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Evolution and Developments in Biofuels as a Sustainable Energy Resource

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Abstract

The primary source of non-renewable energy that cannot make up for its losses over the course of years is fossil fuels, which are also referred to as conventional fuels. According to the findings of the 2019 World Energy Global Statistics Review, both global emissions of carbon dioxide and primary energy consumption went up by 0.5 percent and 1.3 percent respectively, over the previous year. These elevated charges are being implemented as a precautionary measure for both people and the environment. On the other hand, renewable resources, such as biofuels, create fewer greenhouse gas emissions, cause less pollution, and have the potential to be manufactured from biomass in the form of organic waste. When seen from a global perspective, biofuels have demonstrated that they are viable alternatives for lowering emissions of greenhouse gases and finding solutions to challenges inherent in the need for energy. There are several efficient sources for the production of biomass, and these sources may be separated into three distinct types, namely, first, second, and third generation biofuels. The first generation comprises biomass derived from edible crops, the second generation contains biomass derived from lignocellulosic materials, and the third generation contains biomass derived from algae and holds the potential for renewable resources. This paper provides a summary of several forms of biofuels, including biodiesel, as well as their comparative studies, production methods, and applications from the point of view of the environment.

Keywords

Carbon dioxide emission; sustainability; biofuel; low carbon emission; GHG emissions; generations of biofuels

1. Introduction

The increased usage of fossil fuels has resulted in a severe catastrophe for the environment. As a direct consequence of this, there is an extraordinary rise in the need for renewable and clean sources of energy

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(Berla et al., 2013). Biofuels that are clean and alternative, such as bioethanol, can be effective weapons in the fight against climate change and other issues (Bender, 2000). In comparison to fossil fuels such as coal, oil, and natural gas, biofuels are an outstanding alternative fuel. Biofuels are superior to fossil fuels in all respects, including their friendliness to the environment, renewability, abundance, biodegradability, and capacity for long-term sustainability (Lee and Lavoie, 2013). Since the beginning of human history, when humans first started using firewood for warmth and cooking, the use of biofuels has been of great benefit to humanity. In this aspect, the history of biofuels is even older than the history of people and civilization. This is due to the fact that biofuels have previously existed, for instance in the form of wood and grass, long before humans discovered and began to utilise fire. An internal combustion engine powered by ethanol (bioethanol) was invented in 1826, Rudolph diesel (biodiesel) was used in Sadi Carnot engines in 1878, and peanut oil was used in the first trucks and buses in 1896, and so on (Kaltschmitt and Hartmann, 2001). As human civilization progressed, biofuels played increasingly important roles in the lives of the people. For example, methane gas (bio-methane or biogas) was used to heat bath water in the first century BC. In several publications, summaries of the ways in which biofuels might be applied in people's lives can be found. The lives of individuals all around the world were significantly altered and enhanced as a result of these apps.

In addition, biofuels offer the following benefits: (a) they make use of the energy resources that are already present in the area; (b) they encourage the growth of rural agriculture and the investment in it; (c) they broaden the supply base; and (d) they may be imported. Reduce reliance on energy sources, (e) boost employment opportunities, (f) encourage the growth of rural economies, (g) make improvements to local ways of life, etc. (Hassan and Kalam, 2013) As a result, a great number of nations have a number of aims or strategies that are interconnected with one another to encourage and foster the growth of the biofuel business in nations such as the United States of America (USA) and the European Union (EU), Brazil, China, India, and Thailand. Ethanol is one of the most well-known biofuels in the United States; however, other biofuels, particularly biodiesel, are widely utilised in other regions of the world, such as Europe, Asia, and increasingly Brazil. Ethanol is one of the most well-known biofuels in the United States. First-generation biofuels include both ethanol and biodiesel; however, new forms of biofuels, such as cellulose-based ethanol and dimethyl ether (bio-DME), are becoming increasingly popular as second- and third-generation biofuels, respectively. They have the potential to develop into advanced biofuels in the future.

2 Classification of bio fuels

Although ethanol is one of the most well-known biofuels in the Americas, other biofuels largely highlight a number of viable possibilities for making use of biomass. The most common types of solid biofuels are firewood, charcoal, and fibre. The majority of households still rely on fossil fuels like firewood and charcoal as their primary source of cooking fuel. The processing of sugar cane results in the formation of the fibrous substance, which finds widespread application in the production of electricity and steam. The production of methane and other generated gases, which are generally classified as gaseous biofuels, can take place either through the pyrolysis of agricultural waste sand or through the fermentation of pet waste sand that has been gasified. Biodiesel is a generic term that can apply to a number of different types of liquid biofuels, including methanol, ethanol, bio oil, and methyl esters (Dahman et al., 2019). Because of their low cost, tremendous energy potential, and abundance, solid and liquid biofuels are increasingly being employed in the generation of electricity. It takes millions of years to create large yields of biofuels in a short period of time, but the production of coal and petroleum, which are both examples of fossil energy resources or fuels, are both produced from biomaterials. Based on the biomass used and their feed stock, biofuels can be categorized into three different groups (Pal et al., 2017). The flow chart is shown in Figure 1.

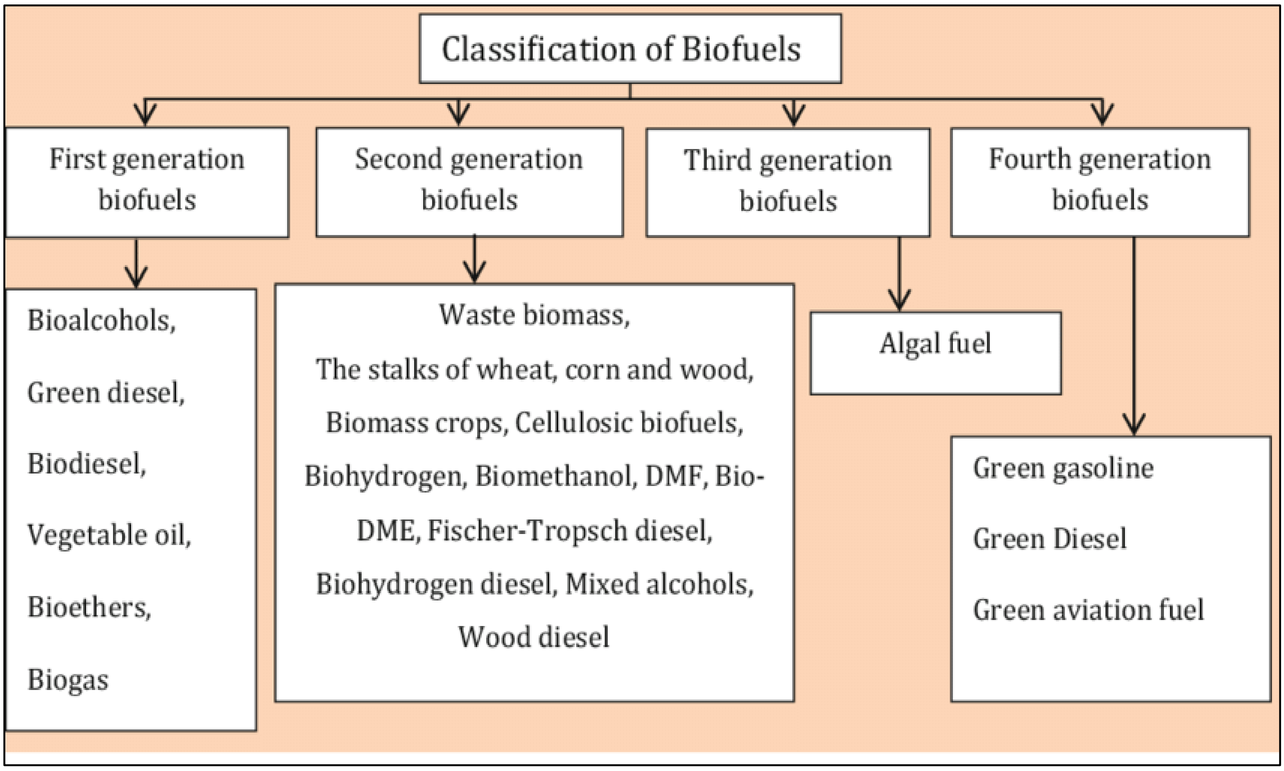

Figure 1. Chart of classification of biofuels on the basis of feed stock

2.1 First-generation biofuels:

Corn and wheat are two examples of food crops that may be used to produce the first generation of biofuels. The biofuels that are utilised in today's society in a very huge scale are considered to be first-generation biofuels. These fuels are also known as conventional biofuels in some circles. Sugar, starch, greasy vegetable or even animal fats can occasionally be used in the manufacturing of first-generation biofuels, but these components make up the majority of the ingredients. They might be consumed as meals, fed to animals, or consist of food residues that were created from sugar, starch, vegetable oils, or animal fats by employing standard procedures such as fermentation, esterification, and distillation, amongst others. As a result, there is no choice but to abandon biofuels of the first generation. If not, the component parts will be used to make food for others. The use of by-products of human food components, also known as second-generation ingredients, in the production of biofuels of the second generation makes more sense as the world's population continues to increase.

2.1.1 Advantages:

- The production of biofuels contributes to the opening of new market possibilities, the expansion of agricultural goods, and the consequent expansion of new sources of income for farmers, all of which contribute to an improvement in the socioeconomic conditions.
- Fermenting plants that contain sugar and starch results in the production of huge quantities of by-products, which may then be used as an essential supplement. This process offers additional health advantages.

2.1.2 Limitation

Raw materials are the main source of first-generation biofuels. The main ingredients are edible crops such as corn and sugar beet. They endanger food prices because biomass is used in the production of biofuels.

2.2 Second generation bio-fuels:

In comparison to biofuels of the first generation, biofuels of the second generation are more technologically sophisticated industrial goods. This fuel is likewise created from sustainable raw resources such as first generation fuels, despite the fact that it does not replicate the typical characteristics of crops used for food production. In general, products made from these sorts of raw materials are not intended for consumption by humans. This suggests that individuals cannot utilise the raw resources that are available from the second generation [8]. In spite of the fact that they are edible crops, they are currently not in a condition where they can be consumed by humans. The second generation of biofuels, also known as "advanced biofuels," gained their name from the fact that it is relatively difficult to generate gasoline from this source. As a result of this difficulty, these biofuels are generally referred to as "advanced." In addition to cellulose, hemicellulose, or lignin, non-food components for biomass that can be utilised in the manufacture of second-generation biofuels include certain types of wood, agricultural leftovers, organic waste, and food waste in addition to specific types of biomass crops.

Utilizing the unavoidable waste products of agricultural production to make biofuels offers a number of potential benefits. This product may be grown using no extra fertiliser, water, or land than what is already available. This non-edible by-product is utilised by the industry in the manufacture of animal feed, but a sizeable portion of it is also suitable for use in the manufacturing of biofuels. The argument against the manufacture of biofuel from second-generation raw materials has afflicted this biofuel pathway. The methods involved in this biofuel pathway are also a little bit lavish. Despite this, research on second-generation biofuels and legislation pertaining to their use have the potential to transform this biofuel route into a source of biofuel with a higher production rate. The conversion process that is used to produce biofuels of the second generation often follows one of two distinct pathways, which are typically referred to as the "thermal" pathway or the "bio" method [13] as shown in Figure2. The method of manufacturing biofuels of the second generation is broken down into its most basic components here.

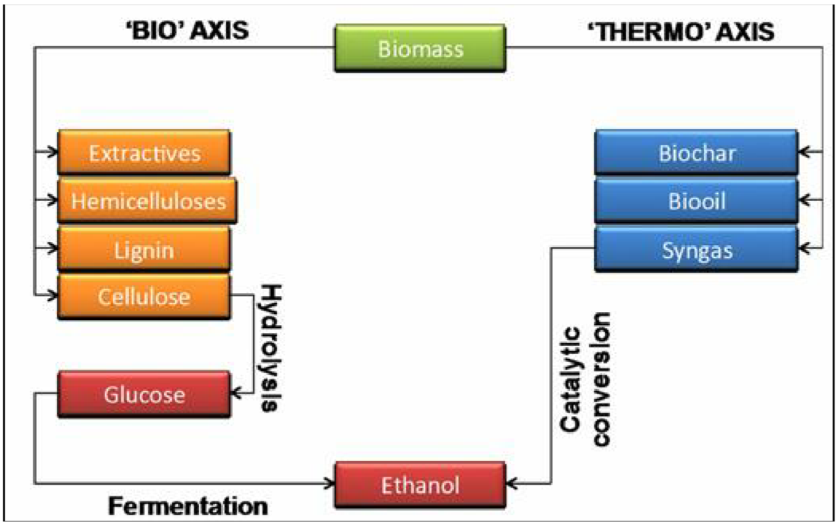

Figure 2. Bio mass generation flow chart

The "thermo" strategy entails a particular procedure of heating with a low amount of oxidizer in the event that biomass is present. Each of these processes separates the biomass into one of three distinct components. a solid that is known as biochar, a liquid that is now known as pyrolysis oil and bio-oil, and a gas that is also called as a synthetic gas that is often consisting of carbon monoxide, hydrogen, short chain alkanes, and carbon dioxide. Because cellulose and lignocellulosic biomass must first be distinguished from one another, the "bio" technique is frequently conceptually analogous to the pulping process in most instances. Investigations have been conducted using a variety of methodologies, such as the traditional pulping approach (Jinn et al., 2010), the steam explosion method (Lavoie et al., 2010), and the organic solvent method (Brosse et al., 2009). The separation of cellulose is a technical drawback. In order to get rid of the vast majority of inhibitors without having to use an excessive amount of energy or chemicals, cellulose needs to be made to the greatest possible purity level.

2.2.1 Advantages:

The biofuels of the second generation are expected to be superior to those of the first generation for a variety of reasons, including the following:

- They make use of non-food elements, such as residues from roots and vegetables, residues from forest products, or lignocellulosic biomass resources, such as materials derived from rapidly developing energy crops. Therefore, second-generation biofuels are distinct from first-generation biofuels in that they are not derived directly from food crops like maize and soybeans like the first-generation biofuels were.
- Fuel is an alternative to traditional fuels that are based on petroleum that can be produced on demand. That is to say, limits are none placed on the combining of substances. It is also possible to utilise it in its natural state, without being mixed with anything else, in vehicles that already exist.
- Biofuels of the second generation are better for the environment and produce fewer greenhouse emissions than the first generation.
- It does not generate any by-products like fodder for animals

2.2.2 Disadvantages

- The production of fuels of the second generation on a commercial basis has not yet begun. This method has not been put through its paces in terms of technological validation because of the large production costs involved.
- The harvesting, storage, and transportation infrastructures that are in place today are not sufficient for the processing and distribution of biomass on a wide scale.
- In order to allow businesses in the industry and the financial sector to give assurance, a policy framework that is both explicit and long-term is required.
- Changing demands on agriculture and forestry to provide biomass raw materials from residues and upland crops have resulted in significant changes to both previous business models and transactions involving raw materials and biofuels. These changes have been brought about by the demand for biomass raw materials from agriculture and forestry.

2.3 Third-generation biofuels:

In this field, biofuels of the third generation are regarded to be relatively new. These biofuels largely consist of algae and trees that develop quickly (Berla et al., 2013). Because there are just a few major facilities, much of the research and development being done right now is on biofuels of the third generation. The cost of the third generation biofuel production process is comparable to that of the second generation biofuel production process, meaning that it is still more expensive than the production process for fossil fuels. There are three distinct types of conversion processes that may be utilised in order to transform algal biomass into sources of energy. H. Conversion of algae via biochemical, chemical, and thermochemical processes, as well as the creation of a biorefinery for algae. Because of this, the manufacture of biofuels of the third generation that are made from the raw materials of algae is still done on a trial scale to this day. Algae, on the other hand, are able to remove carbon dioxide (CO_2) from the atmosphere, create significant quantities of lipids, thrive in a wide range of environments, and develop far more rapidly than terrestrial plants (including second-generation raw materials). Due to this characteristic, algae is an excellent candidate for use as a biomass source in the production of biofuels. Researchers believe that algae will need to play a significant part in the further development of liquid biofuels in the future (Mahapatra et al., 2021).

The production of algal biomass is fraught with various difficulties, some of which are geographical and some of which are technological in nature. Under optimal circumstances for development, algae may generate between 1 and 7 g of biomass per litre per day on average. This indicates that an enormous quantity of water is necessary for its operation on an industrial scale. Countries such as Canada, where temperatures drop below 0 degrees Celsius for a considerable portion of the year, have a tremendous challenge because of this issue. When it is essential to extract lipids from algae contained biomass. It initially should be dehydrated by either centrifugation or filtration before the lipids can be removed, a high water content can also be an issue. This difficulty arises when the water content is high. In order to obtain kerosene grade alkanes that are appropriate for use as drop-in aviation fuels, lipids that are produced from algae can be handled by transesterification using the biodiesel method that was discussed above, or they can be hydro degraded.

3 Methods of bio mass conversion

The conversion of biomass into usable forms of energy is performed via the use of two primary processes: the thermochemical conversion and the biochemical conversion. The process of converting biomass into fuel using thermochemistry may be further subdivided into two categories: high-pressure liquefaction and quick pyrolysis (Perimenis et al., 2011). The following is a list of the methods that are involved in the conversion of the bio mass:

- One of the most important processes involved in the transformation of biomass into biofuels is called pyrolysis. During this procedure, the raw material is heated in an anaerobic environment (one that does not include oxygen), which results in the long-chain molecules being broken down into their corresponding short-chain counterparts.
- The process of carbonation is a form of slow pyrolysis that is largely utilised in the creation of contemporary charcoal.
- Combustion is the process of converting chemical energy into heat, mechanical energy, or electrical energy. This process takes place when biomass is burned in the air.
- Gasification is another type of thermochemical process that makes use of biomass fuels in order to create gaseous products that are high in energy content. Syngas and fuel gas are the primary by-products formed from the burning of a substance.
- The process of liquefaction involves the conversion of biomass or organic matter into liquid hydrocarbons that are stable at high hydrogen pressures while the temperature is kept low.
- In the biochemical conversion process, also known as the biological conversion process, bacteria are utilised in order to convert biomass into gaseous products. This is economically doable and has a wide variety of applications. Fermentation and anaerobic digestion are the two primary processes that take place.
- Fermentation is an anaerobic process that is utilised in the commercial production of ethanol from sugar and starch crops such as sugar cane, sugar beets, and wheat.
- Anaerobic digestion ferments microbial sources without the use of oxygen to release heat, carbon dioxide, as well as methane and hydrogen sulphide.

4. Bio-refinery system

A bio refinery is a facility that incorporates the processes and equipment necessary for the conversion of biomass into fuel, power, and chemicals. These raw materials might come from agricultural, forestry, or waste sources. A bio refinery is a framework or structure that seeks to detoxify, is self-sustaining, and makes best use of biomass in order to create many products.

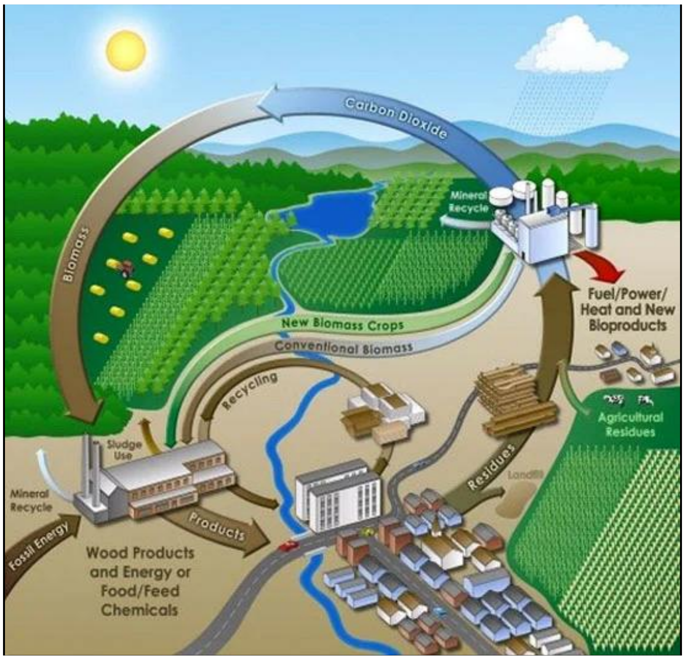

Figure 3. Bio refinery system

This definition describes the bio refinery as a "bio refinery." There are several distinct kinds of bio refineries, and each one serves a particular purpose in the processing of a particular bio material. Among these are:

- A biorefinery that uses grass, green crops, and other green plants.
- A forest and lignocellulosic bio refinery for the processing of lignocellulosic material, which includes polysaccharides, cellulose, and hemicelluloses.
- The wheat, rye, triticale, and maize are some of the raw materials that are utilised at the whole-crop bio-refinery.
- The integrated bio-refinery incorporates a wide variety of additional conversion technologies, such as thermo-chemicals, bio-chemicals, and so on. These technologies, when utilised in conjunction with one another, have the potential to lower economic costs and improve product output.
- A bio-refinery that uses algae to produce algal mass.

5. Conclusion

The production of biofuels is consistently growing in the modern era. The development of biofuel from edible sources appears to offer a more promising, economically feasible, and stable source compared to the production of biofuel from non-edible plant and algal sources, according to trends and statistics. That much is abundantly evident. The effectiveness of the biodiesel sector is contingent on the results of oil recovery in addition to the standard processes that are followed during production and conversion. Traditional methods of producing biofuel may be improved upon by using enzymatic, biochemical, and transesterification processes as alternatives; these improvements will make the processes friendlier to the environment and safer for workers. The use of biofuels from the first generation is a step toward the use of clean and renewable energy. However, gasoline has an advantage in terms of energy density and cost reasons. Even while biofuels of the second generation offer a number of benefits as well, the production of biomass necessitates a number of adaption steps and is in direct competition with agricultural crops used to produce food in some regions of the world. Even while biofuels of the third generation live up to the majority of people's expectations, there is still a significant amount of work that needs to be done in order to bring down the costs of production and make the production of this kind of fuel more economically viable. Concerns have been raised concerning the future of first and second generation biofuels due to a number of factors, including their ethical and environmental impacts as well as their economic viability. However, biofuels of the third generation that are made from algae present are an exciting opportunity for the future of the industry. In addition, as was highlighted in this article, algae have a significant potential to resuscitate the world's energy perspective in a manner that is both extremely cost-effective and environmentally friendly.

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