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A Review on Recent Advances in Bio-Fuel Development

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Abstract: *For the concurrent energy researches around the world, the question of energy availability and the effects of global warming have taken on particular importance. This situation creates room for prospective, more modern and sustainable alternative energy sources. In the industrial, automotive and even as a fuel source for power plants, biodiesel can be used as a sustainable alternative energy. This study offers a detailed overview of the use and advancement of bio-diesel as a fuel for the production of renewable energy from material sources. The creation of various bio-diesel mixture combinations and their use in diverse sectors is a key topic covered in this study. In order to use different types of biodiesel in different parts of the world, its physical and chemical properties have been researched. Although the use of biodiesel reduces emissions and pollutants, a specific approach is required to maximise efficiency and effectiveness, both technically and non-technically. However, the use of biodiesel together with the optimization of its properties and parameters demonstrates that this alternative energy is practical and might be used as a sustainable fuel source for the auto industry and electricity generation in the future.*

Keywords: Bio-diesel, bio-fuel, bio-mass, emission, feedstock

I. INTRODUCTION

All organic resources originating from plants and animals are used as bio-mass for energy. Wood and its waste, agricultural crops and their waste by products, solid waste from cities, food waste, aquatic plants, and algae are all examples of biomass resources. In contrast, biodiesel specifically refers to gaseous and liquid fuels made from biomass, according to FAO. Generally speaking, primary and secondary bio-fuels are the two categories into which bio-fuels fall. The main bio-fuels are firewood, animal waste, landfill gas, wood chips, and pellets, which are often utilised in their natural state for heating, cooking, and even the generation of electricity. While both bio-diesel and bio-ethanol, which are frequently utilised as fuel and in a variety of industrial operations, make up secondary bio-fuel. Because it is derived from renewable resources and has positive environmental effects, biodiesel has recently gained in popularity. A way of choice to reduce manufacturing costs is a continuous transesterification process [1-3]. Researchers from many nations conducted experimental studies using biodiesel and vegetable oils as alternatives to petroleum fuel. The performance and emission parameters of vegetable oil methyl esters were comparable to those of diesel. Vegetable oils' viscosity and un-saturation levels are reduced as a result of the process of transesterification, which alters the molecular structure of the oil molecules. Vegetable oil's viscosity is significantly lowered during transesterification. Diesel's cetane number was raised by adding little mixture biodiesel to mineral diesel. It was discovered that biodiesel has a little lower calorific value than mineral diesel. All of these tests for characterising biodiesel showed that almost all of its key characteristics are remarkably similar to those of mineral diesel, making it a viable choice for use in CI engines. Without changing the engine components, a diesel engine can operate effectively on biodiesel blends [4-6]. A long-term endurance test with biodiesel demonstrated its viability as a long-term replacement for mineral diesel. The 20% biodiesel blend was discovered to be the ideal biodiesel blend concentration, which improved the engine's peak thermal efficiency by 2.5% and significantly decreased exhaust emissions and brake specific energy consumption. The use of biodiesel in the engine resulted in a noticeable reduction in smoke emissions. It has been discovered that transesterification is a useful strategy for preventing various long-term issues related to the use of vegetable oils, such as fuel filter blockage, injector coking, the development of carbon deposits in combustion chambers, ring sticking, and contamination of lubricating oils. In systems powered by biodiesel, the carbon build-up on piston tops and injector coking was significantly decreased [7-10]. The extra lubricity qualities of biodiesel helped to minimise the wear of many important parts by up to 30%. Atomic absorption spectroscopy also supported these physical approach results of wear evaluations. Studies on oil analysis have proven to be an effective method for estimating the state of various moving elements in addition to engines. Ash content, which primarily refers to wear debris, was discovered to be lower in systems powered by 20% biodiesel. In one of the most fascinating experiments ever done on lubricants, the wear of crucial engine components including pistons, piston rings, cylinder liners, etc. was estimated [11-15]. A thorough experimental examination was done to determine how biodiesel blend (B20) compared to mineral diesel in terms of combustion properties. The results of the experimental tests showed that mineral diesel and the biodiesel blend (B20) had generally similar combustion properties. However, in the case of B20, combustion begins earlier. Compared to mineral diesel, B20 has a shorter ignition delay and a somewhat longer combustion time. During the premixed combustion phase, B20 was shown to have a lower heat release rate than diesel. In the case of B20, the overall heat release is less than with mineral diesel. There were no fuels or combustion-related issues with the 20% blend of rice bran oil methyl ester [16-17]. This thorough experimental examination demonstrates that biodiesel can replace mineral diesel without requiring any engine modifications. Consequently, biodiesel can be used as an alternative to diesel fuel. The use of bio-fuels as the fuel for IC engines can significantly aid both developed and developing nations in reducing the negative environmental effects of fossil fuels. Similar to wind energy, biomass-based energy is regarded as a promising renewable energy source; nevertheless, conventional biomass-based energy applications in underdeveloped countries. It has been used for a very long period in a country like India. Therefore, for improved promotion and implementation of biomass energy systems, all stakeholders—especially policymakers, business, and the scientific community—need to put up more sustained effort into the development and deployment of biomass-based energy generation. Today's prospective alternative for global energy and environmental security is bio-fuels (solid, liquid, and gaseous). By converting solar energy into chemical energy through the process of photosynthesis, bio-energy, a secondary renewable energy source, can significantly contribute to maintaining the ecosystem's energy balance. The biomass-based renewable energy is becoming into a significant alternative energy source on a global scale as a result of environmental deterioration, anthropogenic climate change, and global warming. Currently, bio-mass only makes up a small portion of the global production of bio-fuels; the majority still comes from petroleum. But in the future, more people are anticipated to want affordable clean fuel [18-19].

The major emerging nations, including India, are continuously struggling to attain sustainable growth as a result of rising energy demand and continuous and unanticipated fluctuations in fuel prices. Similary, the severe health and environmental dangers associated with biomass as a conventional residential energy source must be addressed as soon as possible. The study conducted by several groups focused on the health and environmental risks connected to home energy consumption, notably the inefficient burning of woody biomass, agro-waste, and cow dung cakes in conventional cook stoves [20-23]. Due to their utilisation and compatibility in the transportation sector, liquid bio-fuels are becoming more popular among the many commercial fuel textures. Additionally, the implications of the newly developed bio-energy policy and its successful execution, as well as the governmental framework and tactics related the promotion of the bio-energy industry, are all clearly defined. The Indian government has also started a national biogas and bio-manure programme and provided funding for the construction of biogas plants in an effort to attain sustainability in energy supply through the agriculture sector. There have been a number of different national programmes, such as the National Program for Improved Cook stoves (NPIC) and, later, the Unnat Chulha Abhiyaan (UCA), which built up four world-class test centres at various locations to support the bio-mass industry in the nation. The potential benefits and solutions for the environment in terms of enhanced biomass cook stoves, fuel wood consumption, and its impact on atmospheric carbon stock have been noted in the United Nations Millennium goals and are extremely well documented earlier by the investigators in different parts of the world. Despite these attempts, the country is still experiencing a number of obstacles for bio-energy technology, so several technical concerns like affordability and durability were also covered. Therefore, advanced biomass energy applications are necessary to maximise biomass energy efficiency while posing less environmental danger. In-depth research and development (R&D) strategies focused on field implementation were also investigated and considered as potential solutions to these problems. Therefore, a special issue of Bio-fuels has been devoted to Latest Advances in Bio-fuels in India, in order to

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highlight the recent advancements in this field, due to the high potential and crucial nature of bio-fuels. This review covers the advances in Bio-fuels development was to present the current trends and the potential benefits that society and industry could derive from both bio-energy and bio-fuels as well as to offer feedback to researchers on bio-energy energy and its connections to bio-fuels, biomass, and future development. In order to help various stakeholders, including but not limited to policymakers, academics, and businesspeople, join forces with concrete efforts that will lead to the techno-economic viability of this sector, the major goal of the special issue is to present recent trends for understanding the complexities associated with bio-fuels and possible roadmaps in the area of bio-energy. Additionally, the technological viability of using waste materials for bioelectricity, using microbial fuel cells, and pre-treating materials for bio-energy choices are also offering fresh insights for upcoming studies in the field of alternative energy. Similar efforts are made with processed solid bio-fuels (pellets), which are commonly employed in the heating and culinary sectors, employing improved combustion equipment with significantly lower pollution emission and higher thermal efficiency [24-29].

The current review, in contrast, presents numerous aspects of biomass and bio-fuels that are relevant to their production, promotion, management, and application. In-depth explanations of technologies like pre-treatment technology and the notion of a bio-refinery were also offered, along with information on the status and potential of liquid and gaseous bio-fuels in national and international contexts [30-31].

By exchanging knowledge and fostering constructive conversation, this review will contribute to describing and resolving the issues that bio-mass and bio-fuels are currently experiencing. It is hoped that such review, will improve both the current and long-term prospects for biomass and bio-fuels internationally in sustainable development of society.

II. BIO-FUEL MIXTURES AND PRODUCTION

Bio-fuel can be produced from different feed stocks (Fig. 1) from both edible and non-edible oils, will yield various compositional values (Table-1) and purities, highly dependent on its technical and nontechnical feasibility, such as cost factors and the resulting purity value. On the other hand, the use of a specific feedstock will depend on the conditions and capabilities of a country based on biological diversity.

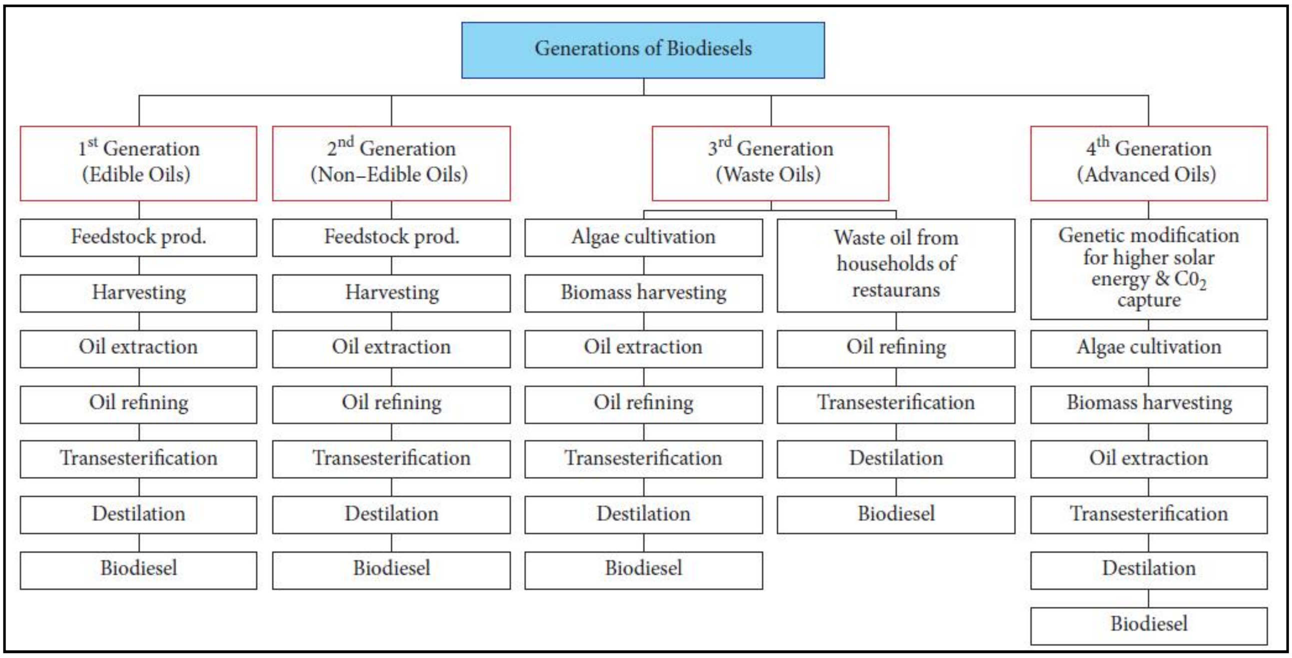


Figure 1: Production of bio-diesel from different feed stocks

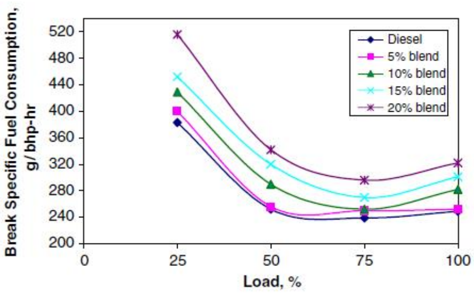
Tropical countries, such as Indonesia and Malaysia, produce more biodiesel with a mixture of palm oil, considering the fact that the production of Crude Palm Oil (CPO) is very abundant. European countries, such as France and Italy, mostly use sunflower and rapeseed oils, while the United States mainly uses soybean oil and India uses its abundant sal, mahua, neem, and Pongamia pinnata oils. Biodiesel mixtures from edible vegetable oils that are often used include soybean oil, rapeseed oil, sunflower oil, canola oil, palm oil, coconut oil, olive oil, peanut oil and mustard oil. Meanwhile, the nonedible vegetable oils that are usually used are Jatropha oil, malapari or Karanja (Pongamia pinnata) oil, neem oil, linseed oil, rubber seed oil, castor oil, stillingia oil and Silybum marianum oil [32-37].

Table 1: Percentage of oil content in different feed Stock

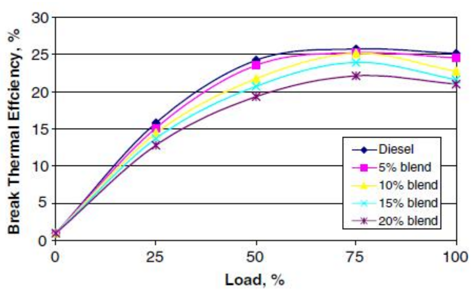
Feed stock	Oil content (%)
Soybean	15-20
Sun flower	25-35
Palm	30-60
Coconut	63-65
Neem	20-30
Castor	45-50
Jatropha	30-40

III. PRODUCTION AND USE OF BIO-FUEL

The process of transesterification involves replacing the alkoxy group on an ester molecule with an alcohol. A base or an acid is frequently used to catalyse the reactions. For the creation of biodiesel from biolipids, transesterification is essential. A triglyceride (fat/oil) and a bio-alcohol combine during the transesterification process to produce esters and glycerol. Vegetable oils must go through the transesterification process in order to be used in internal combustion engines. Transesterification produces biodiesel as a byproduct. Biodiesel is a renewable fuel that may be made from plant and agricultural resources. It is biodegradable, non-toxic, and essentially sulfur-free. Sustainable development, energy management, efficiency, and environmental preservation are all related to biodiesel, an alternative fuel. The process of transesterification creates esters and glycerol when a fat or oil reacts with an alcohol. Glycerol and esters are produced when alcohol and triglycerides mix. Typically, a catalyst is utilised to increase the yield and rate of the reaction. Excess alcohol is needed to move the equilibrium to the product side because the reaction is reversible. Methanol, ethanol, propanol, butanol, and amyl alcohol are some of the alcohols that can be utilised in the transesterification process [38-41]. When considered from the perspective of palm oil, the production of biodiesel has an advanced trend and grows yearly. It significantly affects the likelihood of widespread biodiesel adoption in the automobile and power generation industries. In this instance, palm oil and Jatropha curcas make up the majority of the raw materials used to produce biodiesel [42-44]. Jatropha can be used to produce biodiesel since it doesn't compete with crops that are used to make food, is harmful to animals, has the potential to grow into a new business for the neighbourhood, and its manufacturing processes can be more decentralised. This plant may also easily adapt to a variety of soil types, including clay with good drainage, sand, and soil with a high mineral concentration. One potential alternate fuel for partially replacing conventionally used diesel fuel in CI engines is ethanol. The use of ethanol as a supplemental fuel may help to conserve a significant commercial energy source by lowering environmental pollution, boosting the agricultural economy, creating jobs, and reducing the need for diesel. The impact of employing various ethanol-diesel (diesohol) mixes on brake-specific fuel consumption and brake thermal efficiency shown in Fig. 2. At a 5% level of significance, the results show no appreciable power loss in engine operation while using ethanol-diesel mixes (up to 20%). When compared to conventional diesel, the mixes' brake-specific fuel consumption increased by up to 9% (with ethanol up to 20%). When using ethanol-diesel blends instead of pure diesel, exhaust emissions (CO and NO_x) were all lower. In today's constant speed CI engines, ethanol-diesel mixtures up to 20% can very well be used without any modifications. When greater ethanol blends are utilised, the fuel consumption for brakes is somewhat increased, as illustrated in Fig. 2 [45-47]. According to Fig. 2, there is no discernible difference between the power generated and the engine's thermal efficiency. Figs. 3 show that ethanol-diesel mixes as compared to diesel alone, the usage of ethanol-diesel blends can reduce CO emissions by up to 62%. Using ethanol-diesel blends also results in a reduction in NO_x emissions (up to 24%). The amount of aldehydes released during combustion is somewhat higher when ethanol is added to gasoline. The three-way catalytic converter included in the exhaust systems of all new contemporary vehicles, however, successfully reduces the resulting concentrations, which are incredibly low. The Reid vapour pressure increases when ethanol is added to fuel up to 10% by weight, which indicates that ethanol blends have higher evaporative emissions. Ethanol addition to gasoline often reduces benzene and toluene emissions, yet the catalyst's functioning also negated this favourable effect of ethanol [48-49]. Only the base and the 3% ethanol blend fuel showed acetic acid to be present in exhaust emissions in some instances. Acetaldehyde emissions rise as ethanol percentage in the gasoline blend rises. It is probable that additional acetaldehyde emissions are produced from ethanol fueling in specific operating circumstances since acetaldehyde is an intermediate product from the partially oxidised quenched fuel. Additionally, it has been found that the amount of ethanol in the mix and engine load have a direct correlation with acetaldehyde emissions. Acetaldehyde emissions gradually decrease as engine load rises from idling to their minimum at medium loads, then rise once again at high engine loads. Acetaldehyde emissions are high at high loads due to a thick quenching layer created by the high ethanol content in the fuel as well as low acetaldehyde oxidation rates at low engine loads because of low combustion temperatures and exhaust gas temperatures. To evaluate the effects of ethanol-blend fuels, additional toxic emissions that are unregulated should be taken into account, such as acetaldehyde, formaldehyde, propionaldehyde and acrolein, as well as benzene, ethylbenzene, 1-3 butadiene, acrolein, hexane, toluene, xylene, and fine particulate matter. The ethanol-blended gasoline lowered benzoene emissions by up to 50%. As the ethanol content in the gasoline grew from 0% to 20%, a clear trend of decreased HC and CO emissions and increased NOx emissions was seen (Fig. 3). The standard car was found to run at air/fuel ratios that were considerably richer than stoichiometric, with an average air/fuel ratio of about 12.2:1 when running on gasoline across the FTP cycle. When run on gasoline alone, this amounts to an equivalency ratio of roughly 1.2. The tendency can be the inverse for leaner base circumstances, with HC emissions rising and NOx emissions falling as the ethanol content of the fuel is raised. Without any hardware modifications, diesel engines may operate satisfactorily on biodiesel for extended periods of time. The ideal biodiesel mix has a biodiesel content of 20% for increased performance. However, higher exhaust temperatures also result in higher engine NOx emissions. Long-term usage of neat vegetable oils or their blend with diesel causes a number of engine difficulties, including injector coking, ring sticking, injector deposits, etc., even when short-term testing are almost positive. The main reasons of numerous issues related to the direct use of these oils as fuels are their high viscosity, limited volatility, and propensity for polymerization in the cylinder. Due to its enhanced viscosity and volatility, vegetable oil ester produced via the transesterification process has showed promise as a substitute for diesel fuel [50-51].



(a)



(b)

Figure 2: Effect of alcohol blends on diesel (a) Brake specific fuel consumption (b) Break thermal efficiency.

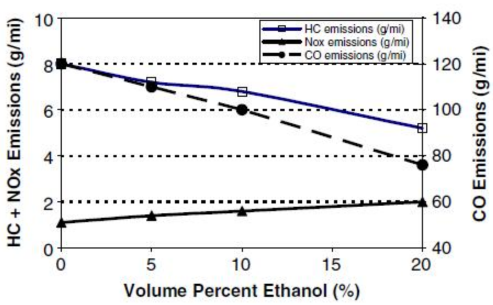


Figure 3: Emission characteristics of ethanol blend diesel fuels.

IV. RECENT DEVELOPMENT AND FUTURE SCOPE

Because it is derived from renewable resources and has positive environmental effects, biodiesel has recently gained in popularity. A way of choice to reduce manufacturing costs is a continuous transesterification process. Researchers from many nations conducted experimental studies using biodiesel and vegetable oils as alternatives to petroleum fuel. The performance and emission parameters of vegetable oil methyl esters were comparable to those of diesel. Vegetable oils' viscosity and unsaturation levels are reduced as a result of the process of esterification, which alters the molecular structure of the oil molecules. Vegetable oil's viscosity is significantly lowered during esterification. Diesel's cetane number was raised by adding 20% biodiesel to mineral diesel. It was discovered that biodiesel has a little lower calorific value than mineral diesel. All of these tests for characterising biodiesel showed that almost all of its key characteristics are remarkably similar to those of mineral diesel, making it a viable choice for use in CI engines. Without changing the engine components, a diesel engine can operate effectively on biodiesel blends. A long-term endurance test with biodiesel demonstrated its viability as a long-term replacement for mineral diesel. The best biodiesel mix concentration significantly decreased exhaust emissions and brake energy use while increasing the engine's peak thermal efficiency by 2.5%. The use of biodiesel in the engine resulted in a noticeable reduction in smoke emissions. It has been discovered that transesterification is a useful strategy for preventing various long-term issues related to the use of vegetable oils, such as fuel filter blockage, injector coking, the development of carbon deposits in combustion chambers, ring sticking, and contamination of lubricating oils. In systems powered by biodiesel, the carbon build-up on piston tops and injector coking was significantly decreased. The extra lubricity qualities of biodiesel helped to minimise the wear of many important parts by up to 30%.

In terms of life-cycle water use, criterion air pollutants, land use effects, and greenhouse gas emissions, various bio-fuel feed stocks and production methods have varying consequences. Therefore, any policy aimed at these more general problems may alter, which could affect the production and usage of bio-fuels. Because maize-based ethanol needs an additional refinement step to separate the sugars in the corn, sugar-based ethanol naturally has a lower carbon footprint than corn-based ethanol. Therefore, rules mandating reduced life cycle greenhouse gas emissions may force a switch from ethanol production based on corn to ethanol based on sugar cane, and as a result, may force a switch from locally produced ethanol to ethanol from foreign producers, increasing transportation costs. Increased demand for agricultural lands, water resources, and sustainability in general will result from the proposed massive increase in bio-fuel production over the coming decade. This might potentially bring bio-fuels in conflict with other more general social objectives. For instance, a recent research on algal-based bio-fuels, a potentially viable source of advanced bio-fuels, revealed a variety of sustainability issues, including water availability, the availability of adequate acreage, and life-cycle greenhouse gas emissions, among others. To ensure the sustainable production and use of bio-fuels, research is required in areas such metabolic engineering, processing subsidies, tax immunity, feedstock identification, equipment development, engine modifications, land use laws, and the use of artificial intelligence. To make bio-fuel production and use worthwhile and sustainable, political leaders from diverse jurisdictions, legislators, financiers, investment analysts, and other development partners must work together. To fully profit from the advantages of using bio-fuel as a transport vehicle fuel, more creative research and technologies that enable the optimal use of bio-fuels as flexible hybrid fuels are required. This is due to the growing popularity of EVs. Utilizing bio-fuels is encouraged and greatly motivated by the need to reduce GHG and other emissions, but for this to happen gradually, the necessary infrastructure and policy framework must be in place. Bio-fuels can be powerful forces for a cleaner environment through waste minimization, correct waste disposal, efficient waste conversion, and climate change mitigation when the necessary conditions and context are present. However, sufficient restrictions are needed because the amount of land, infrastructure, technical know-how, and sustainable practises that are available will limit how much bio-fuel can be deployed sustainably. To guarantee that the lifecycle emissions from bio-fuel deliver significant savings compared to FB fuels, effective policies, education, awareness campaigns, and programmes, as well as increased research and development projects, are required. To guarantee that GHG emissions are not produced during the processes of conversion and deployment in the bio-fuel value chain, there is a need for suitably sustainable frameworks and methods. Building co-cultivation systems for the production of chemicals and bio-fuels has become more and more popular in recent years. Co-cultivation has developed beyond just combining different wild strains and now includes synthetic biology. Future success of synthetic biology and its applications will be considerably enhanced by the addition of synthetic intercellular communication to the cell engineering toolkit. Even if co-cultivation systems could increase production, there are still difficulties. Studies on co-cultivation systems are currently mostly restricted to the levels of intermediate metabolite exchange. We still don't know much about other aspects of environmental variance, like energy flux, signal exchange, and food cycling. The advancement of robustness, stability, and reproducibility can only be made on the basis of a thorough understanding of the interactions between bacteria. Only roughly 25% of this consumption is now met by India's gross domestic production of crude oil. Dependence on imported fuels leaves many nations exposed to supply disruptions, which could cause physical hardships and financial pressures. Oil price volatility puts the world's economic and political stability at serious danger, with particularly dramatic consequences for poorer countries that import energy. Bio-fuels and other forms of renewable energy can help to diversify the energy sector's supply and improve energy security. Strong power and fuel efficiency are provided by the diesel-fueled MCCI engines normally seen in commercial freight trucks, but to comply with emission rules, expensive and complicated control systems are needed. Many proposed MCCI blend stocks have the potential to minimise life cycle GHG emissions by more than 60% compared to traditional petroleum-derived diesel while still meeting production and operating cost requirements for commercial vehicles. The third-generation bio-fuels are still in the early stages of development. Following a target, the financial viability of these cycles will be looked after. Lab-scale cycles must be accelerated during commercialization in order to increase yields and productivities [52-54].

V. CONCLUSION

Internal combustion engines have experienced unceasing expansion due to its limitations like as the environment pollution, poor efficiency, limited stock of operating fossil fuels and sturdier design due to operating mechanism. With superior thermal and chemical qualities to all fossil fuels, the bio-fuels were developed as the ideal alternative fuel. The leaning effect brought on by the addition of the ethanol significantly lowered the CO and HC emissions, while the increased burning resulted in significant reduction in CO_2 emissions. Utilizing oxygen and additives containing methyl ester substantially reduces fuel consumption. Due to the high latent heat of ethanol vaporisation, a decrease in NOx emissions was achieved with the addition of little ethanol. By adding ethanol and methyl ester to petroleum products, the octane and cetane numbers are substantially increased. The internal combustion engine may therefore run at higher compression ratios gives better efficiencies. The use of mixed biodiesel also ameliorates brake power and torque while lowering BSFC. This review provided an outline of the growth of biodiesel as an alternative and renewable fuel for the automobile and power generation industries. The use of biodiesel in the automobile sector and for energy production offers several advantages, both technological and financial. As a potential alternative energy source, bio-diesel offers a wide range of feedstock options that required to be investigated further in near future for its possible wide use in power plants and automobiles. Thus, the use of bio-fuels in internal combustion engines can play a vital role in helping the developed and developing countries to reduce environmental pollution and budgetary impact of fossil fuels.

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