International Journal of Engineering and Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 12 Issue 9 September 2023 || PP 14-24

Algal Biofuels: Biotechnological Approaches and Potential For Carbon Neutral Energy

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ABSTRACT*: Global technology is continually moving toward net zero carbon emissions. The term "carbon neutral energy" refers to the process of neutralizing carbon emissions from the production of electricity or other sources so that there are finally no emissions at all. In order to do this, a variety of biotechnology-related technologies can be used. More energy can be produced through the use of algal biofuel than through the incorporation of terrestrial crops. It is so because algae need the carbon dioxide produced for photosynthesis. Consequently, the paper's evaluation of algae biofuels in the context of carbon-neutral energy optimization.*
KEYWORDS- *algal biofuels, carbon neutral energy, zero carbon emission, evaluation and optimization, zero carbon optimization.*

Date of Submission: 05-09-2023 Date of Acceptance: 16-09-2023

I. INTRODUCTION

1.1 Background

Net zero carbon emission is an ongoing global technological advancement. ***Carbon neutral*** energy is referred to as the neutralization of the carbon produced by electricity generation or other applications which ultimately results in net zero emission of carbon [1]. There are different technologies of biotechnologies that can be applied to achieve such an aim. The application of algae biofuel allows for yielding more energy than the integration of land crops. It is because the algae utilize the produced carbon dioxide for photosynthesis. Therefore, the paper is comprised of an evaluation of the ***algal biofuels*** in ***carbon-neutral energy*** optimization [2].

1.2 Problem statement

Severe effects on the climate are caused due to emission of carbon and other greenhouse gases. The deployment of effective technology to attain such a goal of zero carbon emission is comprised of several plans and techniques [3]. Other biofuel technologies such as the utilization of land crops are not carbon neutral and impact the environment negatively. Such technologies are not effective in zero carbon optimization, thus evaluation and optimization of algae biofuel are effective in the production of carbon-neutral energy [4].

1.3 Aim and Objectives

Aim

The main aim of the paper is to evaluate the significance of ***algae biofuels*** in terms of ***carbon-neutral energy***.

Objectives

Attainment of the aim is comprised of different objectives of the research as followers:

- To evaluate the significance of algae biofuel in carbon-neutral energy.
- To optimize the challenges and benefits of the algae biofuel.
- To understand the application of such biochemical technology.
- To conclude all the potential terms were evaluated from the entire research.

1.4 Research question

The research questions are as followers:

- What is the significance of algae as a biofuel in the optimization of carbon-neutral energy?
- What are the major challenges and benefits of deployment of the algae biofuel?
- What are the major applications of algae biofuel technology?
- What are the potential terms that can be concluded for further evaluation and optimization?

1.5 Rationale

Achievement of ***carbon reduction*** caused by fuel combustion is the major aim of the recent world. Most of the biotechnological approach optimizes different advanced technologies to obtain an exceptional outcome for the applications of energy support. Thus the evaluation of this biofuel, algae is justified for the research.

II. LITERATURE REVIEW

2.1 Introduction

This section is comprised of all the optimized factors from different research papers and literature to understand the basic concept and the scope of this research. Evaluation of the characteristics of the algae in terms of carbon-neutral energy production is the major purpose of this section [5]. Additionally, there are several limitations to such biotechnological applications that must be measured before their application, which will be discussed in this section. Significant analysis of the research gap allows the initiation of the research which has also been discussed. Also, justification of the optimization of major factors from the research papers also has been structured to satisfy the objectives [6].

[56, 57] Nikul K Patel et al. [58] SK Singh et al. also includes non- edible seeds and cotton waste for biofuel energy based on which the current study of algal biofuel to be performed. Further the biofuel study are to be involved in hybrid systems such as heat exchanger [60, 61, 62, 63] Anand Patel et al, cooling tower [64] Patel, Anand and solar air and solar water heater [65, 66, 67, 68, 69, 70, 71, 72].

2.2 Algal Biofuels Challenges and Opportunities

Algal oil or algal biofuels has been an alternative to liquid fossil fuels, that is uses algae and it has been a source of energy-rich oils. Hence it has been containing various challenges and opportunities, this has been discussed here [7]. Those challenges and opportunities are-

Challenges:

Cost:

According to the data producing algal biofuels are expensive than traditional fossil fuels or oils. The high production and extraction costs make it less economically viable [8].

Scale-up:

Scaling up the algal biofuel production has been meeting global energy demands, hence it is a crucial challenge. Producing biofuels has been needing advanced technology and their development stool in the early stages of the development process [9].

Figure 2.2.1: Challenge of production of biofuel from algae

Efficiency:

According to the data this algal has been containing the liquid component, which is known as the basic source of biofuels. It helps to increase the lipid element and help to improve the conversion efficiency of algae into biofuels are ongoing challenges [10].

Water and nutrient requirements:

Algae needs the proper amount of water and nutrients to grow, hence meeting all qualities of sustainability without competing with other water and land uses is a challenge [11].

Environmental impact:
Large-scale legal biofuel production can have environmental impacts, like nutrient runoff, water pollution, and habitat destruction. Making sure sustainable production practices and minimizing environmental harm are crucial [12].

Opportunities:

Renewable energy sources:
According to the data, algal biofuels offer a renewable alternative to fossil fuels, and they deduct greenhouse gas emissions and dependence on finite resources.

High productivity:
Algal can convert the sunlight to ***"carbon dioxide"*** into biomass which also makes them one of the fastest-growing plants on the earth. This high productivity potential makes them a promising source of biofuels [13].

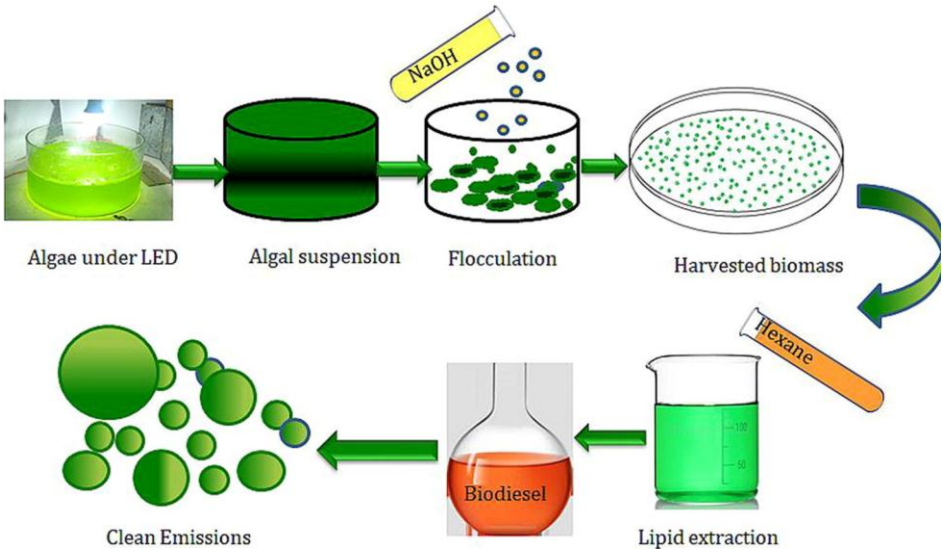

Figure 2.2.2: Algal biofuel opportunities

Carbon capture:
Algae can absorb a large amount of ***"carbon dioxide"*** during their growth, and it has been helping to mitigate climate change and capture and store carbon [14].

Co-products:
Algae have been used to make useful products like animal feed, fertilizers, and various chemicals. This diversification of products can help offset the costs of biofuel production.

Job creation:
The development and commercialization of algal biofuels can create new job opportunities in the research, cultivation, processing, and distribution sectors [15].

Algal biofuel has been creating various challenges, on the other side they also have to contain various crucial opportunities and also contain renewable energy production. It also provides continued research and various technical advancements and these also contain the supportive policies that are crucial to realize the full potential of algal biofuels [16].

2.3 Optimization of photosynthesis for algal biofuel production

The search for energy sources that are environmentally friendly has accelerated significantly in light of rising energy demands and intensifying worries over climate change. Due to the possibility of high lipid content and quick growth rates, algal biofuels made from photosynthetic microorganisms like microalgae present a possible option. Optimizing these microorganisms' photosynthetic productivity is essential if algal fermentation into biofuel is to reach its full potential [17]. In order to increase the generation of algal biofuel, this article explores tactics and developments in photosynthesis optimization [18].

Photosynthesis and Algal Biofuels
The essential mechanism of photosynthesis is the conversion of sunlight into chemicals that are rich in energy through the absorption of atmospheric carbon dioxide (CO2). As single-celled photosynthetic organisms, microalgae have a special capacity to fix CO2 and collect lipids that can be used to make biodiesel [19].

However, a number of elements, including as an accessibility of light, CO2 content, nutrition availability, and cellular development dynamics, limit the efficacy of this process.

Optimizing Light Utilization

In order for photosynthesis to take place, light is essential. Researchers are concentrating on two important issues improving light absorption and limiting sunlight saturation in order to improve light use. To absorb light energy, microalgae rely on pigments including carotenoids, chlorophyll and phycobiliproteins [20]. Genetic manipulation and selective breeding are two methods used to increase pigment expression and increase the range of light frequencies that might be absorbed in order to maximize light absorption. These techniques enable microalgae to more effectively catch light energy [21]. Innovative cultivation technologies have been created to solve the issue of light saturation, which can result in excessive energy loss and severe cell damage. With advanced light distribution systems, photo bioreactors guarantee uniform light exposure throughout the culture, preventing localized oversaturation and enhancing overall photosynthesis [22].

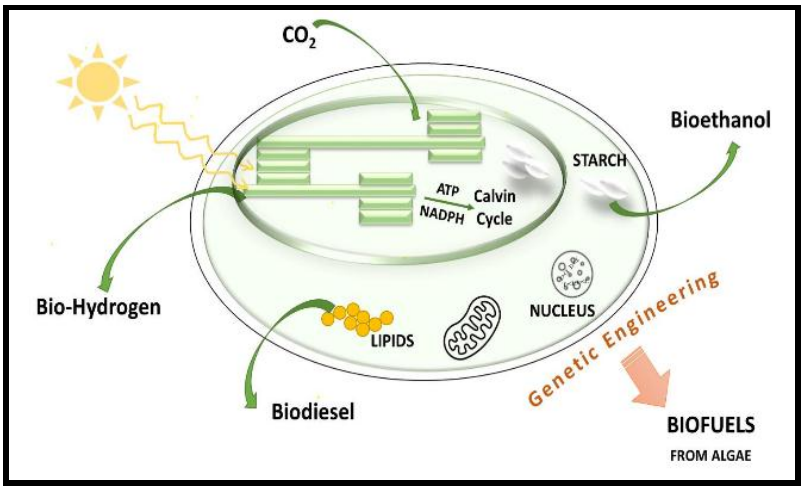

Figure 2.3.1: Using Algae for Biofuel Production

Enhancing CO2 Availability and Nutrient Management

One of the most important substrates for photosynthesis is carbon dioxide (CO2). The profitability of algal cultures can be greatly increased by increasing CO2 availability. Utilizing industrial emissions, such as flue gases, as an important source of CO2, is one strategy. Additionally, cutting-edge culture methods, such as the utilization of carbon capture equipment and CO2-concentrating mechanisms, make it possible to deliver CO2 to microalgae effectively [23]. This increased CO2 availability causes a rise in photosynthetic rates and a rise in the accumulation of lipids. To promote algae development and increase output, efficient fertilizer management is crucial. Among the essential nutrients, both phosphorus and nitrogen are crucial in promoting the development of both biomass and lipids [24]. A surplus of nutrients, however, may cause uncontrolled development and a drop in lipid content. Researchers have developed ways for controlled nutrition feeding, like nitrogen constraints, which promote the buildup of lipids in microalgae. Additionally, reusing wastewater nutrients for algae production offers a sustainable and affordable way to obtain nutrients while simultaneously reducing environmental contamination. Microalgae may experience an increased buildup of lipids in reactions to mild stress situations [25]. Microalgae focus their energy on lipid production in response to circumstances like nutrition shortage, exposure to intense light, and temperature fluctuations. Techniques for genetic alteration are being investigated in order to activate associated stress pathways without endangering cell viability, effectively increasing lipid synthesis. Continuous tracking and data analysis are required for the optimization of the production of algae-based biofuels [26]. Continuous monitoring of environmental conditions and biological reactions is made possible by sensor technologies in conjunction with data analysis and learning algorithms. With the help of this data-driven methodology, researchers are able to modify growth conditions as needed, enabling microalgae to perform at their peak photosynthetic potential [27].

2.4 Enhancing the productivity of marine algae

Seaweeds, commonly referred to as marine algae, are an essential component of marine ecosystems and have a wide range of potential uses, including food and feed, biofuels, and pharmaceuticals. Enhancing the growth rate of marine algae is becoming more and more important as the globe deals with mounting environmental issues and rising resource demands [28]. This article examines the methods and developments intended to raise these amazing creatures' output and unlock their enormous potential. Polysaccharides,

nutritional components, and bioactive substances are all abundant in marine algae. They sculpt maritime environments and sustain a variety of marine life, making major contributions to the global generation of oxygen and carbon fixation. Additionally, seaweeds are a focus of research focused on enhancing their productivity because of the enormous promise they represent for a variety of businesses [29]. Creating efficient cultivation methods is one of the main obstacles to increasing marine algae yield. Wild harvesting is a common practice in conventional ways, which may be unsustainable and harmful to marine ecosystems [30].

Integrated Multi-Trophic Aquaculture (IMTA): IMTA entails raising many species in a single habitat while making use of waste reduction and nutrient recycling that naturally take place. In this system, surplus nutrients generated by fish or shellfish are absorbed by seaweeds, reducing negative environmental effects and increasing algae output [31].

Open Ocean culture: In open ocean culture, seaweed farms are situated offshore, where full of nutrients upwelling's encourage growth. These areas provide a bigger growth area, reducing competition and enabling the production of significant amounts of seaweed. This method has the ability to greatly increase the scale of algae production [32].

Engineering of the Substrate and Habitat: Improvements in attachment as well as the development of marine algae have been made possible by new substrate components and habitat designs. Increased yield can be attained by using engineered substrates that increase attachment rates, encourage nutrient flow, and offer a stable environment for the growth of algae [55].

Photobioreactors: These devices provide an environment of control that optimizes temperature, light exposure, and nutrient availability [33]. Using this technique, scientists can alter the growing environment, boosting productivity and producing particular molecules.

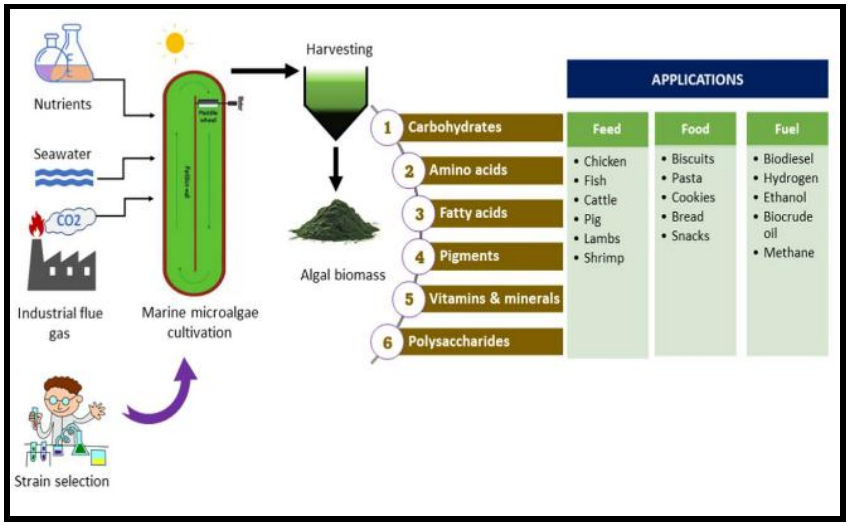

Figure 2.4.1: Potential of the Marine Microalgae

Genetic Engineering and Strain Selection: Genetic engineering and strain selection are essential for increasing the production of marine algae.

1. Strain selection: It's crucial to select strains with desired development traits that perform well. Algae strains with quicker growth rates, better intake of nutrients efficiency, and enhanced resilience to external stressors can be produced by selective breeding [34].
2. Genetic engineering: Methods for genetic manipulation allow the addition or improvement of particular features in marine algae. Scientists are looking into ways to boost lipid content, boost utilization of nutrients, and boost resistance to illnesses and changes in the environment [35].

For sustainable resource use, increasing marine algal productivity has enormous potential. Researchers are at the cutting edge of investigating methods to increase the productivity of marine algae, from novel culture techniques to genetic engineering and nutrient control [36]. These initiatives not only open the way for a sustainable source of nourishment, animal feed, and biofuels but also improve the health of the environment and help to slow down global warming. The potential advantages of marine algae are likely to be fully realized, making these organisms important contributors to a future that is healthier as study advances [37].

2.5 Linkage to Aim

Due to their extraordinary capacity to trap carbon dioxide (CO2) throughout their growth phase, algae biofuels present a distinctive route towards fossil-neutral energy. Algae may absorb atmospheric CO2 and transform it

into biomass through this photosynthesis process, lowering their overall carbon footprint. The purpose of this research is to highlight the potential of algal biofuels to reduce carbon emissions by examining the complex mechanisms underlying this carbon sequestration and later transformation into molecules that are high in energy [54]. The importance of algae biofuels is assessed beyond their capacity to sequester carbon. The full process of producing biofuel, including its planting, harvesting, and conversion into useful energy, will be covered in this essay. This thorough examination will demonstrate the biofuels' carbon neutrality as well as the effectiveness of every phase of production. This study intends to make a strong argument for the incorporation of algal biofuels into the worldwide energy landscape by demonstrating the connection between the carbon-neutral characteristics of algae biofuels and their capacity to reduce environmental challenges [14]. This research ultimately aims to provide a thorough evaluation of algal biofuels' significance as an environmentally friendly source of energy through a detailed analysis of their carbon-neutral potential. The objective is to demonstrate how algal biofuels may play a crucial part in reaching carbon neutrality and accelerating the switch to a more sustainable energy future by illuminating the complex interplay between carbon storage, the efficiency of production, and environmental advantages [15].

2.6 Literature gap

There is a glaring absence in the literature on a thorough evaluation of the scalability and financial sustainability of algal biofuels, considering the growing interest in these kinds of fuels as a source of energy that is carbon-neutral [53]. Few studies have examined the difficulties involved in broad adoption and the related economic issues, despite the fact that many have concentrated on the technological elements of algae growing, lipid removal, and manufacturing of biofuel. Additionally, little research has examined the possible environmental costs and benefits of significant algae farming, including the effects on biodiversity, water supplies, and land usage. Studies that combine interdisciplinary methods and take into account socioeconomic status, policy, and regulatory factors in addition to scientific and engineering ones are also rare [16].

2.7 Summary

In this essay, the importance of algal biofuels in reaching carbon-neutral energy is assessed. Algae's capacity to store carbon dioxide while they are growing offers hope for lowering carbon emissions. The study highlights both environmentally friendly qualities as well as manufacturing efficiency while examining the full biofuel production process, including growing, harvesting, and translation into electricity. A thorough understanding of the scalability, commercial viability, and probable adverse environmental effects of large-scale algae production is nonetheless lacking in the literature. For a comprehensive grasp of algal biofuels' potential, this knowledge gap must be closed. In order to effectively incorporate algal biofuels in the shift to a sustainable energy future, the study underlines the need for multidisciplinary methods that integrate technological, socioeconomic status, and policy factors.

III. METHODOLOGY

3.1 Introduction

The study has been providing essential information about ***"Algal biomass"***, based on this researchers are providing various studies on the topic. Hence it also describes the crucial data which contains the different research approaches and also provides the specific strategy of the research. According to the data, in literature review section has been containing various crucial data and it also describes the challenges and opportunities of algal biofuels, hence it also describes the optimization process of algal biofuel production. It also helps to enhance the productivity of marine algae, and based on that research has been processing their research. Hence they also describe the process of the research which is described in the method section. The research has been containing the specific aim that determining the significance of the algae biofuels based on the term of carbon neutral energy.

3.2 Research approach

The reverse approach has been categorized into two parts ***"the inductive research approach"*** and ***"the deductive research approach"***. Hence for the research approach of the study, the researcher has used the ***"inductive research approach"***. According to the data, the inductive research approach has been processed using the researcher developing the various theories, which are based on the study and appropriate data [38]. This research process has been started with the data collection process and the data collection process has been helped to identify the pattern of research and also provide the various crucial information regarding the research. The main prospect of inductive research is to develop useful; theories [52]. The inductive research process has been providing flexibility in the study, and the study also can be changed based on the particular data which is necessary. Hence the research process also provides various benefits, those are-

Flexibility:
The inductive research process is known as the flexible strategy which allows the researcher to modify their research topics and use techniques regarding the collected data. Hence researcher is also ankle to study new concept of research which they might never think of before, hence this approach also provides freedom of thought [39].

A holistic point of view:
According to the data this research approach has been containing the broad research view reason this has been looking for the data collecting process instead of just focusing on the theories.

Generates new ideas and theories:
This method has been helped to generate a fresh concept for the study and it also helpful for creating fresh inventions or programs. This method helps to produce different viewpoints and ideas regarding the strides, hence the deductive approach is not able to provide this [40].

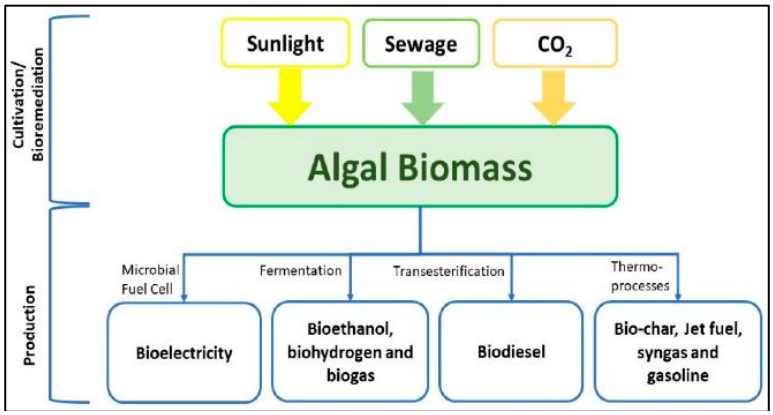

Figure 3.2.1: Algal Biofuel

3.3 Research method

Here researcher has been providing the research methodology, based on the data this has been an important part of the research process. It describes the process of the research intends and varied the proper research, it has been a logical systematic plan which is helping to resolve the research problems [41]. According to the data research method has been categorized into 3 processes ***"quantitative", "qualitative"***, and "***mixed***". Based on this process researcher has used the qualitative research method, according to the data this process involved collecting and analyzing the written and spoken words and textual data also. This research also focuses on body language and visual elements, which has been help to contain a detailed description of the research observations [42]. In this process, research has been collected from the interviews, observations, and focus on the particular group of research. This has been subjective research and it also takes more time than the other two methods. The researcher has been using the qualitative method and it has been containing the aim and objectives of the research process. The qualitative research approach has been containing various advantages and disadvantages [43].

Advantages

- Qualitative methods can turn into viable to recognize attitudes.
- It has been able to generate the content material.
- It has been offering insights that are helpful for industries.
- It gives predictive qualities.

Disadvantages

- It is not a statistical consultant shape of records collection
- It has been based on the level of the research process
- It required more than the particular sessions
- It might create duplicate consequences.

3.4 Research Strategy

According to the data, the researcher has employed the qualitative research method based on this approach, which included gathering and analyzing both textual and spoken data as well as written and spoken words [50].

This study also emphasizes body language and visual components, which has made it easier to describe the research findings in depth. Research has been gathered during this procedure from interviews, observations, and a focus on the specific research group [44]. This research has been subjective, and it takes longer than the other two approaches. The aim and objectives of the research process have been contained by the researcher's use of the qualitative approach [45].

3.5 Justification of Choice

According to the data, the researcher has been choosing the qualitative data analysis process, based on this process researchers are beneficial regarding the research process. Hence it also provides various advantages which help them to understand the topic of the research and provide other information from the data collection process [46].

3.6 Data collection

The qualitative research process has been using various techniques including interviews, focusing on groups, and observations. Interviews might be with the open-ended question, hence the qualitative research approach has been involved with the particular method of collecting data. Like

Interviews

The researcher has been conducting various interviews and collecting data from interviews and doing analysis on this data [47].

Case studies

Researchers also consider the case study for the data collection method ad this has been helping them to collect various data which has been used in the research process.

Secondary research

Researchers also used the secondary data solution process where they utilize the other researchers' study papers and collect various data and information regarding their study [48].

Expert opinions

Researchers also take expert opinions, this has been helping them to understand the concept of the research and also provide previous knowledge of the research.

There are other processes are also available such as ***"Focus groups", "Online surveys", "Paper surveys",*** and ***"Observational studies".***

3.7 Ethical consideration

The statistics show that ethical consideration has been supplying information on the potential effects and implications of the chosen strategy. Giving information on the procedures the researcher has used to reduce the risk associated with their research and to treat data properly has been an ethical consideration [51]. Based on the data, researchers have been ensuring that participants' genuine identities and personal information are protected while also maintaining their privacy and maintaining appropriate secrecy. To prevent unwanted access, this is part of the cautious treatment and storage of data [49].

IV. CONCLUSION

4.1 Critical Evaluation

The value of biofuels has been measured in the field of energy consumption and its environmental benefits. Various applications of biofuels are encouraging the reduction of greenhouse gases with increasing reliance on crude oils. The large-scale implementation and further research must measure the acceleration of product accumulation and productivity with the reduction of water, energy, land footprint, and nutrient consumption. Combustion of the microalgae is responsible for the reduction of the emission of carbon dioxide and lowering the cost of biodiesel production to facilitate practical applications. Microalgae productivity and efficiency can be increased by the measurement of different parameters such as pH, temperature, light intensity, salinity, photobioreactor configuration, rate of CO2 flow, and nutrient ratio. Each of the methods of carbon-neutral energy extraction from algae has different benefits and limitations as optimized from the research papers. While the application of algae in the removal of atmospheric carbon requires lower constraints than the production of biofuel. Such strategies are still in the developmental stage and are conceived to be feasible economically but not commercially.

4.2 Summary of the Achievements

The summarized form of this significant subject is comprised of the application of the algae in different fields with their limitations and effectivenesses. Algae-induced energy production is involved in greater consideration of natural factors to attain an effective process of entire production. The choice of the microalgae species and the cultivation mode is the most important factor as measured from the previously done research and optimizations. These algae are responsible for producing different biotic substances that are applicable in different fields such as chemical, food, carbon sequestration, pharmaceutical, and biochemical industries. It can

be implicated that the entire research process has been performed and optimized with the best perspective of significant objectives.

4.3 Research recommendations

Evaluation of the terms of algae-based neutral-carbon energy production must be performed with the measurement of the limitations and research gaps. Entire research optimizations must be performed from legitimate resources to obtain adequate information on the algae types, cultivation and application. The review has been adequately structured with the achievement of the aim and critical evaluation of the optimized terms that can be used for algae-based biofuel production. Optimization of the technologies and issues of these technologies are also required to be measured before implementation of such technology in any premises.

4.4 Future work

The future scope of the research is involved in the implementation of more advanced technologies and influences of its commercialization. The more improved technological application can be referred to as the implementation of algae-based biofuel production and consumption. Further study of this significant study can be constructed with the reduction or removal of atmospheric carbon dioxide with the application of microalgae. More integration within the choice of algae types is a major objective of the future developments of the study. Therefore, it can be implicated that the entire study is limited to the evaluation of these significant factors such as the integration of different species and atmospheric carbon removal technology.

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