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A SYSTEMATIC REVIEW OF BIOFUELS: THE CLEANER ENERGY FOR CLEANER ENVIRONMENT

WAHIED KHAWAR BALWAN[a1] AND SACHDEEP KOUR[b]

[a]Department of Zoology, Govt. Postgraduate College Bhaderwah, Jammu & Kashmir, India
[b]Educator at Cypress Fairbanks Independent School District, Jones Rd, Houston, Texas, USA

ABSTRACT

Biofuels are one of the largest sources of renewable energy in use today. Biofuels are a renewable energy source, made from organic matter or wastes that can play a valuable role in reducing carbon dioxide emissions. The main idea behind biofuel is to replace traditional fuels with those made from plant material or other feed stocks that are renewable and more environmentally friendly. The two most common types of biofuels in use today are ethanol and biodiesel, both of which represent the first generation of biofuel technology. Biofuel is commonly advocated as a cost-effective and environmentally benign alternative to petroleum and other fossil fuels, particularly within the context of rising petroleum prices and increased concern over the contributions made by fossil fuels to global warming. Biofuels are a source of cleaner energy to promote a cleaner environment. India initiated bio-fuel production nearly a decade ago to reduce its dependence on imported oil and thus improve energy security and is now one of the largest producers of Jatropha oil. The country began 5% ethanol blending (E_5) pilot program in 2001 and formulated the National Mission on Biodiesel in 2003 to achieve 20% biodiesel blends by 2011–2012 (Government of India, 2002, 2003). Similar to many countries around the world, India's biofuel programs experienced setbacks, primarily because of supply shortages and global concerns over food security. India's National Policy on Biofuels in 2009 proposed a non-mandatory target of a 20% blend for both biodiesel and ethanol by 2017, and outlines a broad strategy for the biofuels program and policy measures to be considered to support the program.

KEYWORDS: Biofuels, Bioenergy, Biomethane, Biogas, Syngas, Ethanol, Bio-alcohols, Biodiesel

Biofuels are a type of energy source that are produced directly or indirectly from organic matter such as biomass including plant or algae material and animal waste (Business Dictionary. Com, 2021). Since such organic material or wastes can be replenished readily, biofuels are considered as a source of renewable energy, unlike fossil fuels such as petroleum, coal, and natural gas.India with a population of 1.38 billion people is set to become the most populous in the world (India Online, 'India's Population 2021'). In recent years, the economy has been growing at roughly 8% per annum (Kumar *et al.*, 2010), which is matched by increasing energy consumption at 8.5% per annum (Central Statistics Office, Govt. of India, 2014). India depends heavily on fossil fuels for meeting its energy demand. The shares of coal, oil, gas, nuclear, hydro, biomass/waste and other renewables in the total primary energy demand in 2012 were 45%, 23%, 6%, 1%, 1%, 24%, and below 0.5% respectively. India has very low reserves of fossil fuels and has to import oil, coal as well gas, the import dependence being particularly high in the case of oil. In 2012, imports accounted for about 75% of India's oil demand; it is projected that the import dependence will grow to 92% of demand in 2035 (IEA, 2012). About 50% of the total oil demand is consumed in the transport sector followed by agriculture (18%) and industry sector (11%). India has been enjoying quite fast economic growth in recent years; commercial energy consumption of the country has also been growing fast, keeping pace with its economic growth. For India, it is vital to reduce dependence on oil for reducing its energy import bill, enhancing energy security and mitigating greenhouse gas (GHG) emissions. Promoting biofuels is thus very important in the case of India (Balwan and Kour, 2021).

India initiated its biofuel programme more than a decade ago and launched several policy measures to promote biofuels since then. In 2002, India launched its Ethanol Blending Programme and mandated a 5% blending of ethanol (E_5) with petrol in nine States and four Union Territories with effect from January 2003 (Bandyopadhay, 2015). The Planning Commission of India constituted a Committee on Development of Biofuels in July 2002. The report of the Committee, released in 2003, recommended India to progressively move towards higher targets regarding blending of biofuels, including strengthening of the ethanol blending programme.

[1]Corresponding author

However, the 5% blending mandate in the case of ethanol could not be met due to shortage of bioethanol supply; in October 2004, the mandate was amended requiring E_5 blends only when adequate ethanol supplies were available (Gunatilake, 2011). In 2006, the 5% blending mandate was extended to cover 20 States and 8 Union Territories; again this target could be met due to shortage of bioethanol supply. In September 2008, the Union Cabinet set a target of 5% blending across the country. Although the 5% target could not be realized, the Government set a target of 10% blending in October 2008.

The Planning Commission report of 2003 recommended launching of a National Mission on Biodiesel to be based on non-edible oil and identified *Jatropha curcas* as the most suitable tree-borne oilseed for biodiesel production (Planning Commission, 2003). One aim of the Mission was to gradually raise the blending target to 20% by the year 2012. The Planning Commission estimated that 11.2 million hectare of land would be required for Jatropha plantation to achieve the 20% target by 2012 and identified 13.4 million hectare of land that could be actually used for plantation. In October 2005 the Ministry of Petroleum and Natural Gas announced a biodiesel purchase policy, which required Oil Marketing Companies to procure biodiesel in the country for blending with diesel with effect from January 2006. In order to strengthen the faltering ethanol and biodiesel blending programs, India's National Biofuel Policy was approved by the Govt. of India in December 2009.

The Goal of the policy is to ensure the ready availability of biofuels to meet demand and proposed an indicative target of 20% blending of biofuels, both for bio-diesel and bio-ethanol, by 2017. The blending target for biodiesel was intended to be recommendatory, while the target for bio-ethanol was supposed to be mandatory. Salient features of the biofuel policy include:

1. Biofuels are to be based solely on non-food feed stocks to be raised on degraded or wastelands that are not suited to agriculture, thus avoiding a possible conflict of fuel vs. food security.
2. Cultivation / plantation of non-edible oil seeds to produce bio-diesel will be encouraged through a Minimum Support Price.
3. Plantations that provide the feedstock for biodiesel and bio-ethanol will be supported through a Minimum Support Price for the non-edible oil seeds used to produce bio-diesel. Further, appropriate financial and fiscal measures will be considered from time to time to support the development of biofuels in the country.
4. Research, development and demonstration will be supported to cover different aspects of feedstock production and processing of biofuels, including development of second generation biofuels.

The Policy document also included interventions and enabling mechanisms regarding plantations, processing, distribution and marketing, financing, financial and fiscal incentives, and research and development. However, the biofuel industry is in a sad state of development currently. In the case of ethanol, the 5% blending target has remained elusive even today. Biodiesel blending in the country remains insignificant; only about half a million hectare has actually planted with Jatropha so far and biodiesel production in the country remains negligible (GAIN, 2014).

BIOENERGY

Bioenergy is energy derived from biofuels. Overall, bioenergy covers approximately 10% of the total world energy demand. Traditional unprocessed biomass such as fuel wood, charcoal and animal dung accounts for most of this and represents the main source of energy for large number of people in developing countries who use it mainly for cooking and heating. More advanced and efficient conversion technologies now allow the extraction of biofuels from materials such as wood, crops and waste material (US Energy Information Administration, 2021).

NEED FOR BIOFUELS

Due to a rise in oil prices and global efforts to avert the worst effects of climate change, there is an urgency to the search for clean and renewable sources of energy such as biofuels. Biofuels are a renewable energy source, made from organic matter or wastes that can play a valuable role in reducing carbon dioxide emissions. Biofuels are one of the largest sources of renewable energy in use today. In the transport sector, they are blended with existing fuels such as gasoline and diesel. In the future, they can be particularly important to help de-carbonize the aviation, marine and heavy-duty road transport sectors. As biofuels emit less carbon dioxide (CO_2) than conventional fuels they can be blended with existing fuels as an effective way of reducing CO_2 emissions in the transport sector (Farrell *et al.*, 2006). The use of biofuels has grown over the past decade, driven largely by the introduction of new energy policies in Europe, USA and Brazil that call for more renewable, lower carbon fuels for transport. Today biofuels represent around 3% of road transport fuels in use around the world. Our road travel, flights, and shipping account for nearly a quarter of the world's greenhouse gas emissions, and transportation today remains heavily dependent on fossil fuels. The idea behind biofuel is to replace traditional fuels with those made from plant material or other feed stocks that are renewable and more environmentally friendly (Wang *et al.*, 1997).

GENERATIONS OF BIOFUELS

First-Generation Biofuels

First- generation biofuels are fuels made from food crops grown on arable land. The crop's sugar, starch, or oil content is converted into biodiesel or ethanol, using trans-esterification, or yeast fermentation.

Second-Generation Biofuels

Second-generation biofuels are fuels made from lignocellulosic or woody biomass, or agricultural residues/waste. The feedstock used to make the fuels either grow on arable land but are byproducts of the main crop, or they are grown on marginal land. Second generation feed stocks include straw, bagasse, perennial grasses, jatropha, waste vegetable oil, municipal solid waste and so forth.

Third-Generation Biofuels

Third-generation biofuels are fuels made from algae. Algae can be produced in ponds or tanks on land, and out at sea. Algal fuels have high yields, can be grown with minimal impact on freshwater resources, can be produced using saline water and wastewater, have a high ignition point, and are biodegradable and relatively harmless to the environment if spilled (Demirbas, 2009). Production requires large amounts of energy and fertilizer, the produced fuel degrades faster than other biofuels, and it does not flow well in cold temperatures. By 2017, due to economic considerations, most efforts to produce fuel from algae have been abandoned or changed to other applications (Greenwell, 2009).

Fourth-Generation Biofuels

Fourth-generation biofuels include electro fuels and solar fuels. Electro fuels are made by storing electrical energy in the chemical bonds of liquids and gases. The primary targets are butanol, biodiesel, and hydrogen, but include other alcohols and carbon-containing gases such as methane and butane. A solar fuel is a synthetic chemical fuel produced from solar energy. Light is converted to chemical energy, typically by reducing protons to hydrogen, or carbon dioxide to organic compounds.

CLASSIFICATION OF BIOFUELS

Biofuels can be classified according to *source* and *type*. They may be derived from forest, agricultural or fishery products or municipal wastes, as well as from agro- industry, food industry and food service by-products and wastes. They may be solid, such as fuel wood, charcoal and wood pellets; liquid, such as ethanol, biodiesel and pyrolysis oils; or gaseous, such as biogas.

A basic distinction is also made between primary (unprocessed) and secondary (processed) biofuels. Primary Biofuels, such as firewood, wood chips and pellets, are those where the organic material is used essentially in its natural form (as harvested). Such fuels are directly combusted, usually to supply cooking fuel, heating or electricity production needs in small- and large- scale industrial applications. Secondary Biofuels in the form of solids (e.g. charcoal), liquids (e.g. ethanol, biodiesel and bio-oil), or gases (e.g. biogas, synthesis gas and hydrogen) can be used for a wider range of applications, including transport and high-temperature industrial processes.

GASEOUS BIOFUELS

Gaseous Biofuels include Biogas, Biomethane and Syngas.

Biogas and Biomethane

Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes. It can be produced either from biodegradable waste materials or by using energy crops fed into anaerobic digesters to supplement gas yields. The solid byproduct, digestate, can be used as a biofuel or a fertilizer. When CO_2 and other impurities are removed from biogas, it is called biomethane (Redman, 2008). Biogas can be recovered from mechanical biological treatment waste processing systems. Landfill gas, a less clean form of biogas, is produced in landfills through naturally occurring anaerobic digestion. If it escapes into the atmosphere, it acts as a greenhouse gas. Farmers can produce biogas from manure from their cattle by using anaerobic digesters.

Syngas

Syngas, a mixture of carbon monoxide, hydrogen and other hydrocarbons, is produced by partial combustion of biomass, that is, combustion with an amount of oxygen that is insufficient to convert the biomass completely to carbon dioxide and water. Before partial combustion, the biomass is dried, and sometimes pyrolyzed. The resulting gas mixture, syngas, is more efficient than direct combustion of the original biofuel; more of the energy contained in the fuel is extracted (Evans, 2008). Syngas may be burned directly in internal combustion engines, turbines or high-temperature fuel cells. The wood gas generator, a wood-fueled gasification reactor, can be connected to an internal combustion engine. Syngas can be used to produce methanol, DME and hydrogen, or converted via the Fischer–Tropsch process to produce a diesel substitute, or a mixture of alcohols that can be blended into gasoline. Gasification normally relies on temperatures greater than 700 °C. Lower-temperature gasification is desirable when co-producing biochar but results in syngas polluted with tar.

LIQUID BIOFUELS

Liquid biofuels include Ethanol, Bio-alcohols, Biodiesel, Green diesel, Straight vegetable oil and Bio-ethers. The two most common types of biofuels in use today are ethanol and biodiesel, both of which represent the first generation of biofuel technology.

Ethanol

Ethanol (CH_3CH_2OH) is a renewable fuel that can be made from various plant materials, collectively known as biomass. Ethanol is an alcohol used as a blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing emissions. The most common blend of ethanol is E_{10} (10% ethanol, 90% gasoline). Some vehicles, called flexible fuel vehicles, are designed to run on E85 (a gasoline-ethanol blend containing 51%–83% ethanol, depending on geography and season), an alternative fuel with much higher ethanol content than regular gasoline. Roughly 97% of gasoline in the United States contains some ethanol. Most ethanol is made from plant starches and sugars, but scientists are continuing to develop technologies that would allow for the use of cellulose and hemicellulose, the non-edible fibrous material that constitutes the bulk of plant matter. In fact, several commercial-scale cellulosic ethanol bio-refineries are currently operational in the United States. The common method for converting biomass into ethanol is called fermentation. During fermentation, microorganisms (e.g., bacteria and yeast) metabolize plant sugars and produce ethanol (Farrell, 2006). Brazil and the United States are among the leading producers of ethanol. In the United States ethanol biofuel is made primarily from corn (maize) grain, and it is typically blended with gasoline to produce gasohol, a fuel that is 10 percent ethanol. In Brazil, ethanol biofuel is made primarily from sugarcane, and it is commonly used as a 100-percent-ethanol fuel or in gasoline blends containing 85 percent ethanol. Unlike the first-generation ethanol biofuel produced from food crops, second-generation cellulosic ethanol is derived from low-value biomass that possesses a high cellulose content, including wood chips, crop residues, and municipal waste. Cellulosic ethanol is commonly made from sugarcane bagasse, a waste product from sugar processing, or from various grasses that can be cultivated on low-quality land. Given that the conversion rate is lower than with first-generation biofuels, cellulosic ethanol is dominantly used as a gasoline additive (Hammerschlag, 2006).

Biodiesel

Biodiesel is a liquid fuel produced from renewable sources, such as new and used vegetable oils and animal fats and is a cleaner-burning replacement for petroleum-based diesel fuel. Biodiesel is nontoxic and biodegradable and is produced by combining alcohol with vegetable oil, animal fat, or recycled cooking grease (Biodiesal.org., 2012). Like petroleum derived diesel, biodiesel is used to fuel compression-ignition (diesel) engines. Biodiesel can be blended with petroleum diesel in any percentage, including B100 (pure biodiesel) and, the most common blend, B20 (a blend containing 20% biodiesel and 80% petroleum diesel).

Green Diesel

Green diesel is produced through hydro cracking biological oil feed stocks, such as vegetable oils and animal fats. Hydrocracking is a refinery method that uses elevated temperatures and pressure in the presence of a catalyst to break down larger molecules, such as those found in vegetable oils, into shorter hydrocarbon chains used in diesel engines. It may also be called renewable diesel, hydro treated vegetable oil (HVO fuel) or hydrogen-derived renewable diesel. Unlike biodiesel, green diesel has the same chemical properties as petroleum-based diesel. It does not require new engines, pipelines or infrastructure to distribute and use, but has not been produced at a cost that is competitive with petroleum. Gasoline versions are also being developed. Green diesel is being developed in Louisiana and Singapore by Conoco Phillips, Neste Oil, Valero, Dynamic Fuels, and Honeywell UOP as well as Preem in Gothenburg, Sweden, creating what is known as Evolution Diesel.

Straight Vegetable Oil

Straight unmodified edible vegetable oil is generally not used as fuel, but lower-quality oil has been used for this purpose. Used vegetable oil is increasingly being processed into biodiesel, or (more rarely) cleaned of water and particulates and then used as a fuel. As with 100% biodiesel (B100), to ensure the fuel injectors atomize the vegetable oil in the correct pattern for efficient combustion, vegetable oil fuel must be heated to reduce its viscosity to that of diesel, either by electric coils or heat exchangers. This is easier in warm or temperate climates. MAN B&W Diesel, Wärtsilä, and Deutz AG, as well as several smaller companies, such as Elsbett, offer engines that are compatible with straight vegetable oil, without the need for after-market modifications. Vegetable oil can also be used in many older diesel engines that do not use common rail or unit injection electronic diesel injection systems. Due to the design of the combustion chambers in indirect injection engines, these are the best engines for use with vegetable oil. This system allows the relatively larger oil molecules more time to burn. Some older engines, especially Mercedes, are driven experimentally by enthusiasts without any conversion. A handful of drivers have experienced limited success with earlier pre-"Pumpe Duse" VW TDI engines and other similar engines with direct injection. Several companies, such as Elsbett or Wolf, have developed professional conversion kits and successfully installed hundreds of them over the last decades. Oils and fats can be hydrogenated to give a diesel substitute. The resulting product is a straight-chain hydrocarbon with a high cetane number, low in aromatics and sulfur and does not contain oxygen. Hydrogenated oils can be blended with diesel in all proportions. They have several advantages over biodiesel, including good performance at low temperatures, no storage stability problems and no susceptibility to microbial attack (Evans, 2008).

Bio-ethers

Bio-ethers (also referred to as fuel ethers or oxygenated fuels) are cost-effective compounds that act as octane rating enhancers. Bio-ethers are produced by the reaction of reactive iso-olefins, such as iso-butylene, with bioethanol (Evans, 2008). Bio-ethers are created from wheat or sugar beets. They also enhance engine performance, while significantly reducing engine wear and toxic exhaust emissions. Although bio-ethers are likely to replace petro-ethers in the UK, it is highly unlikely they will become a fuel in and of itself due to the low energy density. By greatly reducing the amount of ground-level ozone emissions, they contribute to air quality. When it comes to transportation fuel there are six ether additives: dimethyl ether (DME), diethyl ether (DEE), methyl *tert*-butyl ether (MTBE), ethyl *tert*-butyl ether (ETBE), *tert*-amyl methyl ether (TAME), and *tert*-amyl ethyl ether (TAEE). The European Fuel Oxygenates Association (EFOA) identifies methyl *tert*-butyl ether (MTBE) and ethyl *tert*-butyl ether (ETBE) as the most commonly used ethers in fuel to replace lead. Ethers were introduced in Europe in the 1970s to replace the highly toxic compound. Although Europeans still use bio-ether additives, the US no longer has an oxygenate requirement therefore bio-ethers are no longer used as the main fuel additive.

BIOFUEL CONVERSION PROCESSES

Deconstruction

Producing advanced biofuels (e.g., cellulosic ethanol and renewable hydrocarbon fuels) typically involves a multistep process. First, the tough rigid structure of the plant cell wall which includes the biological molecules cellulose, hemicellulose, and lignin bound tightly together must be broken down. This can be accomplished in one of two ways: high temperature deconstruction or low temperature deconstruction.

High Temperature Deconstruction

High-temperature deconstruction makes use of extreme heat and pressure to break down solid biomass into liquid or gaseous intermediates. There are three primary routes used in this pathway Pyrolysis, Gasification and Hydrothermal liquefaction. During pyrolysis, biomass is heated rapidly at high temperatures (500°C–700°C) in an oxygen-free environment. The heat breaks down biomass into pyrolysis vapor, gas, and char. Once the char is removed, the vapors are cooled and condensed into a liquid bio-crude oil. Gasification follows a slightly similar process; however, biomass is exposed to a higher temperature range (>700°C) with some oxygen present to produce synthesis gas (or syngas) a mixture that consists mostly of carbon monoxide and hydrogen. When working with wet feed stocks like algae, hydrothermal liquefaction is the preferred thermal process. This process uses water under moderate temperatures (200°C–350°C) and elevated pressures to convert biomass into liquid bio-crude oil.

Low Temperature Deconstruction

Low-temperature deconstruction typically makes use of biological catalysts called enzymes or chemicals to breakdown feed stocks into intermediates. First, biomass undergoes a pretreatment step that opens the physical structure of plant and algae cell walls, making sugar polymers like cellulose and hemicellulose more accessible. These polymers are then broken down enzymatically or chemically into simple sugar building blocks during a process known as hydrolysis.

UPGRADING

Following deconstruction, intermediates such as crude bio-oils, syngas, sugars, and other chemical building blocks must be upgraded to produce a finished product. This step can involve either biological or chemical processing. Microorganisms, such as bacteria, yeast, and cyanobacteria, can ferment sugar or gaseous intermediates into fuel blend stocks and chemicals. Alternatively, sugars and other intermediate streams, such as bio-oil and syngas, may be processed using a catalyst to remove any unwanted or reactive compounds in order to improve storage and handling properties. The finished products from upgrading may be fuels or bio products ready to sell into the commercial market or stabilized intermediates suitable for finishing in a petroleum refinery or chemical manufacturing plant.

ECONOMIC AND ENVIRONMENTAL CONSIDERATIONS

In evaluating the economic benefits of biofuels, the energy required to produce them must be considered. For example, the process of growing corn to produce ethanol consumes fossil fuels in farming equipment, in fertilizer manufacturing, in corn transportation, and in ethanol distillation. In this respect, ethanol made from corn represents a relatively small energy gain; the energy gain from sugarcane is greater and that from cellulosic ethanol or algae biodiesel could be even greater.

Biofuels also supply environmental benefits but, depending on how they are manufactured, can also have serious environmental drawbacks. As a renewable energy source, plant-based biofuels in principle make little net contribution to global warming and climate change; the carbon dioxide (a major greenhouse gas) that enters the air during combustion will have been removed from the air earlier as growing plants engage in photosynthesis. Such a material is said to be "carbon neutral." In practice, however, the industrial production of agricultural biofuels can result in additional emissions of greenhouse gases that may offset the benefits of using a renewable fuel. These emissions include carbon dioxide from the burning of fossil fuels during the production process and nitrous oxide from soil that has been treated with nitrogen fertilizer. In this regard, cellulosic biomass is more beneficial.

Land use is also a major factor in evaluating the benefits of biofuels. The use of regular feedstock, such as corn and soybeans, as a primary component of first-generation biofuels sparked the "food versus fuel" debate. In diverting arable land and feedstock from the human food chain, biofuel production can affect the economics of food price and availability. In addition, energy crops grown for biofuel can compete for the world's natural habitats. For example, emphasis on ethanol derived from corn is shifting grasslands and brush lands to corn monocultures, and emphasis on biodiesel is bringing down ancient tropical forests to make way for oil palm plantations. Loss of natural habitat can change the hydrology, increase erosion, and generally reduce biodiversity of wildlife areas. The clearing of land can also result in the sudden release of a large amount of carbon dioxide as the plant matter that it contains is burned or allowed to decay (Balwan and Kour, 2021).

Some of the disadvantages of biofuels apply mainly to low-diversity biofuel sources like corn, soybeans, sugarcane, oil palms which are traditional agricultural crops. One alternative involves the use of highly diverse mixtures of species, with the North American tall grass prairie as a specific example. Converting degraded agricultural land that is out of production to such high-diversity biofuel sources could increase wildlife area, reduce erosion, cleanse waterborne pollutants, store carbon dioxide from the air as carbon compounds in the soil, and ultimately restore fertility to degraded lands. Such biofuels could be burned directly to generate electricity or converted to liquid fuels as technologies develop.

The proper way to grow biofuels to serve all needs simultaneously will continue to be a matter of much experimentation and debate, but the fast growth in biofuel production will likely continue. In the United States the Energy Independence and Security Act of 2007 mandated the use of 136 billion litres (36 billion gallons) of biofuels annually by 2022, more than a six fold increase over 2006 production levels. The legislation also requires, with certain stipulations, that 79 billion litres (21 billion gallons) of the total amount be biofuels other than corn-derived ethanol, and it continued certain government subsidies and tax incentives for biofuel production (Karatzos *et al.*, 2014).

One distinctive promise of biofuels is that, in combination with an emerging technology called carbon capture and storage, the process of producing and using biofuels may be capable of perpetually removing carbon dioxide from the atmosphere. Under this vision, biofuel crops would remove carbon dioxide from the air as they grow, and energy facilities would capture the carbon dioxide given off as biofuels are burned to generate power. Captured carbon dioxide could be sequestered (stored) in long-term repositories such as geologic formations beneath the land, in sediments of the deep ocean, or conceivably as solids such as carbonates (Dinh *et al.*, 2009, Tomas-Pejo and Moreno, 2017).

FUTURE OF BIOFUELS

Biofuel is commonly advocated as a cost effective and environmentally benign alternative to petroleum and other fossil fuels, particularly within the context of rising petroleum prices and increased concern over the contributions made by fossil fuels to global warming.In 2019, worldwide biofuel production reached 161 billion liters (43 billion gallons US), up 6% from 2018, and biofuels provided 3% of the world's fuels for road transport. The International Energy Agency (IEA) want biofuels to meet more than a quarter of world demand for transportation fuels by 2050, in order to reduce dependency on petroleum. However, the production and consumption of biofuels are not on track to meet the IEA's sustainable development scenario. From 2020 to 2030 global biofuel output must increase by 10% each year to reach IEA's goal. However, only 3% growth annually is expected the next 5 years.

CONCLUSION

The key consideration while reviewing the advantages of biofuels compared to fossil fuels is that the biofuels play a vital role in reducing the carbon intensity. Biofuels play a significant role in reducing the carbon footprint of transportation and other industries, by making the most of our planet's carbon cycle. Every gallon of biofuel that replaces a gallon of fossil fuel helps reduce greenhouse-gas emissions. Thus, replacing fossil fuels with biofuels has the potential to reduce some undesirable aspects of fossil fuel production and use, including conventional and greenhouse gas (GHG) pollutant emissions, exhaustible resource depletion, and dependence on unstable foreign suppliers. To conclude, biofuels have the potential to generate several benefits. In contrast to fossil fuels, which are exhaustible resources, biofuels are produced from renewable feed stocks. Biofuels can be produced domestically, which could lead to lower fossil fuel imports. Biofuels may reduce some pollutant emissions e.g. ethanol ensures complete combustion, reducing carbon monoxide emissions. Last but not the least, demand for biofuels could also increase farm income. There is no doubt that biofuels are a source of cleaner fuels to promote a cleaner environment!

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