[1]Trushna Shah
[2]Dr.Samruddhi Patel
[3]Sumit Banker
[4]Tejal Chaudhari

A Review paper on Recent Progress of Biofuel in Transportation Sector

Journal of Electrical Systems

Abstract: - The declining supply of gasoline generated from petroleum and sustainability issues have prompted an examination of biofuel as a potential substitute energy resource. Biofuels can be a suitable substitute for fossil fuels and have a larger role in providing energy for the transportation sector, power plants, and heat generating sectors because they are environmentally friendly and derived from renewable sources. These days, investigation into biofuels is conducted all over the world due to its two primary characteristics: sustainability and renewability. Since the transportation sector is primarily responsible for the rise in greenhouse gas emissions, significant decarbonization of the transportation sector through the use of renewable fuels is required to facilitate the transition to more efficient modes of transportation. The purpose of the study is to analyze the many sources of biofuels, explain their benefits and sustainability, and examine the manufacturing processes. The evolution, history, categorization, essential elements, and guiding concepts of biofuel technology are all examined in this review paper.

Keywords: Biofuel, Electric Vehicle, conventional fuel, transportation

I. INTRODUCTION

Humanity is currently facing three key issues: hunger, energy scarcity, and environmental degradation. Fighting all three fierceness at once is necessary due to each one of them has the power to wipe out our culture as a whole. The amount of energy consumed worldwide has nearly doubled recently[1], with fossil fuels accounting for more than 80% of this increase. Approximately 80.3% of the world's fundamental energy usage comes from fossil fuels, with the transportation segment consuming 57.7% of this total. [2] Utilization of fossil fuels are related to prevalent environmental concerns today. Burning of conventional fuels results in the harmful emissions of greenhouse gases such as carbon dioxide (CO2), nitrogen oxide (NOx), volatile organic compounds (VOC) and hydrocarbons (HC); incremental for the climate changes [3]–[5] The warming climate issue is currently posing a threat to the world (IPCC 2014). Promoting biofuel as one of the top renewable energy sources has gained attention due to the release of carbon dioxide, which is a major byproduct of burning fossil fuels[6]The use of renewable biofuel as an energy source has grown significantly over the past 20 years due to the depletion of fossil fuel resources and associated environmental consequences. Over the next ten years, biofuel's share of global transportation fuels appears to be roughly 5%. However, a number of estimates suggest that by 2050, biofuel might account for up to 25% of the fuel supply used in transportation.[7]

Renewable manufacture of biofuel can help reduce global warming [8], strengthen local economies, especially in developing nations[9], [10] and improve global energy security[11], [12]. Development of sustainable biofuel alternatives; persistence in finding an approach to the twin challenges of depleting fossil fuel reserves and degradation of the surroundings [13]. Consequently, it is imperative that new, renewable, clean, dependable, and economically viable energy sources be explored[14] The major benefits of biofuel are presented in the table 1 Hence, due to depleting oil reserves, the need for energy security, and growing environmental concerns brought on by growing emissions of greenhouse gases and environmental degradation, biofuels have gained a lot of attention recently.

Table 1.1 Major benefits of biofuels[15], [16]

Commercial value	Variety in fuel mix More sustainable Ability to create many rural jobs Can increased the government revenue through taxes Industrial investments (plant and equipment) will be increased Farming/agricultural sector can be developed Less international competition Independence from imported petroleum

[1]*Corresponding author: Trushna Shah, Department of Electrical Engineering, Government Engineering College, Modasa, Gujarat,India
[2]Dr.Samruddhi Patel: Department of Mechanical Engineering, Government Engineering College, Modasa, Gujarat,India
[3]Sumit Banker: Department of Electrical Engineering, Government Engineering College, Modasa, Gujarat,India
[4]Tejal Chaudhari: Department of Electrical Engineering, Government Engineering College, Modasa, Gujarat,India

Climate change effects	Reduction in release of greenhouse gases Air pollution can be minimized Easy for biodegradation Better combustion efficiency Better carbon sequestration
Indigenous impacts	To achieve the domestic targets More reliability in supply Reduced utilization of fossil oils Ready availability Indigenous distribution

II. Overview of Biofuel Vehicles

Fossil fuels account for 80% of the world's primary energy supply, with the transportation industry using a significant portion of them [17] Although biofuels currently only make up about 2% of gasoline used in transportation, new technologies will likely allow for significant expansion in thefollowing centuries, with biofuels predicted to account for 9% of all energy used in transportation by 2030. According to this path, 32 exajoules of biofuels will be used worldwide by 2050, accounting for 27% of all fuel used for transportation[18] Figure 1 shows the history and timeline of biofuels from the 19th century to 2030. Since 1500 BCE, plant and seed oils have been utilized. In the mid-1800s, they were also utilized as fuel for combustion engines. [19]

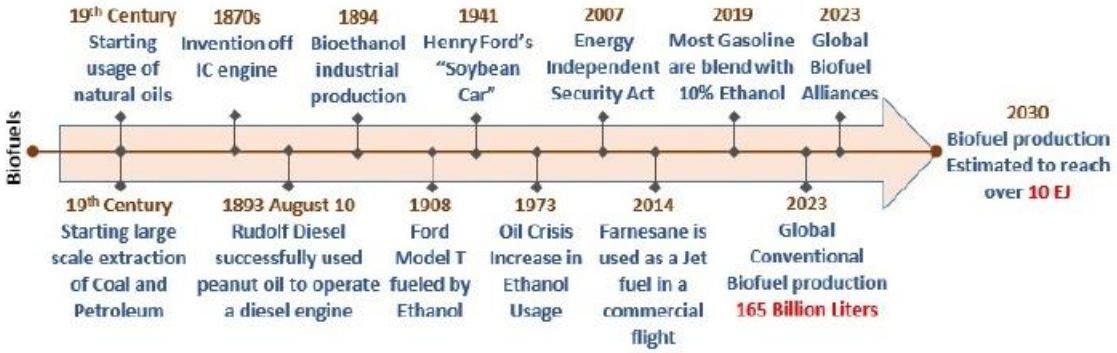

Figure 1. The history and timeline of biofuels[19]

1.Classification of Biofuels

The International Energy Report 2014 projects a 37% increase in global energy demand by 2040. Investigators are working hard to create substitutes made of regenerative raw materials in order to meet the energy demand due to the limited and diminishing resources of traditional petroleum fuels. In addition to potentially meeting the world's energy needs, renewable energy technologies are crucial for lowering greenhouse gas emissions. [20] Nitric oxide (NO2) emissions and carbon emission levels, along with energy consumption and environmental concerns, are the primary factors influencing the production of biofuels [21]. Countries with advanced economies are focusing their investigation efforts on growing the biofuel economy, specifically in the transportation sector. Because this is a labor-intensive field, there has been rising concern in many developing nations about upgrading biomass for an acceptable climate and creating jobs. Modern, sophisticated technology are capable of extracting biofuels in many ways. Biofuels are divided into three groups based on their form of availability: solid, liquid, and gaseous [22].

Solid biofuels: Fuels made from organic materials, biomass, and municipal trash are known as solid biofuels. Thermal and electrical energy can be generated from solid biofuels. These sustainable fuels come from a variety of sources, including animal remains and the leftovers of agriculture and forestry. The most well-known solid biofuels include charcoal, wood pellets, wood chips, and firewood. [23][24] These biomasses are widely used in the energy, heat, and power generation industries [25].

Liquid biofuels: Liquid biofuel is the term used to describe any liquid renewable fuel. Electricity generating and the transportation sector are the main applications for liquid biofuels. Notable examples of liquid biofuels are pyrolysis bio-oil, bioethanol, and biodiesel. Because of their special qualities, liquid biofuels are more widely used than fossil fuels because they are safer to transport, more affordable, stable in storage, have a high energy-to-mass ratio, are highly combustible, and emit fewer greenhouse gases. [26], [27]Bioethanol, biodiesel, and pyrolysis bio-oil are the most often utilized liquid biofuels [24] Because of their high energy density, liquid

biofuels are superior to gaseous as well as solid biofuels in many ways, making them perfect for storage, transportation, and retrofitting. [28]

Gaseous biofuels: Gaseous biofuels are another type of biofuel. It should be noted that two of the most popular gaseous biofuels are syngas and biogas. Gaseous biofuels offer a wide range of uses, particularly in microgrids and the power generation sector. Due to the numerous advantages of biofuels, a great deal of study has been done recently to assess these fuels. Benefits of using gaseous biofuels include reduced waste production during usage, greater reactivity, simplicity of control, and a lower requirement for oxidants [29], [30]

2. Generations of bio fuels

Through gasification or pyrolysis, the biowastes are transformed into gaseous biofuels. Afterwards, to generate heat or electricity, these biofuels are fed into Otto engines that are wired to an electricity generator. Depending on the feedstock used for manufacture, they are classified as the following [31] –

First-generation biofuels:

First-generation biofuel is made from vegetable oil, carbohydrates, sugars, and lipids. The primary source of first-generation biofuels is food products or crops used as animal feed [32]. These biofuels are also known as "conventional biofuels" since they are produced using a number of well-known technologies and procedures, such as fermentation, distillation, and transesterification [32]. These processes do not require membranes because the process is largely focused on producing fuel alone, with the remaining non-fuel stuff being dumped as waste[33].

Second-generation biofuels:

All of the feedstocks used to manufacture second-generation biofuels are non-food sources, including lignocellulosic plants, farming and forest leftovers, waste products, and specific energy crops [32].The second generation of biofuel production is an enhanced technique that prioritizes the creation of secondary raw materials as well as enhanced fuel recovery over the first generation. It is an economically viable strategy because, in contrast to the first generation process, it concentrates on creating useful fuels while lowering the total energy cost and quantity of waste produced. For these reasons, in order to increase the yield of biofuel, researchers typically support methods like membrane filtering and the integration of multiple biorefineries. To produce biofuels, organic acids, and amino acids, a range of mesophilic and thermophilic organisms are employed in batch and continuous operations.[33]

Third-generation biofuels:

Transesterification or hydrotreatment of the algal oil is how third-generation biofuels are made from microalgae [32]. When compared to first-generation biofuels made from conventional crops, these techniques can effectively raise the annual yield of biofuel.[34] Since research and development are still ongoing, the second and third generations of biofuels are collectively referred to as advanced biofuels [32]. Among the main sources are workable resources that are adaptable with regard to environmental parameters, workable, and do not disrupt the food chain. Microalgae, fish oil, animal fat, waste cooking oil, animal oils, etc. are the main sources of these materials. Reducing water contamination and the burden on waste treatment plants are two more noteworthy advancements.[35], [36] Furthermore, the primary benefit of algal biomass is its ability to grow directly on a range of carbon emission sources, such as factories, power plants, etc., and convert those emissions into fuel [37], producing no carbon dioxide emissions in the process. The main difficulties in producing third-generation biofuel are in enormous scale microalgae culture, which is necessary to meet consumer demands because these plants need a lot of phosphate, nitrogen, and water[38].

Fourth-generation biofuels:

Photobiological solar fuels, electrofuels, and genetically modified (GM) algae are used in the processing of fourth-generation biofuels [36][39]. Light penetration, photosynthetic efficiency, and biofuel production are all enhanced by the biomass of GM algae [39]. Fourth-generation solar raw resources are infinite, broadly accessible, and less expensive. By triggering cell autolysis and product secretary systems, the genetic manipulation of microalgal biomass holds prospective applications in oil extraction methodology. Bioinformatics technologies that are frequently used for genome editing include zinc-finger nuclease (ZFN), transcription-like effector nucleases (TALEN), and clustered regularly interspaced palindromic sequences (CRISPR/Cas9)[39][40]

III. TECHNOLOGICAL FEATURES OF BIOFUEL VEHICLES:

When it comes to biofuels, liquid biofuels are frequently used either as a full replacement for traditional fuels or as a blend with regular gasoline or diesel. Generally speaking, using liquid biofuels doesn't call for any further special adjustments. Liquid biofuel cars' main parts and technological features are similar to those of conventional petroleum-based fuel vehicles [41].

The subsequent part will look at cars that run on gaseous biofuel. Because they provide equivalent fuel range support for systems that operate inside a site with stable compressed biogas refueling facilities biogas cars are perfect for high-mileage, centrally fueled fleets. When used as a transportation fuel, biogas has many advantages over conventional gasoline and diesel fuels, including a plentiful supply across the nation, a vast distribution network, and reduced greenhouse gas emissions. Skilled retrofitting professionals can use alternative transformation machinery to safely and effectively convert a variety of automobiles to run on biogas. In this field, CBG and LBG are thought to be alternative fuels with bright futures[42] Gaseous biofuel-powered adaptable automobiles come in three different varieties. Specialized vehicles are built specifically to run on gaseous biofuel. Gaseous biofuel or petroleum can be used to power bi-fuel vehicles thanks to their two separate fueling systems. Dual-fuel cars use natural gas-powered fuel systems, but they also need diesel fuel to help with ignition. Usually, only automobiles intended for heavy-duty use can have this configuration. Gaseous biofuel vehicles keep biogas in a gaseous state by storing it in compressed tanks.[43]

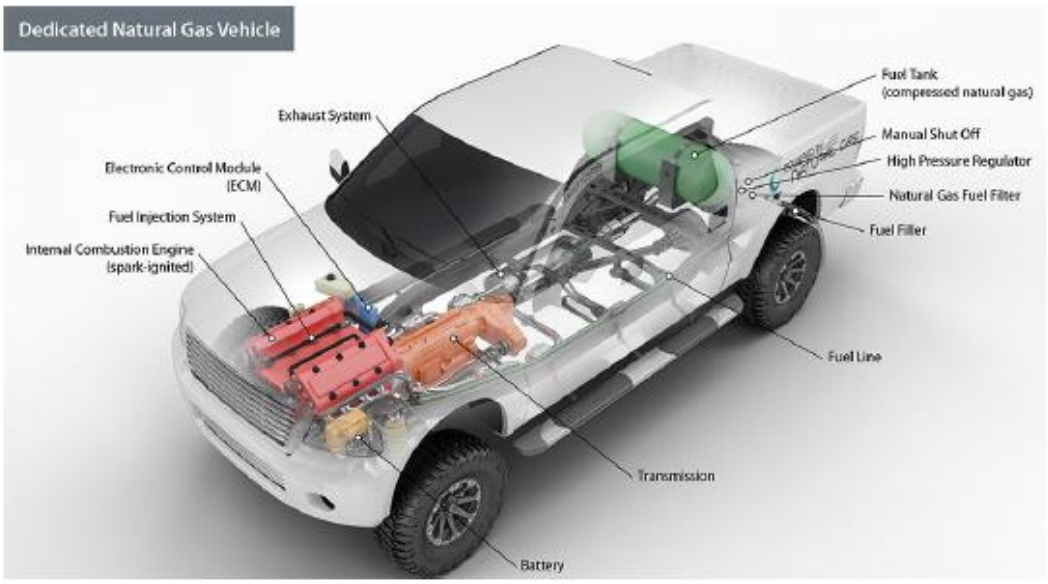

Figure 2. Technical components of biofuel(gas) vehicle inner assembly.

Compared to CBG, LBG has a better energy density because its liquid condition allows for greater quantities of fuel to be preserved in automobiles. For Class 7 and Class 8 trucks that need a longer range, LBG is a great fit. The particular needs of the vehicle's function (such as power requirements) and the intended driving distance usually have an impact on the fuel choice. Due to the lower energy density of natural gas, gaseous biofuel vehicles often have a shorter range than comparable diesel or petrol vehicles. Adding storage tanks could increase the carrying capacity, but the additional weight could limit the amount of cargo that can be transported. Gaseous biofuel has the potential to reduce greenhouse gas (GHG) emissions over the course of its life cycle when used as a vehicle fuel, as opposed to conventional fuels [44]. The magnitude of these advantages is contingent upon various factors, including the vehicle's kind, usage habits, and engine calibration. Moreover, natural gas reduces some engine emissions. The byproduct of burning gasoline in an automobile's engine is tailpipe emissions. Carbon monoxide (CO), carbon dioxide (CO2), nitrogen oxides (NOx), and controlled hydrocarbon emissions are the main emissions to be concerned about [45]. There are various gas vehicles are available in the market manufactured through various company.

Benefits of vehicles powered by biofuel

- Because they are renewable, biofuels encourage sustainability.
- Increased dependability and local production are possible.

- Decrease reliance on imported energy sources.
- Can assist in keeping energy prices stable.
- Biofuels facilitate the growth of rural areas.
- Biofuels have a role in lowering air pollution.
- The manufacture of biofuel can utilize waste from farms and marginal lands.
- One way to sequester carbon is through biofuels.

Drawbacks of vehicles powered by biofuel

- Before being used, biofuels must undergo pre-treatment procedures.
- It can be costly to develop technologies for biofuels.
- Enhancing the efficacy of biofuel producing technology is crucial.
- It is necessary to obtain subsidies in order to produce biofuel.
- Research and development funding is required.
- It can be difficult to increase biofuel production to a commercial scale.
- It can be difficult to set up an effective network for collecting feedstock for biofuels.
- Specialized storage facilities are necessary for biofuels.
- The production of biofuels has the potential to rival that of food.

IV. Conclusion and Future Scope

It is anticipated that there will be an extensive petroleum fuel scarcity in the near future, which will have dire environmental consequences. Therefore, finding a clean substitute fuel is essential. Biofuels show great promise as a replacement for fossil fuels. The state of biofuels for road transportation and their potential to counteract climate change were examined through a study of the literature. To reduce harmful vehicle emissions, using cars that run on alternative fuels like biofuels has been suggested as the best solution. But there are often concerns about the sustainability of using these alternative fuels, potential hazards, and what will happen to them after they run out of fuel. For this reason, a thorough analysis of the variables affecting the use of this alternative fuels for vehicles is required. From the future prospective there will be a trend which will revealed from indicating that there will be a paradigm shift from the biofuel paradigm to a bio-electric energy paradigm, both of which can contribute to a low-carbon, sustainable transportation future.

References

[1] Bentley RW, Introduction to peak oil. 2016.
[2] J. C. Escobar, E. S. Lora, O. J. Venturini, E. E. Yáñez, E. F. Castillo, and O. Almazan, “Biofuels: Environment, technology and food security,” Renew. Sustain. Energy Rev., vol. 13, no. 6–7, pp. 1275–1287, 2009, doi: 10.1016/j.rser.2008.08.014.
[3] C. Chavez-Baeza and C. Sheinbaum-Pardo, “Sustainable passenger road transport scenarios to reduce fuel consumption, air pollutants and GHG (greenhouse gas) emissions in the Mexico City Metropolitan Area,” Energy, vol. 66, no. 2, pp. 624–634, 2014, doi: 10.1016/j.energy.2013.12.047.
[4] P. Friedlingstein et al., “Persistent growth of CO2 emissions and implications for reaching climate targets,” Nat. Geosci., vol. 7, no. 10, pp. 709–715, 2014, doi: 10.1038/NGEO2248.
[5] M. Reuter et al., “Decreasing emissions of NOx relative to CO2 in East Asia inferred from satellite observations,” Nat. Geosci., vol. 7, no. 11, pp. 792–795, 2014, doi: 10.1038/ngeo2257.
[6] S. Kumar, P. Shrestha, and P. Abdul Salam, “A review of biofuel policies in the major biofuel producing countries of ASEAN: Production, targets, policy drivers and impacts,” Renew. Sustain. Energy Rev., vol. 26, pp. 822–836, 2013, doi: 10.1016/j.rser.2013.06.007.
[7] A. Contamination, Perspectives on Water Usage for Biofuels Production. 2018. doi: 10.1007/978-3-319-66408-8.
[8] F. Creutzig et al., “Bioenergy and climate change mitigation: An assessment,” GCB Bioenergy, vol. 7, no. 5, pp. 916–944, 2015, doi: 10.1111/gcbb.12205.
[9] J. Van Eijck et al., “Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation based jatropha biofuel production systems in Tanzania,” Biomass and Bioenergy, vol. 61, pp. 25–45, 2014, doi: 10.1016/j.biombioe.2013.10.005.
[10] J. van Eijck, B. Batidzirai, and A. Faaij, “Current and future economic performance of first and second generation biofuels in developing countries,” Appl. Energy, vol. 135, pp. 115–141, 2014, doi: 10.1016/j.apenergy.2014.08.015.
[11] Jatrofuels, “No Title,” From Feed. Cultiv. to full Mark. Integr., 2012.
[12] S. R. Hughes, B. R. Moser, and W. R. Gibbons, “Moving toward energy security and sustainability in 2050 by reconfiguring biofuel production,” Biotechnol. Agric. For., vol. 67, pp. 15–29, 2014, doi: 10.1007/978-3-642-55262-5_2.
[13] Smith K., Biofuels, air pollution, and health: a global review. 2013.
[14] B. E. Dale et al., “Take a closer look: Biofuels can support environmental, economic and social goals,” Environ. Sci. Technol., vol. 48, no. 13, pp. 7200–7203, 2014, doi: 10.1021/es5025433.

[15] M. Balat, “Potential alternatives to edible oils for biodiesel production - A review of current work,” Energy Convers. Manag., vol. 52, no. 2, pp. 1479–1492, 2011, doi: 10.1016/j.enconman.2010.10.011.
[16] M. Balat, “Production of bioethanol from lignocellulosic materials via the biochemical pathway: A review,” Energy Convers. Manag., vol. 52, no. 2, pp. 858–875, 2011, doi: 10.1016/j.enconman.2010.08.013.
[17] M. K. G. Deshmukh, M. Sameeroddin, D. Abdul, and M. Abdul Sattar, “Renewable energy in the 21st century: A review,” Mater. Today Proc., vol. 80, no. xxxx, pp. 1756–1759, 2023, doi: 10.1016/j.matpr.2021.05.501.
[18] F. L. Eisentraut A, Brown A, Technology roadmap: biofuels for transport. 2011.
[19] V. J. Reddy, N. P. Hariram, R. Maity, M. F. Ghazali, and S. Kumarasamy, “Sustainable Vehicles for Decarbonizing the Transport Sector: A Comparison of Biofuel, Electric, Fuel Cell and Solar-Powered Vehicles,” World Electr. Veh. J., vol. 15, no. 3, 2024, doi: 10.3390/wevj15030093.
[20] P. Liang et al., “Electricity generation by the microbial fuel cells using carbon nanotube as the anode,” Huanjing Kexue/Environmental Sci., vol. 29, no. 8, pp. 2356–2360, 2008.
[21] T. M. Y. Khan, A. E. Atabani, I. A. Badruddin, A. Badarudin, M. S. Khayoon, and S. Triwahyono, “Recent scenario and technologies to utilize non-edible oils for biodiesel production,” Renew. Sustain. Energy Rev., vol. 37, pp. 840–851, 2014, doi: 10.1016/j.rser.2014.05.064.
[22] Y. Yang, Z. Tian, Y. Lan, S. Wang, and H. Chen, “An overview of biofuel power generation on policies and finance environment, applied biofuels, device and performance,” J. Traffic Transp. Eng. (English Ed., vol. 8, no. 4, pp. 534–553, 2021, doi: 10.1016/j.jtte.2021.07.002.
[23] M. Kiehbadroudinezhad, A. Merabet, C. Ghenai, A. G. Abo-Khalil, and T. Salameh, “The role of biofuels for sustainable MicrogridsF: A path towards carbon neutrality and the green economy,” Heliyon, vol. 9, no. 2, pp. 1–42, 2023, doi: 10.1016/j.heliyon.2023.e13407.
[24] R. S. Thwaites et al., “Info _ Outline,” Crit. Rev. Clin. Lab. Sci., vol. 8, no. 1, pp. 1–5, 2020, [Online]. Available: https://doi.org/10.1016/j.medcli.2020.05.012%0Ahttps://doi.org/10.1080/10408363.2020.1776675%0Ahttps://doi.org/10.1007/s11033-021-06148-9%0Ahttp://dx.doi.org/10.1038/s41584-021-00608-z%0Ahttp://dx.doi.org/10.1038/s41409-020-0931-4%0Ahttps://doi.org/10.118
[25] B. M. Y. Dahman, K. Syed, S. Begum, P. Roy, Biofuels, Biomass, Biopolymer- Based Materials, and Bioenergy. 2019.
[26] A. Devi, A. Singh, S. Bajar, and H. I. Owamah, “Nanomaterial in liquid biofuel production: applications and current status,” Environ. Sustain., vol. 4, no. 2, pp. 343–353, 2021, doi: 10.1007/s42398-021-00193-7.
[27] P. G. del Río, J. S. Gomes-Dias, C. M. R. Rocha, A. Romaní, G. Garrote, and L. Domingues, “Recent trends on seaweed fractionation for liquid biofuels production,” Bioresour. Technol., vol. 299, p. 122613, 2020, doi: 10.1016/j.biortech.2019.122613.
[28] J. Sarkar and S. Bhattacharyya, “Application of graphene and graphene-based materials in clean energy-related devices Minghui,” Arch. Thermodyn., vol. 33, no. 4, pp. 23–40, 2012, doi: 10.1002/er.
[29] E. Mäki, H. Saastamoinen, K. Melin, D. Matschegg, and H. Pihkola, “Drivers and barriers in retrofitting pulp and paper industry with bioenergy for more efficient production of liquid, solid and gaseous biofuels: A review,” Biomass and Bioenergy, vol. 148, no. May 2020, 2021, doi: 10.1016/j.biombioe.2021.106036.
[30] S. M. Safieddin Ardebili and A. Khademalrasoul, “An assessment of feasibility and potential of gaseous biofuel production from agricultural/animal wastes: a case study,” Biomass Convers. Biorefinery, vol. 12, no. 11, pp. 5105–5114, 2022, doi: 10.1007/s13399-020-00901-z.
[31] P. E. V. Paul, V. Sangeetha, and R. G. Deepika, Emerging trends in the industrial production of chemical products by microorganisms. Elsevier Inc., 2018. doi: 10.1016/B978-0-12-816328-3.00009-X.
[32] H. K. Jeswani, A. Chilvers, and A. Azapagic, “Environmental sustainability of biofuels: A review: Environmental sustainability of biofuels,” Proc. R. Soc. A Math. Phys. Eng. Sci., vol. 476, no. 2243, 2020, doi: 10.1098/rspa.2020.0351.
[33] A. N. Oumer, M. M. Hasan, A. T. Baheta, R. Mamat, and A. A. Abdullah, “Bio-based liquid fuels as a source of renewable energy: A review,” Renew. Sustain. Energy Rev., vol. 88, no. October 2017, pp. 82–98, 2018, doi: 10.1016/j.rser.2018.02.022.
[34] S. Hafeez, S. M. Al-Salem, G. Manos, and A. Constantinou, “Fuel production using membrane reactors: a review,” Environ. Chem. Lett., vol. 18, no. 5, pp. 1477–1490, 2020, doi: 10.1007/s10311-020-01024-7.
[35] M. Tariq, S. Ali, and N. Khalid, “Activity of homogeneous and heterogeneous catalysts, spectroscopic and chromatographic characterization of biodiesel: A review,” Renew. Sustain. Energy Rev., vol. 16, no. 8, pp. 6303–6316, 2012, doi: 10.1016/j.rser.2012.07.005.
[36] D. Singh, D. Sharma, S. L. Soni, S. Sharma, P. Kumar Sharma, and A. Jhalani, “A review on feedstocks, production processes, and yield for different generations of biodiesel,” Fuel, vol. 262, no. July, p. 116553, 2020, doi: 10.1016/j.fuel.2019.116553.
[37] J. P. Maity, J. Bundschuh, C. Y. Chen, and P. Bhattacharya, “Microalgae for third generation biofuel production, mitigation ofgreenhouse gas emissions and wastewater treatment: Present andfuture perspectives - A mini review,” Energy, vol. 78, pp. 104–113, 2014, doi: 10.1016/j.energy.2014.04.003.
[38] R. Slade and A. Bauen, “Micro-algae cultivation for biofuels: Cost, energy balance, environmental impacts and future prospects,” Biomass and Bioenergy, vol. 53, no. 0, pp. 29–38, 2013, doi: 10.1016/j.biombioe.2012.12.019.
[39] B. Abdullah et al., “Fourth generation biofuel: A review on risks and mitigation strategies,” Renew. Sustain. Energy Rev., vol. 107, no. February, pp. 37–50, 2019, doi: 10.1016/j.rser.2019.02.018.
[40] Y. Maeda, T. Yoshino, T. Matsunaga, M. Matsumoto, and T. Tanaka, “Marine microalgae for production of biofuels and chemicals,” Curr. Opin. Biotechnol., vol. 50, pp. 111–120, 2018, doi: 10.1016/j.copbio.2017.11.018.
[41] M. Gustafsson, I. Cruz, N. Svensson, and M. Karlsson, “Scenarios for upgrading and distribution of compressed and liquefied biogas — Energy, environmental, and economic analysis,” J. Clean. Prod., vol. 256, p. 120473, 2020, doi:

10.1016/j.jclepro.2020.120473.
[42] S. Dahlgren, “Biogas-based fuels as renewable energy in the transport sector: an overview of the potential of using CBG, LBG and other vehicle fuels produced from biogas,” Biofuels, vol. 13, no. 5, pp. 587–599, 2022, doi: 10.1080/17597269.2020.1821571.
[43] M. Channappagoudra, “Comparative study of baseline and modified engine performance operated with dairy scum biodiesel and Bio-CNG,” Renew. Energy, vol. 151, pp. 604–618, 2020, doi: 10.1016/j.renene.2019.11.062.
[44] F. Cignini, A. Genovese, F. Ortenzi, S. Valentini, and A. Caprioli, “Performance and Emissions Comparison between Biomethane and Natural Gas Fuel in Passenger Vehicles,” E3S Web Conf., vol. 197, 2020, doi: 10.1051/e3sconf/202019708019.
[45] T. Limpachoti and K. Theinnoi, “The Comparative Study on Compressed Natural Gas (CNG) and Compressed Biomethane Gas (CBG) Fueled in a Spark Ignition Engine,” E3S Web Conf., vol. 302, 2021, doi: 10.1051/e3sconf/202130201005.