaerobic digestion.	3rd generation (advanced biofuel) Substrate: micro/macroalgae, bacteria, or fungi. Products: Biodiesel by transesterification of microbial oils (microalgae. bacteria, fungi, etc.) Bio crude from microalgae by thermochemical processes. Bioethanol from macroalgae Bio hydrogen from green algae.

fuels' development and use. This results in insufficient energy delivery and a possible undersupply of biofuels, assuming that performance and consumption are net positive externalities. Accounting for these gains, potentially by subsidies (Msangi et al., 2007), would result in economic efficiency in the quantity and price of biofuels. In reality, biofuel-related subsidies (either iteration) compensate for the external advantages of having a smaller net environmental footprint relative to fossil fuels and increasing the availability of fuel (Demirbas et al., 2016; Doshi, 2017a) and national/regional energy independence (De Fraiture et al., 2008; De Gorter and Just, 2010; Khanna et al., 2008). However, it is essential to consider the presumptions about these advantages' existence and practical importance, particularly those discussed below.

5.2. Energy return

While biofuels' advantages have been thoroughly clarified in the literature, unique benefits can contradict such caveats. This is also due to energy-intensive refining an existing dependency on fossil fuels, which can outweigh the advantages of biofuel production and transport in terms of energy and GHG (Cherubini et al., 2009; Ulgiati, 2001). Less promising findings have been seen for biofuels in the Energy Return on Investment (EROI) study, which measures the available energy derived from the resulting biofuel, divided by the energy used in production. Between biofuels, the most energy-efficient of their respective fuel types are sugarcane ethanol and palm oil biodiesel (de Vries et al., 2010; Gasparatos et al., 2012; Menichetti and Otto, 2009). This feedstock was also found to be the most productive in terms of power per cultivation area. On the other side, ethanol and biodiesel from rapeseed and soybean maize are low in energy productivity (Chiriboga et al., 2020).

For conventional biofuel, though, the EROI is considerably smaller than fossil fuel and diesel, as with fossil fuel. The prevalent biofuel in the United States, Corn ethanol, is particularly small at the EROI range of 0.8 to 1.7 compared with 10 in fossil fuels (Chiriboga et al., 2020). The second-generation model needs a marginal decline in energy consumption, with a promising EIRO (Farrell et al., 2006) as well as an energy return per harvest area (up to five times as high as the first generation) (Demirbas et al., 2016; Doshi, 2017a). The quality changes between the two energy feedstocks produced are facilitated (Scharlemann and Laurance, 2008). Nevertheless, it has been seen that many feedstocks with second-generation energy returns are comparatively low compared with fossil fuels (Demirbas et al., 2016; Doshi, 2017a).

5.3. Net carbon benefit

Several research findings on biofuel pollution have found that greenhouse gas emissions (GHG) are lower by up to 90 percent relative to fossil fuels (Scharlemann and Laurance, 2008). However, these reports have also neglected to account for the impact of improvements in land use arising from the increased planting of biofuel crops that can counteract these GHG gains from development and consumption (Andersson et al., 2020). That is because the land conversion for biofuels is a source of permanent carbon sinks, primarily for deforestation (Chung et al., 2011b). The emissions from land clearance (Fargione et al., 2008) are projected to be 17 to 420 times higher, resulting in a long "payback" period to minimize net emissions (Demirbas et al., 2016; Doshi, 2017a).

5.4. Socioeconomic benefits from energy independence

The ability to provide some degree of energy independence that benefits society, especially in developing countries, is advantageous for biofuels. This means decreased dependency on imports and improved fuel protection (Rajagopal et al., 2007). This has been done in Brazil by national policies and parts of Africa at smaller population levels (Alexandros Gasparatos et al. 2012). This latter demonstrates more benefits in agricultural, land-locked areas with self-supporting fuel sources; rapid fuel access is advantageous for jobs, growth, commerce, and local trade to emerging communities. This is achievable at low levels of skills like agriculture, science and development, and higher skills (e.g., Brazilian artistic engines) (Demirbas et al., 2016; Doshi, 2017a).

However, biofuel subsidy programs, combined with mixing conditions, are seen as potential leads to increased demand for fossil fuels by a 'green paradox' to boost biofuel production and demand (Demirbas et al., 2016; Doshi, 2017a). This happens as the trends in policies introduced to facilitate the use of environmentally sustainable or 'green' alternatives increase private producers' use of 'non-green tools to optimize returns. This will result in supply-side results that can overwhelm the expected replacement effect of the initial 'green' policy (Doshi, 2017a). Works by De Gorter and Just (2009) also found that the ethanol tax incentive policies introduced in the U.S. were ineffective when applied along with gasoline quotas, leading to more substantial dependencies on fossil fuel importation fuel.

5.5. Impacts on food prices and agricultural resources

The theoretical cost of reinvesting farm crops & services would be increased demand for traditional biofuels (Prabhakar and Elder, 2009). This is because of the competitiveness of these food processing components. Most feed crops are currently concentrated in food and use scarce field inputs (particularly soil and water). In quantitative assessments, particularly for first-generation feedstock, biofuels had more essential impacts on food prices than energy prices (Demirbas et al., 2016; Doshi, 2017a). Studies have shown that maize and corn products are allocated at rates of ethanol of 40 percent of price increases. The expectation of rising biofuels of the first generation contributes to a 5–15 percent rise in grain and livestock prices (Fischer et al., 2009). This decreases food availability and supply and exacerbates global malnutrition.

However, conflicting research suggests that other causes can trigger food price changes. Slow adoption of biofuels does not improve the productivity of agricultural goods enough to affect food prices (Bastianin et al., 2013; Groth and Bentzen, 2013) or demonstrate any long-term links to food prices (Ajanovic, 2011; Bastianin et al., 2014; Myers et al., 2014). There are projected to be a slightly less than expected impact of biofuel production on food prices (Baffes and Haniotis, 2016; Baier et al., 2009). Incent oil prices have seen to have a growing impact on food prices, volatile weather conditions, increased population demand, and more particularly speculative effects.

The effect of land or water sources on the growing demand for biofuels was identified as a potential concern (Kosinkova et al., 2015). Growing world population and restricted arable land resource shortage patterns indicate the unsustainable value of traditional biofuels, which will lead to a 44 percent rise in demand for arable land by 2020 (Demirbas et al., 2016; Doshi, 2017a), this will, however, satisfy only a limited share of fuel demand. It has also been noted that the resultant strain on farmers to turn food crops into biofuel crops has already impacted food prices due to rising biofuel demand. This demand for arable land was also counterproductive in the mass deforestation of palm oil in Southeast Asia (Chung et al., 2011a; Koh and Wilcove, 2008) and for sugar cane and soybeans in Brazil (Lapola et al., 2010, 2014); this resulted in losses of both carbon stocks and biodiversity of the environment. Second-generation feedstocks have also been shown to increase trade-off problems with food and fodder land, particularly in more impoverished rural communities.

It is also water-intensive to plant terrestrial-based biofuel feedstock in terms of water allocation, which results in trade-off problems. Water demand estimates have been shown to be undervalued to the extent that both in the United States (Yi et al., 2015) and Brazil (Pimentel, 2003) are higher than the normal replenishment rates of aquifers (de Oliveira et al., 2010). Special water intensives have been identified in the related feedstock's, such as sugarcane (de Oliveira, etc.) and palm oil (Theesfeld, 2008). While comparatively less water is required (Carriquiry et al., 2011), the second output generation's crops may experience trade in productivity and biomass production.

It is currently impossible to quantify the actual impact of increased market use of biofuels on food prices. This is because of many factors, including overt competition in crops and indirect competition in agricultural resources. Biofuels are still not a great consumer choice in most countries, making it challenging to create solid, quantifiable relations (Demirbas et al., 2016; Doshi, 2017a). More research needs to be undertaken to address this void, but only by increasing market insertion of agricultural biofuels dependent on fuel can it possibly be motivated. However, the things mentioned here are reasonably assumed that increased production of traditional feedstock biofuels may significantly impact food price.

6. Algae-based biofuels

To resolve many of the above concerns, the advancement of third-generation biofuels based on algae (Severes, Hegde, D'Souza, and Hegde, 2017), particularly the implications of feeding supply and the rivalry for both arable and water resource supplies, have been highlighted (Singh, 2015). Algae's capacity as a biofuel feedstock has been the subject of significant attention over the last decade. For bioethanol production, marine microalgae sugars, such as seaweed, are suitable (Wei et al., 2013; Zuorro et al., 2021). Also, biodiesel from macro-algae is feasible (Cancela et al., 2016). However, higher growth and lipid deposition capacities of microalgae and higher biodiesel energy content relative to ethanol (by as much as 34 percent) have created greater scientific interest in the production of microalgae-based biodiesel (Chisti and Yan, 2011). It was also proposed to boost the safety of current and future fuel demands with the high processing ability of microalgae biofuels (Scott et al., 2010), which warrant policy investments in the US.

Under controlled conditions, microalgae are typically grown under open ponds or in plastic tubes known as photo-bioreactors (PBRs). They are grown under a nutrient and carbon dioxide (CO_2) growth medium. The biomass of the algae is processed to produce biodiesel similarly to other lipid feedstocks (transesterification). The cells will also ferment the sugars to produce ethanol. The processing viability and reliability of microalgae can be tested by specific aspects of the development of microalgae biodiesel; by cultivation (Andersson et al., 2020; Jorquera et al., 2010), harvesting (Rahman et al., 2020; Sander and Murthy, 2010), lipid extraction (Bat) studies by Brentner et al. (2011), and Laurens, Chen-Glasser, & McMillan, (2017) indicate the different routes by which biomass/biodiesel production and the final unit costs can be decided at each stage of the process. These processes' specifics can be discussed only if they apply to particular challenges, effects, and externalities (Andersson et al., 2020).

6.1. Financial feasibility

Micro-algae biofuels do not currently compete with fossil fuels, like most of the first and second generations, which are usually not competitive in the absence of subsidies (Doshi et al., 2017). Due to their lightweight energy properties could be conceivable as alternative aviation fuels (Norsker et al., 2011). They were of interest to pilot-scale companies (Ansari et al., 2020). Research has also identified possible developments in both production and cultivation to minimize capital cost by low-cost machinery primarily intended for microalgae processing. High prices can also be minimized by purchasing low-rates CO_2, fertilizer, and water or recycling in the homes (Perin and Jones, 2019). The required volumes are seen as a limiting factor in the achievable development of microalgae, especially nutrients and water. The feasibility of such ideas has not been studied in industrial practice as long as real manufacturing is confined to smaller research and development undertakings (Rahman et al., 2020).

Microalgae production can also generate other by-products of commercial significance. Just over 30 percent of the biomass harvested consists of lipids (converted to biodiesel) or other energy-related products such as ethanol (Sander and Murthy, 2010), biogas (Odlare et al., 2011), and even hydrogen that can be used for fuel, are likely to be beneficial animal feed or other energy-related foods. The economic advantage of microalgae over traditional biofuels is that they can generate high-value residual biomass co-products. The future marketability of biofuel microalgae may also be dependent on the proper marketing use of microalgae (Jacob et al., 2020).

6.2. Energy requirements

The requirement for terrestrial feedstock is critical due to the several types of machinery and capital inputs required by constantly expanding microalgae cycles. As a result, conventional biofuels have reduced net capacity, making them unfeasible and potentially non-competitive (Andersson et al., 2020). In principle, this strong energy demand would result in the net loss of energy from conversion to microalgae or, at most, a marginal increase in existing technologies (Scott et al., 2010). The first demonstrates a better EROI compared with open-pond and PBR. Sander and Murthy (2010), which took into account higher open-basin value figures, was one exception. Open pools also showed a lower energy-intensive community, with higher energy costs resulting from harvesting and drying processes, contributing up to 10 times the energy quota (Adeniyi et al., 2018; Branco-Vieira et al., 2020; Slade and Bauen, 2013).

In comparison, the more regulated PBR conditions led to significantly higher energy costs and a lower energy-EROI ratio. Building and cultural flows pay the bulk of electricity costs (Javed et al., 2019). This increases concerns about the feasibility of PBRs in current technologies, given their high energy requirements (Hulatt and Thomas, 2011). However, because the industry is comparatively new, there is a chance that the probability of a positive net energy balance could be improved by algal strain and processing technology, but this is an environment awaiting further research (Gonzalez-Fernandez and Muñoz, 2017).

6.3. Net carbon benefits

Microalgae, like terrestrial agriculture, convert carbon dioxide into biomass via photosynthesis (Andersson et al., 2020). This approach has shown that microalgae are more valuable than other feedstocks for cultivation (Rosenberg et al., 2011; Wilson et al., 2020) calculated the net expense of lowering emissions by producing microalgae using a solar collector to be US$100 per ton of carbon dioxide (Ono and Cuello, 2003). They emphasized the importance that marketable outputs would reduce net costs. Compared to its land partners, micro-algae's commercial production is also expected to benefit from net carbon emissions due to the regulated production climate, particularly for PBRs (Slade and Bauen, 2013). Compared to traditional biofuels, fossil fuel use will also compensate for the advantages of carbon dioxide sequestration for upstream crops (Wang et al., 2020).

The cultivation course also recommended the recovery of power plant flue gas to reduce carbon emissions neatly. As carbon dioxide input, flue gas can be split14 into the growing medium of microalgae, bringing benefits from increased (Simonazzi et al., 2019). This application's performance and reliability in the area of high-concentration flue gas supply (also simulated) has been demonstrated by some laboratory and deployment studies (Negoro et al., 1993; Nhat et al., 2018; Simonazzi et al., 2019). The emissions arising from the eventual fuel use of biomass are affected by the net CO_2 microalgae's sequestration. As combustion produces the assimilated CO_2, the net emission schedule depends on the energy intensity of biomass production that could include fossil fuels (Maheshwari et al., 2021; Mata et al., 2010).

6.4. Nitrogen benefits

The production of microalgae requires nutrients, mainly nitrogen, within the growth media. This offers a means of extracting microalgae at elevated levels in the drainage fluid from nitrate compounds and a significant cause of eutrophication (Pittman et al., 2011). In addition to the high effectiveness of nitrogen sequestration, microalgae production also represents an inexpensive and low-chemical wastewater treatment process, providing sufficient growth conditions. Batten et al. (2013) found that microalgae biodiesel could be generated at less than US$1 litres with wastewater treatment as its primary objective, and water and nutrients recycled in the algae tanks. The findings were focused on a waste carbon dioxide source. However, a culture medium dependent on wastewater can limit biofuel production capacity because the inverse relationship between the growth conditions of nitrogen saturation and lipid production exists (essential for the production of biofuels) (Javed et al., 2019; Williams et al., 2010).

6.5. Socioeconomic benefits

The production of the biofuel industries with microalgae also has a range of socioeconomic advantages that can lead to a socially sustainable impact. The opportunity to provide an equal allocation of economic benefits through society, such as rural and urban populations (El Semary, 2020; Pachapur et al., 2020) and improving quality of life are among other aspects of social sustainability. Social sustainability. The most noticeable advantage is the development of an oil sector that is capable of supporting long-term fuel requirements and creating jobs and economic prosperity in rural areas. This is contradictory to current fossil-based enterprises, which are relying on capital constraints and synthetic biofuels. Microalgae biofuel will also create prospects for developing relevant employment through skills comparable to those associated with traditional biofuels as a long-term sustainable sector (Correa et al., 2019).

In non-metropolitan and rural counties, micro-algae industries are also a chance for economic development. Bioenergy ventures also rely on public and private funding, particularly in rural regions, on industries and local communities' jobs and income prospects (El Semary, 2020; Pachapur et al., 2020). Substantial prospects have been indicated for sustainable farming industry development and profits by traditional biofuels (Anuar and Abdullah, 2016). However, considering its effect on a wider population in terms of higher food prices and capital limitations, it will, in many cases, be challenging to explain policy support for traditional biofuel development. On the other hand, a superior solution may be the microalgae community, combined with the current complementary industry. Synergy from the bio fixation of waste effluents and creating valuable goods (e.g., feed, fertilizer) (Alam et al., 2012) can be economically advantageous to the local communities and augment the income of the seasonal industries.

7. Limitations of current policies for biofuels

In light of challenges to fossil fuel availability, biofuels are a crucial alternative to transport fuels. This is due to the close substitutability with fossil fuels, and therefore customers are losing their transformation prices (Klein et al., 2019). Furthermore, biofuels are believed to have various environmental impacts, extensively debated in the literature (Goh et al., 2019; Sun et al., 2019). Socioeconomic benefits, especially energy independence and fuel protection, may include innovations and growth in these new industries (Gasparatos et al., 2013). In certain nations, biofuels earned considerable political funding. This has allowed relatively steady growth of some first-generation feedstocks, supply chains, and technologies, mainly if the policies support widespread production and usage. Case studies in the US and Brazil highlight this critical role that policies will play in fossil-fuel transforming and promoting the growth of biometrics industries (Goh et al., 2019; Sun et al., 2019).

There can be argued that the lack of substantial policy funding is the primary factor behind Australia's lack of biofuels. Concerning domestic policy, the tax compensation subsidy's ending implies some inefficiency because of the outer costs of existing fossil fuels and the outside advantages for biofuels identified (Gasparatos et al., 2013). However, the arguments were evidently justified for the increased taxes on biofuels. Economic research indicates that fuel protection, jobs, and pollution cuts did not balance the economic benefits of grants with the high funding expense, distortion in the competition for capital and energy (including food demand competitiveness), and costs of maintaining an industry which is claimed to be unviable (Connor, 2016).

Also, the absence of additional State-based legislation promoting biofuels' production or use disincentives the future market. This includes the biofuel words in NSW that have struggled to support biofuel use due to the inconsistency of premium fuels policy, as determined by the PULP and ethanol mixtures consumption figures. Further, the absence of significant funding in the production of these technologies has hindered any feasible move away from economic cost-intensive first-generation biofuels due to the ability to grow various feedstocks in all the different states (Mathimani and Mallick, 2018).

With Brazil's influential case study, politics certainly significantly affect the biofuel markets and industry's growth. The initial provision of export subsidies, lower duty, and tax relief contributed to ethanol based on sugar cane, becoming the world's most commonly consumed gasoline (Sorda et al., 2010). This goes against the lack of a biofuel policy system, except for minor advances in NSW, which has relatively stagnated the industry's growth. The outcome is a lack of critical supply chains for production and restricted consumer visibility, which prohibits further business growth (Santeramo and Searle, 2019). More precisely, the lack of robust biofuel funding, unlike previous claims, will impede the development of second and third-generation biofuels. This would reduce society's well-being, particularly concerning the economic and transformative costs of continued dependency on fossil fuels (Balsalobre-Lorente et al., 2018; Connor, 2016).

7.1. Policy recommendations

The literature shows how policy is crucial to the biofuels industry's growth in a region (Gasparatos et al., 2013). While some policies may be wasteful (Kalkuhl et al., 2013, 2020; Kozicka et al., 2017) and the economic costs of first-generation biofuels in Australia, significant policy frameworks may lead to a move to more stable and economic innovations (Azad et al., 2014). Implementing suitable regulatory mechanisms to reflect the most cost-effective price can enhance production feasibility and viability as a long-term and sustainable alternative to fossil fuels. Producers and consumers respond to incentives offered by such policies, as seen by the relatively quick expansion of terrestrial feedstock (for example, in Brazil). While similar rules apply to microalgae production, the greater start-up costs and hazards act as a further deterrent to investing in the business compared to lower-cost agricultural-based production. With the technological developments required to justify these incentives and the fuel's feasibility, finding a policy mix that provides appropriate incentives for third-generation biofuels while transitioning away from conventional approaches and managing the associated risks is likely to be as difficult. Accepting these obstacles, however, would appear to be based on long-term confidence rather than utopian assumptions, considering the potential of microalgae as a biofuel feedstock.

Additional, federal investment in technical research and development in processing and conversion processes for new feedstock goods could provide this policy help (second and third-generation). The production of drop-in biofuels that perform likewise, if not better than petrol and diesel (incl. premium variants), should be encouraged, particularly for comparable prices. This also extends to ensuring that the use of engines and manufacturers in a broader range, especially existing vehicles, reduces the share of vehicles that are not compliant with biofuels (and blends). This feature of biofuels has been defined in the scientific literature as having less energy and less viscosity due to current biofuels. However, growth in biofuel processing and understanding of drop-in biofuels' chemical properties continues (Bergthorson and Thomson, 2015). Increased funding for R&D activities in this region by federal and state governments could theoretically accelerate technological change (Ding et al., 2018).

These policy instruments will make it easier to internalize optimistic biofuel externalities. By investing in the critical areas listed above, this strategy would essentially move the transportation fuel supply to a renewable substitute, yet to lower costs of a private transfer from other transport energy sources (e.g., compressed natural gas and liquefied gas, LPG). This transition ensures that society benefits from direct external benefits such as decreased contamination and reduced impacts on agriculture and biodiversity (Ding et al., 2018). It also promotes the establishment of a long-term fuel supply and work market and economic growth.

In the long term, it is crucial to boost higher-percentage blends and build technology for pure biofuels. However, the low percentage of biofuel mixtures is a vital transition for all transport fuel stakeholders. It enables customers to replace fossil-based purchases of transport fuel at a lower cost and enables the creation of established production systems (Doshi, 2017a). This will lead to a subsequent improvement in transport fuel demand, prompting the production, dealers, and engine producers to make additional biofuels' investments. Thus, if consumers are misinformed of biofuel mixtures' replacement ability, this step away from fossil fuels is hampered and will focus on future social welfare.

Political action is also essential to remedy this loss on the economy. The realistic effects for engine performance and maintenance of existing biofuel blend use require better communication to customers. This should be achieved in the context of publicity campaigns and more successfully to reduce the dissemination of disinformation amongst suppliers, dealers, and mechanics (Saravanan et al., 2018). Such initiatives guarantee that customers can obtain complete details and make the socially most effective decisions concerning biofuel mixtures' effect. Furthermore, this possible shift in customer choice may change consumer preferences as consumers become more conscious of organic fuels' external benefits. The longer-term impact of biofuels could be best understood, stimulating increased demand from farmers and consumers for existing blends. Therefore, consumers expect less use of fossil fuel, which would cause fuel farmers and producers to spend more on a higher percentage of R&D mixtures or pure transportation biofuels.

8. Discussion

Despite the fact that conventional biofuels' early environmental and supply benefits generated widespread policy support, research suggests that these benefits may have been exaggerated. Negative externalities connected with food and resource allocation have also increased scepticism about the transition to biofuels' long-term viability. This study discusses the economic benefits and costs of conventional biofuels, as well as the need for additional research and development of an algae-based third-generation feedstock. Given the various positive externalities associated with microalgae as a source of biofuels, the paper gives recommendations on the possibility for a policy framework to promote microalgae as a source of biofuels.

Due to the existing dependency on liquid fuels for transport and the limited presence of market-controlled fossil fuels, additional biomass-based fuels are required. Terrestrial feedstock has received extreme treatment and related production procedures. The external benefits of such systems were initially positive. The policy reinforcement was intended to be non-market advantages (in the United States and Brazil, for example) (Gasparatos et al., 2013). The literature may, however, overestimate these advantages. The loss of significant carbon sinks, as earth clearing for crop production, especially in tropical regions, shows a substantial increase in greenhouse gasses.

The total social and economic gain of traditional biofuels is also unstable because of the effect of land clearance and conversion on food prices and supply and caused the loss of non-market ecosystem services. These shifts have dynamic societal consequences. The opportunity for extra jobs and earnings from crop-based production of biofuels and increased access to fuel will compensate for higher food prices in more impoverished regions in particular. Increased costs for food will often contribute to better wages for producers, mostly in low-income groups, many of whom. However, as feed crops' advantages cannot be efficiently spread through society, the allocation of income between net producers and net buyers of farm commodities remains an analytical problem to be answered to recognize the ultimate effect on human well-being (Msangi, 2018).

Algae, particularly microalgae, provide a new biofuel potential, which appears not to have the same degree of negative development outcomes. Microalgae biodiesel is not actually competitive on fossil fuels, as it was for most biomass-based biofuels. However, this may be exacerbated by the relative infancy of manufacturing and processing technologies (Tu et al., 2018). In addition to the likelihood of technical changes that decrease production costs, biomass could also be diverted to other commodity production and increased financial profitability. However, limited studies have been carried out on allocating viable organic fuel to infer the feasibility of cultivating microalgae for biofuels.

The fact that microalgae are capital and resource-intensive is a further downside of production and transformation. Besides artificial ecosystems being designed and sustained, the facility requires significant electricity, water, and associated nutrients to generate adequate biomass (Fuhrman et al., 2020). Though waste materials can be recycled as processing inputs (Xu et al., 2018), high energy requirements mean that the various downstream processes may rely on fossil fuel energy in short to medium term (Zhu and Xu, 2020).

Despite these challenges, the favourable results of microalgae biofuels indicate possible social gains. Algae-based solutions solve resource competition problems, impacting both the costs of food and biodiversity and environmental benefits. Besides, these technologies may contribute to social resilience through employment and income generation, particularly for regional communities that historically depend on seasonal industries. Much has benefitted from the production of conventional biofuels from numerous policy initiatives. It entails measures such as tax exemptions, fuel excises (Korting et al., 2019) and incentives for development and infrastructure (Kraal et al., 2020); or indirect actions such as biofuels binding mandates and trade action to shelter domestic biofuel from the cheaper international supply (Al Mamun et al., 2018).

Implementing the economically productive price policy mechanisms would improve efficiency as an alternative to long-term and sustainable fossil fuels (Lee and Shih, 2011). Recognizing the relatively rapid increase in the land feed (e.g., in Brazil), producers and consumers react to these policies' incentives. But for conventional biofuels, the study has identified considerable economic costs, demonstrating that policy financing for the development of such industries is insufficient. While these policies can be expanded to include microalgae output, higher start-up costs and complexities further prevent investment in the sector rather than lower farm production costs. Seeking an opportunity strategy balance for the third generation's biofuels while ignoring the traditional policies and balancing the uncertainties associated with them is perhaps the most significant obstacle in terms of technical advances to justify these benefits and fuel viability. However, microalgae's ability to fulfill fuel requirements with more net external benefits than conventional biofuels must be investigated and evaluated.

9. Conclusion

This study aimed to analyze conventional synthetic fuels' economic challenges and highlight the essential economic advantages of microalgae biofuels compared to their traditional counterparts. The critical shortcomings for traditional biofuels were established, particularly in the debate between food and fuel, indicating that alternative feedstock needs to be created. Government action has been suggested on microalgae biofuels that meet long-term demands for renewable transport fuel, which would not raise society's social and environmental costs. This has a significant effect on the production and usage of conventional biofuels. The economic difficulties surrounding plant-based biofuels from first, second, and third-generation feedstock were discussed in this article. The limits of first and second-generation biofuels are highlighted in this paper, notably in the food against fuel issue. Microalgae have been discovered to overcome many of the flaws that plagued their predecessors, although high production and energy costs are significant drawbacks. The importance of policy involvement in the development and usage of conventional biofuels was underlined. As a result, based on the long-term requirement for a liquid fuel alternative that does not increase society's environmental and socioeconomic costs, this study proposes that economically efficient policy assistance for the development of microalgae biofuels is possibly required.

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Declaration of Competing Interest

I have no conflict of interest to report.

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