



## Capabilities of Algae to Be Utilized As a Renewable Energy Source

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### Abstract

Algae are simple plants and most of them are aquatic and can grow in different water assets, for example, fresh water, salty water, and wastewater so they are considered as the more secure, non-focused and more effective plant. They have different pathways to fix dangerous gases such as Carbon Dioxide (CO<sub>2</sub>), Chlorofluorocarbons (CFCs) that causing climate change and converting sunlight, nitrogen and phosphorous into biomass. The objective of this article is to review the literature regarding the algae as biological alternative products and renewable energy source to throw light on a broad range of algae applications for provide some information on their related technology and industry that are financially feasible to counter balance in oil, and alleviate CO<sub>2</sub> discharge or not. Algae have been explored for different applications as food; bioactive substances due to their high development rates, sensible developmental densities and high oil contents all that have been referred to as motivations to turn algae into biofuels. However, there are various obstacles including the sourcing of these algae, strain isolation, nutrient source, production management, harvesting, coproduct improvement, fuel extraction, refining and lingering biomass use. The use of algae as fuel might seem of no importance today, but it can gain importance tomorrow as petroleum is getting depleting day after day. The International Energy Agency expects contribution of biofuels by 6% of aggregate fuel use by 2030, yet could extend essentially if undeveloped oil fields are not gotten to or if generous new fields are not distinguished.

**Keywords:** Algae; Strain isolation; Biological system; Bioethanol; Biodiesel; Biofuel prospects.

## 1. Introduction

Algae are simple plants that can run from the microscopic (microalgae) to huge seaweeds (macroalgae), for example, monster kelp more than one hundred feet long. Microalgae include both cyanobacteria (i.e., like-bacteria were previously called blue-green algae) as well as green, brown and red algae.

The significant heredities of the algae are the Chlorophyta (green algae), Rhodophyta (red algae), Glaucocystophyta, Euglenophyta, Chlorarachniophyta, Heterokonta, Haptophyta, Cryptophyta, and the dinoflagellates [1]. The algae, which can be characterized as photosynthetic eukaryotes/protists barring the land plants, have a dazing cluster of cell morphologies and life cycles as they inhabit a large number of habitats.

Most of the algal species are aquatic (live in water), autotrophs (i.e., produce their own food as they are photosynthetic, which can capture light energy and convert inorganic matter to organic matter), have non-vascular tissues and can use lipids and oils for floating in water [2]. As well as algae can be grown using different water assets, for example, salty water, and wastewater as potentially they can help in its treatment and purification, while profiting from utilizing the nutrients present [3], regarding their capacities to develop without much care on waste nutrients. Therefore, algae are currently turning into the primary source of biofuel production generation on the planet [4-6], as they are considered as the more secure, non-focused and more effective rowing life forms among those could be utilized and manipulated for biodiesel creation.

Algae are particularly interesting because they can be grown rapidly and produce large amounts of fuel relative to the resources used to grow them; does not compete with agriculture, with high yield per acre, contains no sulfur no SO<sub>2</sub> emission, besides do not require soil for growth [7-9]. As most microalgae grow through photosynthesis – by converting sunlight, Carbon Dioxide (CO<sub>2</sub>) and a few nutrients (nitrogen and phosphorous) into biomass [3, 10]. The high growth rates, sensible development densities, and high oil contents have all been referred to as motivations to invest significant capital to turn algae into fuels.

Microalgae generate/create various sorts of renewable biofuels such as biogas that formed by anaerobic digestion of the algal biomass [6]; biodiesel from microalgae oil [4, 5] and photobiological production of hydrogen [11, 12]. Algal biofuels were touted as the answer to these issues and attempted to hold their high profitability at a larger scale in spite of lots disadvantages and regardless of biofuel potential, i.e., Algae produce more O<sub>2</sub> and oils per unit biomass than terrestrial plants.

The objective of this article is to reveal the literature regarding the algae as biological alternative renewable energy source for biofuel generation, how algae develop, as a financially feasible stage to counterbalance oil, and thusly alleviate CO<sub>2</sub> discharge, as the review cover abroad range of questions that range from how and where to develop these industries.

## 2. Present and Potential Uses of Algae

Since from olden days, algae are intimately connected with human begins as a source for food. Algae have been part of the human diet for a long time, in view archaeological proof from 14,000 YBP in Chile [13] and early composed records (e.g., in China, 300 A.D.; in Ireland, 600 A.D.; [14]). In North America, the Tsimshian First Nations' people named the month of May for the season when they collected the essential food crop of *Pyropia Deveau* [15]. All the more contemporaneously, the worldwide harvest of seaweeds in 2013 was estimated by \$6.7 billion and more than 95 % was produced in mariculture, with China and Indonesia being the top producers [16].

Notwithstanding macroalgae, some microalgae are cultivated for foods and food additives [14, 17, 18]. The FAO [19] assessed that 38 % of the 23.8 million tons of seaweeds in the 2012 worldwide harvest was eaten by people in forms conspicuous to them as seaweeds (e.g., kelps, nori/laver), without counting the extra utilization and use of hydrocolloids (e.g., agar, alginates, carrageenans) that utilized as thickening in foods and refreshment.

In the field of health, food and pharmaceuticals medicines, algae can be utilized for making vitamins, vaccines, nutraceuticals, and other nutrients which when made utilizing animals or plants. As well as numerous kinds of algae and the products got from them have shown medicinal values and nutritional applications. There is a variety of pigments present in microalgae, which are associated with light incidence [20]. These include: Chlorophyll (the primary photosynthetic compound), Phycobiliproteins which improves the efficiency of light energy utilization, Carotenoids which protects algae against the solar radiations and their adverse effects, 1 $\beta$ -Carotene which is utilized as a vitamin A precursor, Lutein, Zeaxanthin and Canthaxanthin which are utilized in Chicken skin coloration and also for other pharmaceutical purposes and Astaxanthin which is utilized in aquaculture to provide fishes like salmon its natural red colour.

Algae have been used as a fertilizer in many parts of the world [21], and it has a high mineral content that helps to increase the water binding capacity in soil [22, 23]. It is capable of fixing atmospheric nitrogen and thus can be utilized to make biofertilizers [23]. Algae can be developed simultaneously with the other crops and furnish the crops with nitrogen, and when plants fertilized with algae it resists diseases and insects' attacks. Moreover, algae maintain and build up the soil fertility thus expanding the yield. It likewise improves the physio-chemical properties, helps in the slow development of nitrogen and carbon in the soil, and improves the pH and the electrical conductivity [23, 24].

## 3. Production of Biofuels from Different Crops

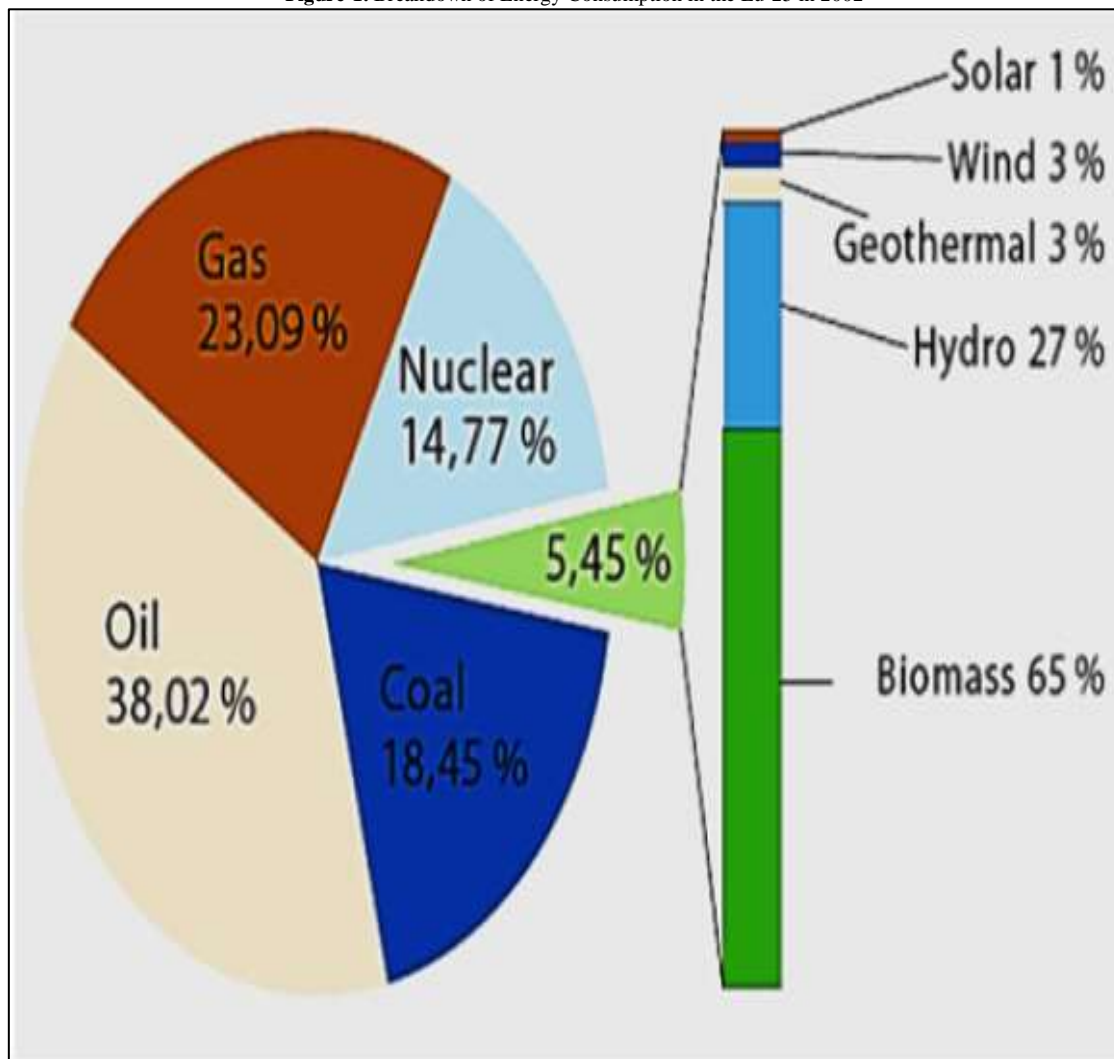
Biofuels, as demand for low carbon impacts are ignitable fuels created from algae biological material through biomass. The term biofuel is normally used to reference for example, ethanol, and biodiesel that are utilized as replacements for transportation fuels like petroleum, diesel, and jet fuel [25]. Biofuel mainly produced from agricultural crops that grown for food and animal purposes, such as wheat, sugar cane, oily seeds ...etc Hu, *et al.* [26]. Table (1) shows varieties of crop oils can be used to biofuel production, and algae yield is multiple times higher than other biofuel crop [27].

**Table-1.** Classified crops used to produce biodiesel with different quality and quantity

Crop	Oil yield (Gallons/acre)
Corn	18
Cotton	35
Soybean	48
Mustard seed	61
Sunflower	102
Rapeseed/canola	127
Jatropha	202
Oil palm	635
Algae (10g/m <sup>2</sup> /day at 50% TAG)	1200
Algae (10g/m <sup>2</sup> /day at 50% TAG)	10000

Source: Mata, *et al.* [27].

Biofuel produced from algae by different oil extractions methods, such as oil press method; hexane solvent method, supercritical fluid extraction; enzymatic extraction and ultrasonic assisted extraction. There are two primary kinds of biofuels- ethanol and biodiesel [28]. Ethanol is an alcohol formed by fermentation and can be used as its or added to other substances where biodiesel is created by extracting natural oils from its plants and seeds in a process called transesterification.

**Figure-1.** Breakdown of Energy Consumption in the Eu-25 in 2002

Source: Commission [29]

Approximately one billion gallons of biodiesel is produced every year, and bioethanol has an annual production of about 22 billion gallons, but with the increasing production of heavy and medium machinery, and the increased human needs associated with decreasing fossil fuels, we need to increase the production of biofuels and work to find other types of fuel, economic and clean [27].

The United States announced a 15-year plan to produce 150 billion liters of ethanol by using wheat, some plants and timber [30]. Followed by Brazil, which relies on sugar cane and produces 36 per cent of the world's total production. France, Spain and Germany rely on ethanol to produce wheat, while biodiesel production [31, 32], America and Brazil produce soybeans and EU rapeseed (Figure 1).

#### 4. Production of Biofuels from Different Microalgae Strains

The use of vegetable oil as fuel might seem of no importance today, but it can gain importance in the course of time compared with today petroleum is getting depleting day after day. Therefore, it so important to explore the potential of getting oil from algae as many investigators have quantified the microalgae involved in energy (biodiesel) production [5, 26] beside others that were presented in Table (2).

Depending on species, microalgae produce a wide range of sorts of lipids, hydrocarbons and other complex oils [4, 33, 34]. In general, numerous algae species have the oil content going from 20 to 50 % by dry weight of biomass, and in some of them have oil content up to 80 % [26]. The yield of the oil delivered by algae is significantly higher (100000 L/ha) in contrast with different crops, for instance soybean (446 L/ha), sunflower (952 L/ha), rapeseed (1200 L/ha), castor (1413 L/ha), coconut (2689 L/ha) and palm (5950 L/ha).

Table-2. Lipid content and biomass productivity potential in reported microalgae species

Microalgae Species	Lipid Content (% dry wt. biomass)	Lipid Productivity dry wt. (g l <sup>-1</sup> day <sup>-1</sup> )	References
<i>Amphora sp.</i> (Persian gulf)	24	0.16	Talebi, <i>et al.</i> [35]
<i>Ankistrodesmus sp.</i>	24.0-31.0	0.09	Mata, <i>et al.</i> [27]
<i>Botryococcus braunii</i>	25.0-75.0	0.18	Talebi, <i>et al.</i> [35]
<i>Chlorella emersonii</i>	25.0-63.0	0.29	Talebi, <i>et al.</i> [35]
<i>Chlorella salina</i>	25.0-63.0	0.17	Talebi, <i>et al.</i> [35]
<i>Chlorella sorokiniana</i>	19.0-22.0	0.27	Ngangkham, <i>et al.</i> [36]
<i>Chlorella vulgaris</i>	5.0-58.0	0.46	Talebi, <i>et al.</i> [35]
<i>Chlorella vulgaris</i>	5.0-58.0	0.015	Song, <i>et al.</i> [37]
<i>Chlorella pyrenoidosa</i>	5.0-58.0	0.25	Song, <i>et al.</i> [37]
<i>Chlorella protothecoides</i>	14.6-57.8	2-7.70	Mata, <i>et al.</i> [27]
<i>Chlorella pyrenoidosa</i>	2.0	2.90-3.64	Mata, <i>et al.</i> [27]
<i>Chlorella pyrenoidosa</i>	2.0	0.05	Nautiyal, <i>et al.</i> [38]
<i>Cryptocodinium cohnii</i>	20.0-51.1	10	Mata, <i>et al.</i> [27]
<i>Dunaliella sp.</i> (Persian gulf)	16.7-71.0	0.12	Talebi, <i>et al.</i> [35]
<i>Dunaliella salina</i> (shariati)	23-25	0.05	Talebi, <i>et al.</i> [35]
<i>Dunaliella salina</i> (UTEX)	23-25	0.15	Talebi, <i>et al.</i> [35]
<i>Dunaliella primolecta</i>	23.1	0.09	Talebi, <i>et al.</i> [35]
<i>Haematococcus pluvialis</i>	25.0	0.06	Talebi, <i>et al.</i> [35]
<i>Isochrysis sphacrica</i>	7.1-33.0	0.017	Song, <i>et al.</i> [37]
<i>Lyngbya kuetzingii</i>	ND*	0.016	Song, <i>et al.</i> [37]
<i>M. pussilum</i> YSW08	24	0.11	Abou-Shanab, <i>et al.</i> [39]
<i>Monodus subterraneus</i>	16.0	0.19	Mata, <i>et al.</i> [27]
<i>M. afer</i> PKUAC	ND*	9 0.09	Guo, <i>et al.</i> [25]
<i>Pavlova salina</i>	30	0.16	Mata, <i>et al.</i> [27]
<i>Pavlova lutheri</i>	35.5	0.003-1.9	Mata, <i>et al.</i> [27]
<i>Pavlova salina</i>	30	0.16	Mata, <i>et al.</i> [27]
+ <i>Phaeodactylum tricorutum</i>	18.0-57.0	0.14	Mata, <i>et al.</i> [27]
<i>P. tricorutum</i>	18.0-57.0	0.017	Song, <i>et al.</i> [37]
<i>Porphyridium cruentum</i>	9.0-18.8/60.7	0.36-1.50	Mata, <i>et al.</i> [27]
<i>Scenedesmus sp.</i>	13.3-31.8	0.10	Talebi, <i>et al.</i> [35]
<i>Scenedesmus sp.</i>	19.6-21.1	0.06	Guldhe, <i>et al.</i> [21]
<i>Scenedesmus obliquus</i>	11.0-55.0	0.004-0.74	Mata, <i>et al.</i> [27]
<i>Scenedesmus obliquus</i>	11.0-55.0	0.014	Song, <i>et al.</i> [37]
<i>S. abundans</i> PKUAC 12	11.0-55.0	0.11	Guo, <i>et al.</i> [25]
<i>S. obliquus</i> YSR01	11.0-55.0	0.08	Abou-Shanab, <i>et al.</i> [39]
<i>S. obliquus</i> YSR04	11.0-55.0	0.094	Abou-Shanab, <i>et al.</i> [39]
<i>S. obliquus</i> YSR05	11.0-55.0	0.083	Abou-Shanab, <i>et al.</i> [39]
<i>S. obliquus</i> YSW06	11.0-55.0	0.086	Abou-Shanab, <i>et al.</i> [39]
<i>Skeletonema sp.</i>	13-51	0.09	Mata, <i>et al.</i> [27]
<i>Thalassiosira pseudonana</i>	20.6	0.08	Mata, <i>et al.</i> [27]
<i>Tetraselmis suecica</i>	8.5-23.0	0.12-0.32	Mata, <i>et al.</i> [27]

\*ND= Not determined

Microalgae are fit to yield 15-300 times extra oil for biodiesel generation than land abiding harvests per acre basis Maceiras, *et al.* [32]. Besides, the harvest plants procured once or two times each year through microalgae have short gathering cycle (1-10 days subject to the process), permitting several or continuous harvests with considerably bigger yields. Along these lines, for a similar amount of biodiesel delivered, microalgae would require just 23% of the land-utilized crops, when contrasted with 61% if palm plantations, a standout amongst the most beneficial oil delivering crops, were to be used [10, 40]. Isolation of microalgae strains bearing huge oil substance will help to tend to these issues [41].

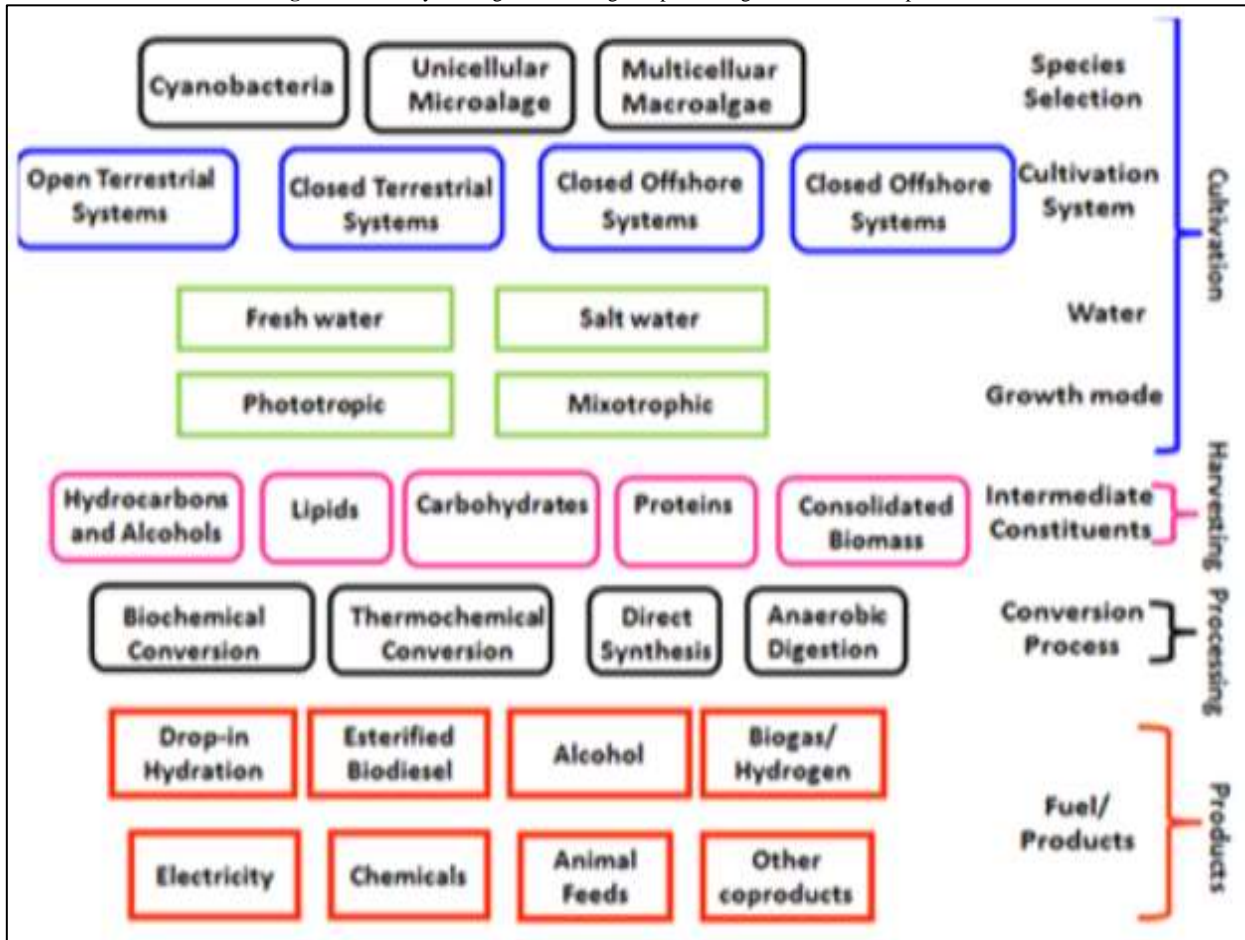
## 5. Production Pathways for Algae-Based Biofuels

Pathways for creating fluid biofuels share numerous regular highlights regardless of the biomass feedstock being utilized, as all have a cultivation step, a collection or harvest step, and a processing or finishing step (Figure 2). Each line of the diagram details a processing step or process option, with potential variation in each step.

Oil-producing crops, such as soybean, jatropha, and camelina, are harvested and the oil is separated for subsequent processing. Sugar in sugarcane and starch in corn grain can be changed over effectively to ethanol by yeast and bacteria. Devoted energy crops, for example, poplar, switchgrass, and Miscanthus are chosen in light of their development with a low contribution of nutrients or their capacity to store carbon in soil [42-44]. The lignocellulosic biomass can be changed over chemically, thermochemical, or biologically to fluid fuels [45].

Patterns observed in the science and technologies for other biofuel production and generation are probably going to happen in algal biofuel creation as the last creates as an industry. An extra pattern is a move toward drop-in fuels that are compatible with existing infrastructure for petroleum-based fuels. Ethanol and fatty-acid methyl esters (FAME; or generally called biodiesel) have similarity and performance issues in vehicles that hamper their reception [42, 45].

Figure-2. Pathways for algae cultivating and processing to fuels and their products

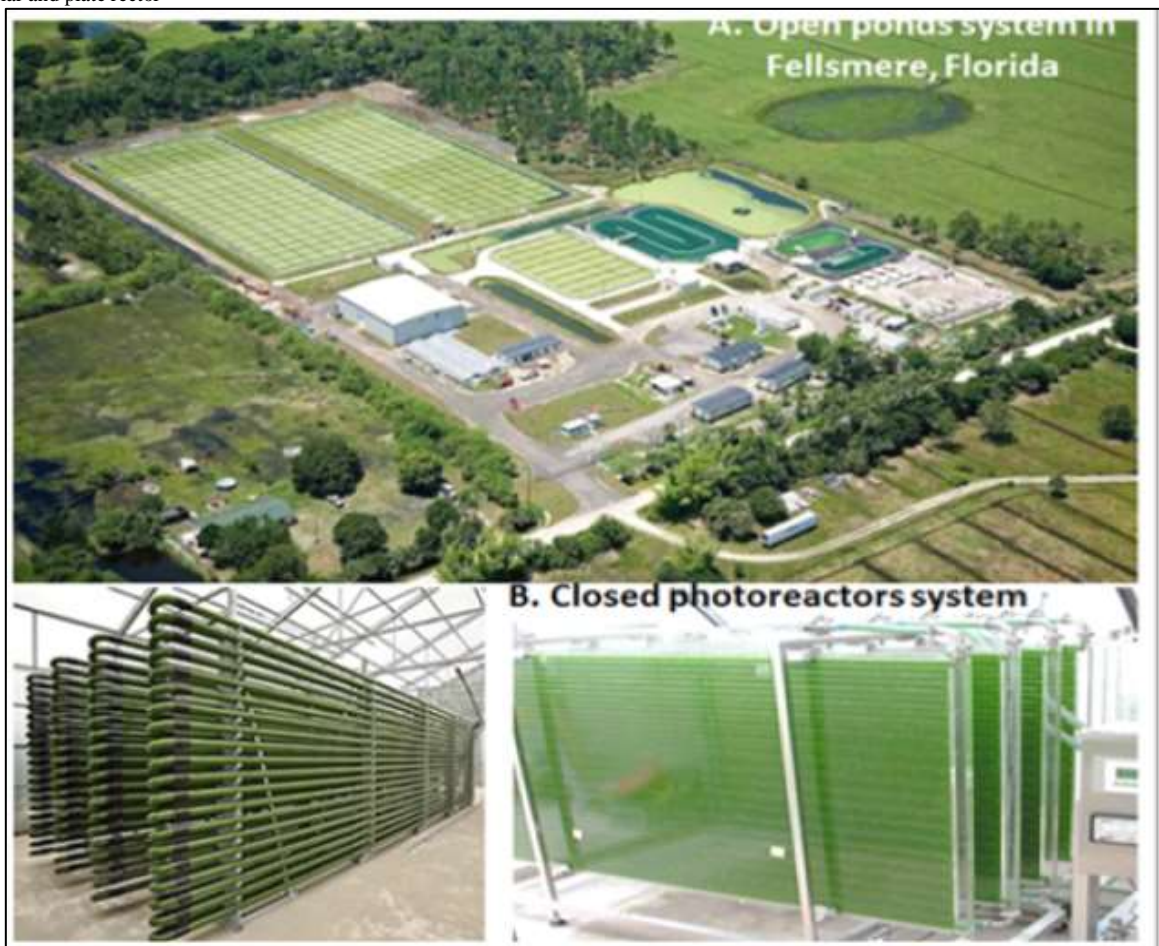


## 5.1. Production Comprises of Four Essential Processes

### 5.1.1. Algae Cultivation

Algae production system can be organized into two systems: open ponds system and closed photoreactors system which allows more precise control over growth conditions and resource management (Figure 3). Then after either sessile growth of algae or the biofilm one, it will attach to a surface, regarding its growth mode [46].

**Figure-3.** Algae production system A. Open ponds system B. closed photoreactors system and the photoreactors have two basic design plate tubular and plate reactor



Source: <https://commons.wikimedia.org/w/index.php?curid=25767678> [47]

### 5.1.2. Pathways for Biomass Harvesting

Cultivation yields natural algal biomass, which comprises of algal cells suspended in the culture medium [47]. Before algal cells can be separated into oil and residues for fuel and coproduct production, the raw biomass must be harvested from the culture medium. Harvesting comprises of biomass recovery, which expels wet biomass from the cultivation system, and is frequently combined with stopping and drying processes [48].

There are a few methods for recouping algal biomass, the execution of which may change contingent upon the cultivation system. Commonly used techniques include flocculation, dissolved air flotation, centrifugation, microfiltration, and decantation [47]. Recuperation systems require the chemical or mechanical manipulation of the culture medium that ultimately separates the biomass (product) from the process wastewater (output).

Dewatering and drying decline the moisture content of the biomass to an adequate level for the desired downstream conversion pathway(s). Dewatering diminishes the moisture content of the biomass depleting or mechanical methods. Drying proceeds have been utilized by a drum dryer, freeze dryer, spray dryer, and rotary dryer, or by solar drying [49].

Harvesting technologies in terms of recuperation, dewatering, and drying—and several environmental benefits, concerns, and obscure effects are distinguished. At scale, some of these drying systems are exceptionally energy intensive and can influence the energy balance of creation [48].

### 5.1.3. Pathways for Algal Oil Extraction

In the oil extraction process, harvested biomass experiences chemical or mechanical control to isolate the algal oil from the cell membrane (R). Triglycerides found in the algal cells are the primary product looked for with the end goal of biodiesel generation. The rest components of algal biomass carbohydrates, proteins, nutrients, and ash alluded to overall as algal buildup.

Algal oil extraction can be accomplished through various methods, for example, expulsion, solvent extraction, or supercritical fluid extraction [50].

The criteria for maintainable oil extraction ought to consider energy sources and potential ecological toxicity and security worries of chemical solvents, which have properties known to hurt biological systems. A few effects may have been unexpectedly disregarded in view of the restricted accessibility of data about chemical and energy inputs to algal oil extraction methods.

### 5.1.4. Pathways for Oil and Residue Transformation

Algal biomass that experiences oil extraction yields and buildup, whereas biomass that is pretreated thermochemically yields bio-oil and buildup. The two oils, algal oil, and bio-oil, are chemically distinct and should in this manner be refined or “upgraded” under various conditions.

Oil and residue conversion pathways include transesterification, fermentation, anaerobic digestion, gasification, pyrolysis, liquefaction, and hydro processing [48]. These conversion processes are not unique to algal biomass and have been utilized for use in conventional biofuel refining for some time. Nevertheless, a few environmental benefits, concerns, and unknown impacts can be identified. Some conversion processes are particularly energy intensive and output low-value coproducts or byproducts with certain or potential environmental impacts [48]. The criteria for sustainable change ought to consider potential energy demand also, assortment and ease of use of nonfuel products [42].

## 6. Environmental and Ethical Restrictions for Algae

The exploitation of land for energy crops and the conversion of agricultural crops producing food crops for human or animal consumption into biofuel fields is causing problems in global agricultural diversity, deforestation and natural reserves, increasing soil erosion and consuming large amounts of water. Some studies estimate that the production of one litre of biofuel needs 5,000 liters of water, and that the production of 13 litres of ethanol needs - for example - 231 kg of maize [51].

Biofuels cause high levels of water and air pollution which resulted from the large amounts of agricultural pesticides and fertilizers required by energy crops, and will affect soil quality and soil degradation [1].

Ethical restrictions are the most important constraints in the light of the declaration by some developing countries not involved in fuel production to condemn them in international forums for their production of agricultural products, because of the conversion of human food to food for the machine while many countries suffer food crises and reached the extent of famine [1].

Different limitations incorporate oil discoveries in various parts of the world, particularly in the Middle East, which play an important role in rearranging the present energy system and shaping it towards reconsidering strategies to grow or quicken the generation of biofuels and energy alternatives in general. In addition to the stability of oil costs, this will decrease the competitiveness of biofuels and debilitate the patterns of quickening and expansion of production.

## 7. Conclusions

The development of industry, agriculture and transport sector is associated with the use of various energy sources such as biodiesel, biogases and electricity towards sustainable production and use of different resources .

Life-cycle analysis on biodiesel production from microalgae: water footprint and nutrients balance, beside superior technology associated with was so promising as by 2050, biofuels could cut emissions by 1.7 billion tons a year, or more than 80 percent of current emissions from transportation.

The cycle of production and use of this fuel reduces the overall emissions by approximately 80 per cent of carbon dioxide emissions and almost 100 per cent of sulfur dioxide emissions. It also leads to significant reductions in the toxic carbon monoxide emissions ratio compared to the oil produced, and reduces the risk of cancer for other fuels to 90 percent. Furthermore, biodiesel contains 11 percent oxygen and does not contain any sulfur content; it has more lubrication than oil; is safe from the point of control and transport and the technology has proven successful, using 30 million miles of vehicles in the United States alone.

For production and high growth rates, identification of suitable algal species is required. The development of algae needs appropriate conditions, and work on their developments that shape substantial improvements in their productions as it faced by some challenges that need scientific prospects. However, producing algal biodiesel requires large-scale cultivation and harvesting systems, with challenging of reducing cost per unit area. More advancement in genetically engineering species growth is required to produce required amounts of biodiesel in short time and less energy utilization. Furthermore, the algal growth conditions need to be carefully controlled for the sequential processes and application for CO<sub>2</sub> from the flue gas emissions with wastewater remediation processes. Also light, nutrients, temperature, CO<sub>2</sub> and O<sub>2</sub> need to be adjusted for biomass yield production.

Therefore, technical experience and technological development are also required for micro algae production b using cheap sources of CO<sub>2</sub> for culture enrichment, using of wastewaters, use of economic design for increasing algal yields that will reduce waste emissions and increase the application of algal biomass for different markets and industry.

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