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Algae biofuel: Current status and future applications

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ABSTRACT

An algal feedstock or biomass may contain a very high oil fraction, and thus could be used for the production of advanced biofuels via different conversion processes. Its major advantage apart from its large oil fraction is the ability to convert almost all the energy from the feedstock into different varieties of useful products. In the research to displace fossil fuels, algae feedstock has emerged as a suitable candidate not only because of its renewable and sustainable features but also for its economic credibility based on the potential to match up with the global demand for transportation fuels. Cultivating this feedstock is very easy and could be developed with little or even no supervision, with the aid of wastewater not suitable for human consumption while absorbing CO_2 from the atmosphere. The overall potential for algae applications generally shows that this feedstock is still an untapped resource, and it could be of huge commercial benefits to the global economy at large because algae exist in millions compared to terrestrial plants. Algae applications are evident for everyday consumption via foods products, non-foods products, fuel, and energy. Biofuels derived from algae have no impact on the environment and the food supply unlike biofuels produced from crops. However, any cultivation method employed could control the operating cost and the technicalities involved, which will also influence the production rate and strain. The scope of this paper is to review the current status of algae as a potential feedstock with diverse benefit for the resolution of the global energy demand, and environmental pollution control of GHG.

1. Introduction

Algae biofuels are advanced renewable fuels derived from algal feedstock via different conversion processes, this is due to the oil-rich composition of this feedstock that can be associated with its ability to abundantly photosynthesize [1]. Algae are aquatic species with over 3000 different breeds and they have the fastest ability to reproduce, therefore more diverse than land plants [2]. They suck up CO_2 from the atmosphere and convert it to oxygen [3], and have great oil yield which is extracted by breaking down their cell structure [4]. The major advantage apart from their oil mass is the ability to convert almost all the feedstock's energy into different varieties of useful biofuels [2]. Other application includes wastewater treatment, production of energy co-generation (electricity or heat) even after the extraction of oil, CO_2 removal from industrial chimney gases (algae bio-fixation), bio-fertilizer, animal feeds, healthcare and food products. Algae exist in any imaginable environment and can withstand extreme temperature, irradiation, drought, and salinity. However, the environmental condition of a country will definitely influence their cultivation method. For example, marine and freshwater algae such as Cyanophyceae (blue-green algae), Chlorophyceae (green algae) and in some cases Pyrrophyceae (fire algae) could be cultivated naturally in the UK. While Phaeophyceae (brown algae) could be genetically modified along with artificial cultivation methods of photobioreactors (PBRs). Though lipidic algae such as Cyanophyceae, Chlorophyceae and Pyrrophyceae were recommended for the production of fatty acid methyl ester (FAME) [6–12], the Phaeophyceae, on the other hand, tends to be the most suitable algae feedstock for ethanol production due to its high sugar content [13,14].

In the research to displace fossil fuels, algae have emerged as a suitable candidate due to its renewable and sustainable features coupled with economic credibility to match up with the global demand for transportation fuels [2]. Though, algae biofuel conversion methods such as transesterification, fermentation, and hydrotreatment are more complex and economically expensive, when compared to fossil-derived fuels and even biofuels from other feedstocks. There is potential ground for optimism based on the sustainability of this feedstock [15] and greater likelihood of new applications and products due to its diversity. Therefore, from all the above positive algae features, it can be inferred that this feedstock is one of the world most valuable, sustainable, and renewable fuel resource which could also play a fundamental role in controlling environmental pollution [2].

CO_2 emissions from different fossil fuel sources have been a major threat to the environment. Though the global economy has in the past

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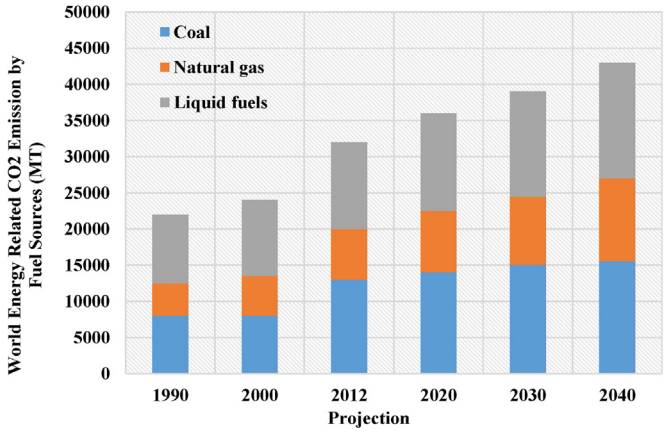

Fig. 1. Global energy-related CO_2 emission projection based on three different classifications of fuel sources [15].

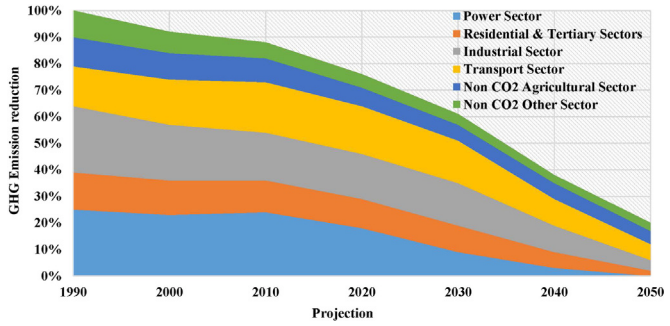

Fig. 2. EU GHG emission reduction projection [17].

Table 1
2030 framework for climate and energy [17].

Year	Greenhouse gas emissions	Renewable energy	Energy efficiency	Interconnection
2020	− 20%	20%	20%	10%
2030	≤ − 40%	≥ 27%	≥ 27%	15%

benefitted from fossil fuel, yet it contributes greatly to the CO_2 level in the atmosphere, which has led to global warming. In 2012, CO_2 emissions generated from the consumption of liquid fuels alone was 36% of global emissions and this has been a major concern to both fuel producers and engine manufacturers [20,21]. This has led to overall CO_2 emission projection to be doubled by the year 2035 [151] and might as well get up to 45,000 mega tonnes by the year 2040 [6] as indicated in Fig. 1. For this reason, the European Union Renewable Energy Directive (RED) recommends that 15% of energy delivered to the UK consumers by 2020 should be obtained from renewable resources [21]. This would mean 6% reduction of emissions from transport sector, 12% reduction from heating energy generation sector and 30% reduction from electrical energy generation sector. The European Renewable Energy Policy objectives were to drastically reduce greenhouse gas emission to 20% by the year 2050, with an initial reduction plan to the 60% mark due to major emissions from the power sector as illustrated in Fig. 2 [22]. Which led to the short-term targeted agreement for the reduction of GHG emissions for the year 2020 and 2030 [22] as indicated in Table 1.

Technology improvements in the exploration of crude oil have successfully reduced the production cost of fossil fuel over the years, though affecting biofuel growth [21]. However, the global concern for crude oil's sustainability and emission effects cannot be overruled. Another global challenge with fossil fuel is its biased and uneven allocation, which has resulted in some countries been threatened to run

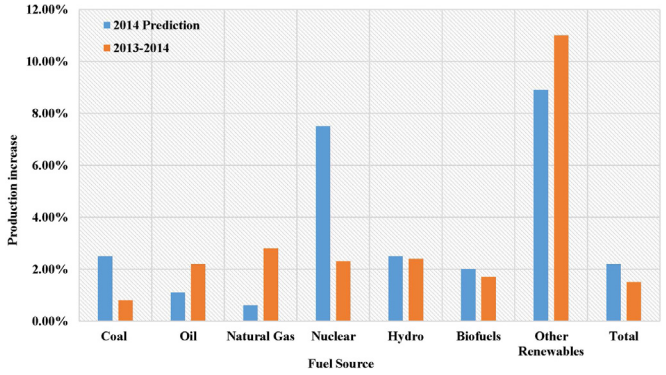

Fig. 3. Global increase in energy production by fuel sources [18].

out of petroleum reserves while others became wealthy and control the foreign exchange market because of their crude oil reserves [2]. The only viable solution to all these aforementioned challenges for both the global economy as well as the GHG emissions is a fuel produced from plant material.

Though other sources of renewable energy such as solar, wind and geothermal might not be as economically feasible as biofuels, these green energy sources still play a significant role in solving the problem of global warming. From the statistics in Fig. 3, constant growth in the global production of other renewable energy sources was reported but biofuel production was even behind its 2014 expectation [23]. These biofuels are products of different biodegradable and sustainable feedstock that can be converted liquid, gaseous and solid fuels by biological and thermochemical process [16]. And these feedstocks are capable of creating opportunities for agricultural development due to direct involvement with agricultural plants [2].

Major oil producing countries have shown great interest in biofuel and renewable energy by setting specific future goals and targets about the production as well as the applications. Countries like UAE have planned to run 10% of its transportation on biofuel by 2020 and USA has proposed to substitute 20% of its road transport fuel for biofuel by 2022 [24]. The role of legislation policies devised by the government to reduce or eliminate CO2 emissions from fossil fuel has buttressed the need for renewable fuel. The renewable transport fuel obligation statistics from the UK department of transport, recommends that every transport fuel supplier must make sure proportions of renewable source (biofuel) are present their products [25]. Inline to ensure that there is consistency in the renewable fuel proportional quality, a certificate called Renewable Transport Fuel Certificates (RTFC) will be awarded to the supplier that fulfills this requirements [25]. Global demand for this renewable fuel was also supported politically due to the global imbalance in the exploration of crude oil and uneven allocation, which affects energy security, rural development and climate change [26].

From 2021 car manufacturers will have to comply with the 95 g CO_2/km threshold, set by the EU in order to reduce CO_2 emissions from their fleet of new sold passenger cars, this means that biofuels will be one of their viable solutions [27]. With this in mind, the UK Sustainable Biodiesel Alliance (UKSBA) has recommended the implementation of a minimum price of 15p per litre for RTFCs in order to facilitate more market for biofuel producers [28]. The Renewable Energy Directive (RED) has also drafted a legislation to boost the production of advance biofuels like algae by 2020 [29]. Since the European Parliament have capped all food crop-based biofuel in order to support the production of biofuels from algae and other non-edible biomass [29].

Land availability with respect to the increase in biofuel demand has also contributed to GHG emissions, due to the current land mass carbon generation [30]. For this reason, biofuel from aquatic cultivated feedstock such as algae could be the solution [2], because they can be produced using non-arable land, brackish or non-potable water [4].

The major reason for biofuel is to displace fossil fuel in order to