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Production of Biofuels from Biomass as an Approach Towards Sustainable Development: A Short Review

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Abstract. Alternative fuels reduce the carbon footprint of internal combustion engines. Biofuels are the most important alternative fuels. Manufacturing processes for biofuels have made it possible to reduce greenhouse gas (GHG) emissions from well to wheel. There are a number of popular alternative fuels for use in internal combustion (IC) engines, including biodiesel, bioethanol, and bio methanol. Biodiesel and petroleum diesel fuel blends in compression ignition (CI) engines have received a lot of attention. Biofuel is any liquid fuel derived from "biomass," such as plants and animal waste. Biofuels replace gasoline and diesel. Biofuels are promising because the carbon dioxide (CO2) they emit is recycled through the environment. Biofuel plants collect CO2 from the air and release it when burned. In principle, biofuels can be a "carbon neutral" or "carbon negative" means to power automobiles, trucks, and planes. Biofuels can reduce CO2 emissions without requiring many infrastructural changes. They can be used in existing cars and mass-produced from biomass like chemicals and pharmaceuticals. Future biofuels may be moved using current pipelines. Making carbon-neutral biofuels is difficult. Fermentation, processing energy, transportation, and even plant nutrients can produce CO2 and other greenhouse gases before biofuels are consumed. Biomass agriculture can have climate consequences if it replaces CO2-storing woods. How biofuels are generated and used affects their potential as a climate solution.

Keywords/ Bio-Fuel, Liquid Bio-Fuel, Gaseous Bio-Fuel, Solid Bio-Fuel, Climate Change.

Introduction

Humanity faces three major challenges in terms of road mobility today: (1) greenhouse gas (GHG) emissions and global warming; (2) renewable or sustainable forms of energy; and (3) energy security [1]. This led to an EU target of at least 40% domestic reduction in GHG emissions by 2030 compared to 1990, which the European Council agreed to in October 2014 [2], [3]. As the world's population grows, so does the need for fuel in all of its forms. The material world plays an important role in human existence [4]. In order to produce and transport these items, fuel-driven vehicles are used, but fuel is mostly accumulated in a small number of countries, particularly in the Middle East. Governments in a number of countries around the world are working hard to find an alternative to fossil fuel, which is slowly but steadily being depleted as economies grow [5]. A binding target of at least 27 percent for renewable energy consumption in the EU in 2030 has been established; and an indicative target at the EU level of at least 27 percent has been set for improving energy efficiency in 2030, compared to projections of future energy consumption based on the current criteria [6]. European Commission (EC) stated in March 2018 that the EU aims to achieve climate neutrality by 2050 "through a fair transition that encompasses all sectors of the economy [7], [8]. These issues sparked a great deal of debate about the global impact of road mobility at the international level. According to these articles, the EU's transportation sector is responsible for about a quarter of all GHG emissions [8]. Road transportation accounts for about 75 percent of this CO2, which is a rapidly expanding industry around the world [9]. Global oil consumption increased 1.8% or 1.7 million barrels per day in 2017, surpassing the 10-year average of 1.2% for the third consecutive year. Global oil production rose by 0.6 million barrels per day, below average for the second year. This shows that fossil fuels are depleting, so researchers are looking for renewable fuels [10]. The diesel engine's exhaust gas emissions can be reduced in two ways. First, exhaust gas treatment devices such as catalytic converters and diesel particulate filters can be used to reduce emissions [11][12]. However, the Diesel engine's performance is affected by the use of these devices. Fuel additives are a second method for reducing emissions and improving the performance of CI engines. For example according to the findings of this study, diethyl ether can be used as a fuel additive to improve engine efficiency and reduce exhaust emissions [13]. Particulate matter and nitrogen oxides (NOx) are the primary pollutants produced by diesel engines (PM) [14]. Biofuels were thought to be the most prominent alternative fuels for internal combustion engines that could replace fossil fuels (biodiesel, bioethanol, bio-methanol, etc.) [15], [16]. Vegetable oil biofuels appear to be a good alternative to fossil fuels because their production is simple; they are cleaner, biodegradable, nontoxic and recyclable; and they do not contain benzene, a carcinogen [8], [17]–[22]. The biofuel combustion in an ICE reduces CO2 emissions because of the photosynthesis process that occurs in the biomass that is used as fuel. The use of fossil fuels for agricultural machinery and transportation in biomass production and biofuel production processes may lead to high GHG emissions[23], [24]. Contrarily, soil contamination by fertilizers, herbicides, and insecticides must be taken into consideration. A biofuels life cycle analysis (LCA) is therefore a critical tool for making strategic decisions in this field (raw materials, land-change techniques, biofuel manufacturing technologies, etc.). In Figure 1, a simplified LCA framework is depicted [14].

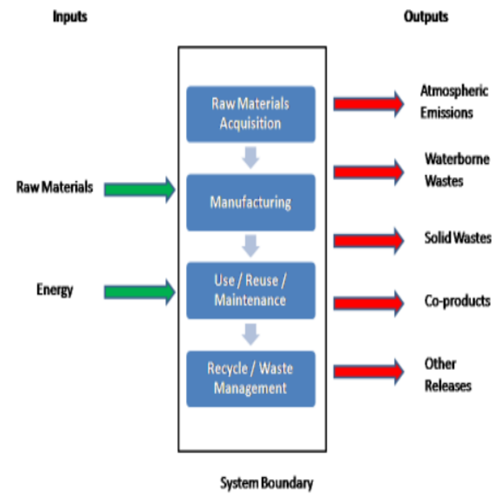

Figure1. a simplified LCA framework is depicted Inspired by previous works [14].

The seventh sustainable development goal is one of the seventeen goals adopted by the United Nations General Assembly in 2015, and it aims to "make modern, sustainable, reliable, and affordable sources of energy available to all." We must end fossil fuel pollution and accelerate the transition to renewable energy before we burn down our only home, as UN Secretary-General Antonio Gutierrez stated on January 21, 2022. Another essential aspect related to the commercialization of biofuels also raises concerns about environmental impact [25], [26]. In spite of biofuels' potential to reduce GHG emissions, concerns have been raised about their long-term viability due to their potential to divert agricultural land and water from human consumption. Loss of biodiversity and shifts in land use are also predicted to become pressing issues. Similarly important to the production of second-generation biofuels are the characteristics of the land on which it is grown.

Biofuel Varieties

Biofuels are divided into two types: primary and secondary fuels. Fuel woods used for cooking are examples of primary fuels. Biofuels are also categorised into generations based on the feedstock utilized in their manufacture. First-generation biofuels are made from food crops such as corn, sugarcane, rapeseed, and so on. They are involved in the manufacture of bioethanol or biobutanol by the fermentation of starch or sugars derived from food crops, as well as the generation of biodiesel through the transesterification of oil crops. The fundamental challenge with first-generation biofuels is the trade-off between food and fuel. The majority of first-generation biofuels have a negative energy gain, according to a life-cycle analysis (LCA). Nonfood crops, such as lignocellulosic biomass, are used to create second-generation biofuels. The life cycle assessment (LCA) of second-generation biofuels found an increase in net energy gain. In comparison to first-generation biofuels, this highlights the improvements made by the second generation. Algae are used to create biofuels of the third generation. Due to their high lipid content, CO2-fixing capabilities, and quick growth rate, microalgae are a possible source for biofuel generation. Biodiesel made from microalgae, biohydrogen produced by algae and other microorganisms, and bioethanol made from seaweeds is all examples of third-generation biofuels. When compared to first- and second-generation biofuels, third-generation biofuels are superior. In addition to these benefits, neutral lipid buildup, high productivity, CO2 sequestration, and wastewater bioremediation are also possible [27]–[29].

Biofuels that come in liquid form

At present, global change is acting on a variety of scales, having an impact on both biodiversity and human activities. Intensified production of greenhouse gases and the diversion of land from its natural state are two major factors. Human and animal feeding, timber harvesting, and construction of buildings and facilities are just a few examples of the many reasons for changing land use, both of which contribute to a high rate of biodiversity loss on a global and regional scale [30]. First, second, and third-generation biofuel raw materials exist. First-generation biofuel feedstock is limited to avoid crop conflicts. Second-generation biofuel production eliminates first-generation flaws by using non-edible agricultural and forestry wastes. New technologies can produce second-generation biofuels more efficiently and sustainably [31]. Second-generation biofuels may or may not play a significant role in the decarbonization of transportation [32]. Algal biomass is frequently cited as a source for the third generation of biofuels [33]. Based on oil yields, cultivation, harvesting, and processing, algae are the ideal feedstock for biofuels, according to EU sustainability criteria. Micro- and macro-algae have high biomass productivity and favorable biomass composition [34]. Directive (EU) 2015/1513 was made by the European Commission to cut down on the use of first-generation biofuels in favor of second- and third-generation biofuels [35], [36]. Because of climate change and the global energy crisis, we need to find renewable energy sources to power the economy as it makes the shift from relying on fossil fuels to relying on renewable materials [37]. As such, biofuels present a significant opportunity for policymakers, academics, and businesses. The production and use of advanced biofuels on a massive scale can help alleviate the world's energy crisis and combat climate change. Capturing solar energy and carbon from ambient CO2 in growing biomass is central to the definition of biomass as a renewable energy resource. The sustainable development and climate change mitigation benefits of biofuel production from biomass are substantial [38], [39].

Biodiesel

Biodiesel is a fuel derived from animal and vegetable sources that can be used to power a mechanical engine. It can be produced primarily from vegetable oils or animal fats[42]–[40] . However, when it comes to replacing petroleum diesel fuels with biodiesel, issues such as high viscosity, low volatility, and the polyunsaturated nature of vegetable oils arise the researchers found some techniques to improve these issues. Pyrolysis, microemulsion, dilution, and transesterification techniques can all help to improve these results. Figure2. List the biodiesel production methods.

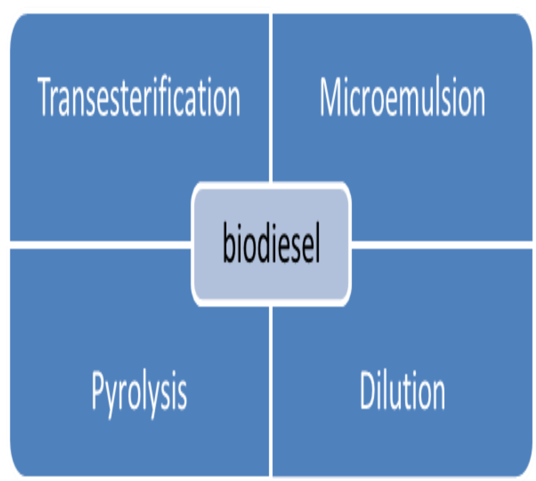

Figure2. Biodiesel production methods

Pyrolysis

The process of converting one substance into another by means of heat, with the assistance of a catalyst, and in the absence of oxygen is referred to as pyrolysis. The procedure does not generate any waste and does not cause any pollution. Pyrolysis is a relatively simple method of cracking, especially when compared to other cracking processes, and it appears to be effective [43]. This method, however, has been criticized by other researchers due to the high amount of energy it requires and the low conversion rate it achieves [44]. The biodiesel production process depicted in Figure 3 is known as pyrolysis [45], [46].

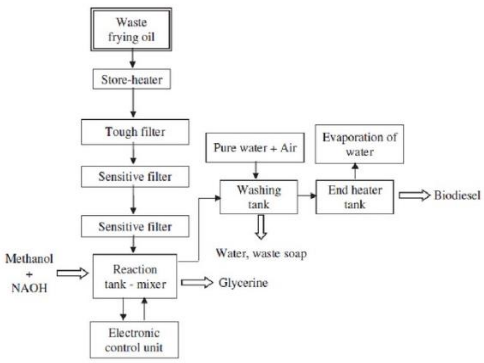

Figure3. shows a diagram of biodiesel production using pyrolysis technology Inspired by previous works [47].

Microemulsion

A microemulsion is a colloidal equilibrium dispersion of optically isotropic fluid microstructures. These microstructures form spontaneously when two normally immiscible liquids are mixed with one or more ionic or non-ionic amphiphiles. The microemulsion is defined as colloidal equilibrium dispersion [48]. According to the same study, the explosive vaporization of the low-boiling constituents in micelles has the potential to improve the spray characteristics. In addition, as was discussed in the same study, it lessens the viscosity of the biodiesel, but at the same time, it has a detrimental effect on a CI engine that runs for an extended period of time when fuel is obtained using this method (incomplete combustion generating carbon deposits inside the cylinder). Figure 4. shows the microemulsion diagram.

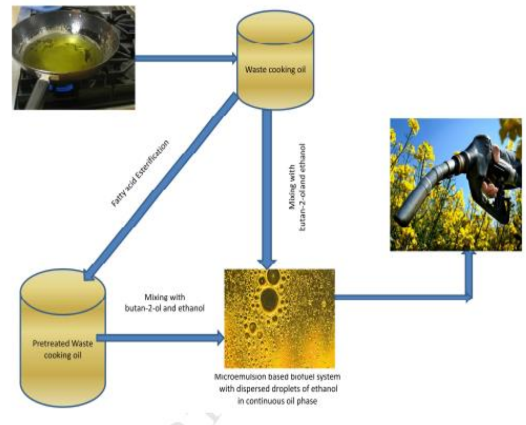

Figure4. Micro-emulsion technology for biodiesel production schematic diagram Based on the literature [49].

Dilution

The definition of dilution is a mixture of vegetable oil and petroleum diesel fuel. This reduces the viscosity of the blend below that of the vegetable oil, making it suitable for engine use. In this study, the combustion and emissions of a single-cylinder compression ignition engine that ran on diesel, hydrogenated vegetable oil, or a mix of the two (50/50) were carefully looked at. In the end, at a steady-state, mid-load operating point on the given engine platform, hydrogenated vegetable oil allowed for 43 percent indicated thermal efficiency with nitrogen oxides and carbon monoxide emissions that were close to Euro VI limits. This was 1.5 percentage points more efficient than the best diesel operation [50].

Transesterification:

Transesterification is the process by which a fat or oil reacts with alcohol to produce esters and glycerol. Typically, a catalyst is used to increase the reaction rate and yield. Depending on the type of catalyst employed in the transesterification reaction, three distinct processes are implemented:

(A) alkali-catalyst.

(B) acid catalyst.

(C) lipase catalyst.

Transesterification is the most common industrial process out of the ones listed above. This is because it has a high conversion rate, low production costs, mild reaction conditions, and the properties of the product are very close to those of fossil diesel [51]. Biodiesel has a higher oxygen content than diesel, ensuring complete combustion when compared to hydrocarbon-based diesel fuel[52] . Lipase from Nile tilapia viscera was used as a biocatalyst in the production of biodiesel from used cooking oil [53], [54]. The best biodiesel yield (96.50 percent) was achieved with enzyme loading of 30 k Units, a methanol/oil molar ratio of 4:1, a water content of 3%, a reaction temperature of 45oC, and a reaction time of 28 hours. This enzymatic process may be a viable option for producing biodiesel from low-cost used cooking oil on an industrial scale. Nonetheless, this enzyme-catalyzed reaction has a limitation: a lengthy reaction time [55]. Banana trunk ash was found to be a labor- and cost-efficient green solid base catalyst for the production of biodiesel from soybean oil in this study. Aside from the ease of preparation, the catalyst's availability as a naturally occurring waste product makes it particularly promising. At a temperature of room temperature, the reaction procedure was also carried out. We believe this protocol has broad industrial applicability due to its high economic viability and environmental friendliness [56]. This Figure5 show us the production of biodiesel by using transesterification.

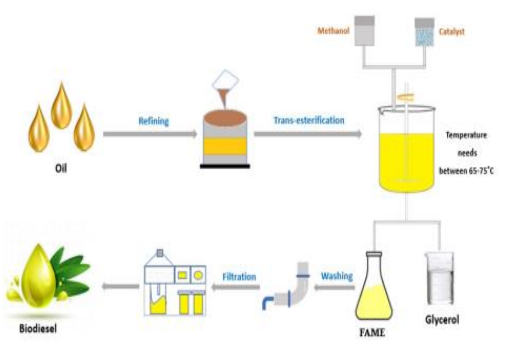

Figure5. Transesterification process Inspired by previous works [57].

In the process of transesterification, using the KOH catalyst resulted in the highest conversion and yield of biodiesel when compared to using the NaOH catalyst [58].

Bio- Methanol

Natural gas, coal, coke-oven gas, hydrogen, and biomass are the most common sources of methanol [59]. Separate steps for upgrading biogas, electrolysis, and bio-methanol production are shown in Fig. (6) [60]. This was based on the assumption that the biogas production plant was already up and running, negating the need for new investment. Additionally, a biogas ideal composition of 60% CH4 and 40% CO2 was assumed. Bio-methane is generated at the biogas upgrading stage, and the captured CO2 is then used to produce bio-methanol [61], [62]. With its potential to lower initial investment and yield a high-purity bio-methane stream, membrane technology stands out as a top contender among biogas upgrading methods [63]. There was no delay in incorporating them into the economic framework. The alkaline electrolyzer (AE) was chosen as the electrolysis plant for hydrogen production because it is the one most commonly recommended by suppliers [64].

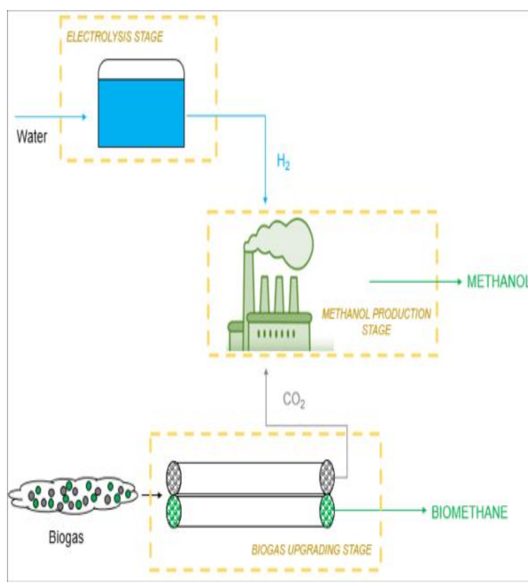

Fig.6.Schematic of a Process for Transforming Biogas into Bio-Methanol Using Carbon Dioxide adapted from the literature.

A dual benefit is achieved by the biogas–biomethane chain, which not only reduces waste sent to landfills but also generates energy from the residues left over [65]. A shift to a circular economy is required if a new paradigm for social progress is to be adopted. This necessitates switching to renewable energy sources, recycling more, and cutting back on emissions of greenhouse gases. Methanol's use in manufacturing and transportation is the most promising option [66].

Bio- Ethanol

Many countries, including the United States, Brazil, and India, use bioethanol as an environmentally friendly fuel. When added to gasoline, it lowers the amount of fossil fuels in the fuel and, in turn, the contribution of transportation to climate change. First-generation biotechnologies using corn, sugarcane, or molasses as feedstocks produce nearly all bioethanol today [67].The overuse of fossil fuels in modern times is the primary cause of the worldwide energy crisis and climate deterioration. Fossil fuel is one of the nonrenewable resources and a major contributor to greenhouse gas emissions [68], [69]. Because of their renewable qualities, biofuels have garnered a lot of attention as a means of addressing this crisis through alternative energy development [70], [71]. Among biofuels, bioethanol has been the subject of extensive research and industrial production thanks to advances in technology; it also boasts the largest production capacity and accounted for more than 90% of total biofuel consumption in 2011 [72]–[75]. Grain starch and sugars are the primary components of bioethanol made from corn and wheat. Among potential bioethanol precursors, this one is widely regarded as the least complicated. Manufacturing-scale fuel ethanol is primarily produced in the United States from corn [76]. The use of second-generation bio-ethanol made from corn Stover has gained prominence in recent years. This is not only because of China's rising appetite for biofuels but also because it protects the environment from the haze pollution caused by burning waste in the open [77].

Bio-Butanol

To make butanol using natural processes, acetone-butanol-ethanol fermentation is used. Butanol can be made through microbial fermentation, just like ethanol, but there are still a number of obstacles that need to be overcome before it can be used as a replacement fuel. Substrate price, low yield, low productivity, and a process that requires a lot of energy to recover are all issues [78]. Among the renewable fuel options, bio-butanol holds a lot of promise. Fermentation of lignocellulosic biomass is another method of its production [79], [80]. Bio-butanol has a high octane number, low volatility, and low vapor pressure, and can be blended with a wide variety of fuels; it is safer, less hygroscopic, and has fewer ignition problems; it is also inter soluble and has higher viscosity and lubricity [81]. Energy crops like sugar corn can be grown quickly. looked into making biobutanol from sugar corn juice for the first time. Sugars like sucrose, glucose, and fructose, which make up about 80% of the total sugars, were found to make up 145 g/L of the juice's total content, according to the analysis of the juice's constituent chemicals. Traditional biomass-to-biofuel processes may require less energy and enzyme inputs if they use this feedstock [82]. Waste peapods accumulate at a high rate during the processing of peas [83], [84]. The majority of the damage it does to the environment comes from having been dumped on the ground. Data from the compositional analysis shows that it is rich in cellulose (32.08%) and hemicellulose (21.12%), making it a promising feedstock for biobutanol production [85].

Bio-fuels that come in gaseous form

Bio-gas

Producing biogas from biomass is an environmentally sound method of generating electricity, and the leftover material can be put to good use as a soil amendment. Anaerobic biological decomposition of organic waste results in the production of biogas. It is mostly made up of methane and carbon dioxide. Biomass, the primary source of energy, consists primarily of flammable methane (50%-85%). It can be put to use in boilers to produce heat. Boilers can consume biogas when it has been upgraded [86]. Biogas production process factors such as feedstock type and carbon-to-nitrogen ratio were studied. Wheat stalk, soybean straw, and black gram stalk were shown to be the most promising agro-residues for biogas generation [87].

Bio-hydrogen

Bio-hydrogen is a renewable energy source since it can be created from biomass. It's a green energy option with high efficiency and no pollution. Hydrogen may be extracted from many different materials, including biomass, natural gas, heavy oils, etc. Sustainability and environmental friendliness in the production of hydrogen from biomass are the focus of multiple ongoing research and development projects as of this writing [88].Gasification of biomass is the most cost-effective method for producing bio-hydrogen [89]. synthesis of biohydrogen from biomass is believed to be more economically viable than biohydrogen production from steam reforming of natural gas because of the production of a coproduct. Creating biohydrogen from biomass has a number of benefits but also some drawbacks. Fewer greenhouse gas (CO_2) emissions, longer product life, and a lighter ecological footprint are all positive outcomes. Seasonal biomass supply and technological constraints are drawbacks [90]. The feasibility of producing biohydrogen from agro-industrial byproducts such as starch was assessed. Biohydrogen may be produced from starch agroindustrial leftovers at a lower cost, according to the study. This would increase the accessibility and affordability of the fuel [91].

Biofuels that come in solid form

Bio-char

Bio-char is the carbon-rich byproduct of biomass that has been thermally decomposed (between 350 and 700 degrees Celsius) [92].When used as a soil conditioner and fertilizer, bio-char is quite useful. Since it lowers atmospheric CO_2 concentrations, boosts soil carbon stocks, and enhances soil carbon storage, it is crucial in combating climate change [93]. According to the results, adding bio-char to the growing medium improves conditions for seed germination and plant growth. Element analysis demonstrated that bio-char provides nutrients that stimulate plant development. Soil conditioned with bio-char made from Miscanthus collected at 400°C for 10 minutes reduced the growth of maize seedlings. When soils were amended with bio-char derived from Miscanthus and heated to 600 degrees Celsius for 60 minutes, the results were unexpected. This suggests that different types and varieties of seedlings call for different kinds of bio-char prepared in different ways to achieve optimal results. The process of bio-char production from waste biomass was analyzed [94], [95]. The research showed that the physicochemical parameters of bio-char made from empty fruit bunches are significantly impacted by the pyrolysis temperature. Both the bio-char generation yield and the BET (BrunauereEmmetteTeller) surface area decrease as the pyrolysis temperature rises. It was found in this research that yields were highest at 400C (50.6%). Under these conditions, the cation exchange capacity was also quite high, which is a positive indicator of both soil fertility and soil quality.

Analyze sustainability

The conversion of biomass to biofuels raises serious concerns about the long-term sustainability of this process. The biomass used for biofuel production must be sustainably sourced and meet recognized sustainability requirements for biodiversity and land-use change [87]. Research into the ecological impact of making biofuels takes several forms. Some examples of such quantitative approaches are life cycle assessment (LCA), material flow accounting (MFA), and strategic environmental assessment (SEA). The environment, externalities, and economics are the usual focus points of a sustainability analysis. Emissions of air pollutants throughout the biofuel production process should be evaluated, as should the effects on air quality and human health. Furthermore, research on sustainable biomass resource utilization is required. Models and computational tools at different sizes of operations have been developed and used thanks to recent breakthroughs in biofuels research. A few examples are LCA models, crop simulations, process design simulations, large-scale crop models, and mathematical optimization tools [96]. Each of these reports adds new information to the conversation about biofuels' long-term viability. Tests in the field and small-scale tests in the lab make up the initial stage of study. Research into these areas includes biomass cultivation methods, parameter optimization for biofuel production, reaction kinetics analysis, etc. It is necessary to undertake a process-scale analysis when these procedures have been established in the laboratory. Agriculture crop models and conventional process design analysis are both used in this procedure. A number of large-scale crop models, including those for herbaceous crops, woody bioenergy crops, and crassulacean acid metabolism crops, have been developed to mimic the development of bioenergy crops [97], [98]. Biomass yield, nutrient cycling, water needs, carbon flux, emission levels, and other critical parameters are simulated in these models as a function of various crop management strategies. The third level of analysis takes into account the flow of materials, energy, and emissions over the whole supply chain, thus expanding the analytic boundaries. With this method, researchers investigate environmental effects outside the scope of conventional process design. Life cycle assessment (LCA) is one method used to determine how harmful a product or process is to the environment over its entire lifespan [99].

Conclusion

Biofuels are versatile and can be used in a wide variety of applications. Biodiesel is made from oil crops, bioethanol is made from crops with a lot of sugar, and biogas is made when organic matter breaks down. With growing demands to reduce carbon dioxide emissions, biofuels play an increasingly valuable role in cleaner energy production. For market participants, keeping abreast of market developments and reliable price assessment is key to identifying short-term trading opportunities, and a detailed understanding of long-term market trends guides strategic planning, including long-term capacity investment, sourcing decisions, and marketing strategy. One of the most important goals of the final draft is the reduction of greenhouse gas emissions in Iraq, which can be achieved in part or entirely through the use of biofuels and other renewable energy sources. In addition, between 2021 and 2030, it intends to implement Nationally Determined Contributions that will result in a 1% to 2% emission decrease.

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