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Alternative Transportation Fuels

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Abstract

Energy is a necessity for economic development. Energy is used extensively in transportation and power generation. Human civilization would not have advanced to modern living standards without the transportation of millions of personalized and mass transport vehicles and the availability of 24x7 power. The global economy and society are heavily reliant on energy availability because it touches every aspect of human life and activity. Because of the rising population and urbanization, energy demand has skyrocketed. Thus, growing energy consumption has resulted in the world becoming increasingly reliant on fossil fuels such as coal, oil, and gas. Therefore, a sustainable energy path must be developed. Fossil fuels provide more than 80% of global consumption and more than 95% of global transportation energy. While global fossil fuel reserves are depleting, global energy demand is rising due to the evolution of energy-intensive lifestyles. To improve energy security and reduce greenhouse gas emissions, it is critical to investigate alternative fuels for the transportation sector. This paper summarizes the information on current transportation fuels and the potential use case of alternative transportation fuels.

Keywords: Alternative fuels; Transportation fuels; Energy; Fossil fuels; Biofuels

1. Introduction

In the near future, gaseous fuels appear to be a potential solution for energy supply to the automotive sector. Because these gaseous fuels contain more hydrogen and less carbon, they emit fewer greenhouse gases and fine particulates. Compressed natural gas (CNG), liquefied petroleum gas (LPG), and liquefied natural gas (LNG) do not contain polyaromatic hydrocarbons (PAHs), airborne toxins, or Sulphur dioxide (SO_2), and CNG/LPG/LNG vehicles have quieter engine operation, fewer vibrations, and less odor than conventional diesel engines. However, some of the disadvantages of using CNG/LPG/LNG vehicles include higher vehicle costs, shorter driving range, heavier fuel tanks, an expensive distribution and storage network, and potential performance and operational problems when compared to liquid fuels.

Because biofuels have emerged as a potential alternative fuel to enter the transportation sector, their use does not necessitate significant changes in infrastructure or existing vehicles. There are several biofuels used in vehicles, the most common of which are biodiesel and alcohol. The production of these biofuels currently relies on proven technologies, which are expensive. Aside from researching new alternative fuels, it is critical to improve existing technologies in order to improve the properties of both alternative and conventional petroleum fuels. The most important aspect of alternative fuel sustainability is the use of these alternative fuels [1].

The transportation system is critical to the economic development of any country in the world. The primary issue for the global transportation sector today is energy supply, which is provided by fossil fuels such as gasoline and diesel fuel. Because of the development of the motorization industry, the global average consumption of energy in the transportation sector has increased by 1.1% per year. According to reports, only the transportation sector will account

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for 63% of the increase in total global liquid fuel consumption between 2010 and 2040 [2]. Furthermore, the significant growth of the global motorization industry has resulted in an increase in harmful pollutant emissions to the environment. It is critical to note that the transportation sector accounts for approximately 22% of global GHG (greenhouse gas) emissions. Not only has the International Energy Agency (IEA) predicted that GHG (carbon dioxide) emissions from the transportation sector will increase by 92% between 1990 and 2020, but it is also estimated that 8.6 billion metric tons of CO_2 will be released into the atmosphere between 2020 and 2035 [3]. Vehicle emissions such as particulate matter (PM), hydrocarbons (HC), carbon dioxides (CO_2), carbon monoxide (CO), and nitrogen oxides (NO_x) are major contributors to the deterioration of air quality [4]. Figure 1 depicts the predicted share of global transportation sector energy consumption and CO_2 emissions.

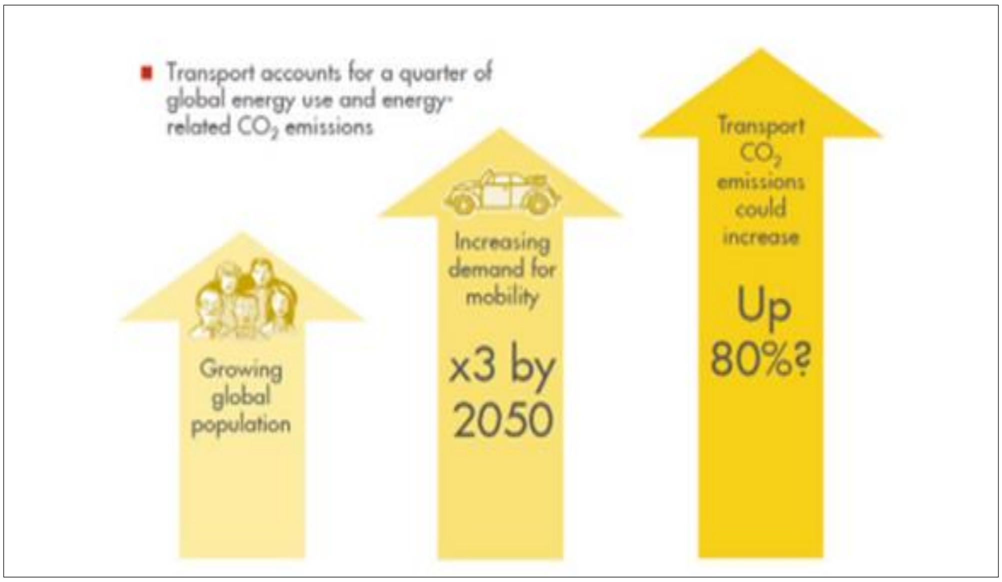

Figure 1 Prediction of the share of the transportation sector on global energy and CO_2 emissions [5]

2. Liquid Fossil Fuels

Crude petroleum is the primary source of liquid fuels; other sources include shale and tar sands. Coal and natural gas can be used to produce synthetic hydrocarbon fuels such as gasoline and methanol. Ethanol, which is used in some automobiles, is derived from vegetable matter. Crude petroleum and refined products contain a diverse range of hydrocarbons, including aliphatic (straight or branched-chain paraffin and olefins), aromatics (closed rings with six carbons per ring and alternate double bonds joining the ring carbons, with or without aliphatic side chains), and naphthenic or cycloparaffins (closed single-bonded carbon rings, five to six carbons). In its natural state, crude petroleum is used very little. Refining is required to produce marketable products that are separated into fractions by distillation into a specific boiling range. Further processing (such as cracking, reforming, and alkylation) changes the molecular structure of some hydrocarbons, improving the yield and properties of the refined products [6].

For most of human history, our ancestors relied on simple forms of energy such as human muscle, animal muscle, and the combustion of biomass such as wood or crops. However, the Industrial Revolution unlocked a completely new energy source: fossil fuels. Fossil energy has been a key driver of subsequent technological, social, economic, and development progress [Our World in Data, https://ourworldindata.org/fossil-fuels , Last accessed on 02/10/22]. Fossil fuels (coal, oil, and gas) have dominated and continue to dominate global energy systems. The amount of fossil fuel (coal, oil, and natural gas) available is finite, and any extrapolation of our current consumption rate will result in the depletion of readily available reserves in about 100 years (or somewhere between 30 and 300 years). It is estimated that we have already depleted approximately 16% of the earth's readily available hydrocarbon (oil and natural gas) reserves of fossil fuel, and our consumption rate is roughly doubling every 10 years. The scarcity of fossil fuel reserves and the negative environmental consequences of using them have fueled the search for renewable transportation biofuels. The potential role of alternative renewable fuels in addressing these environmental concerns is motivating the first steps toward the development of a sustainable fuel supply [8].

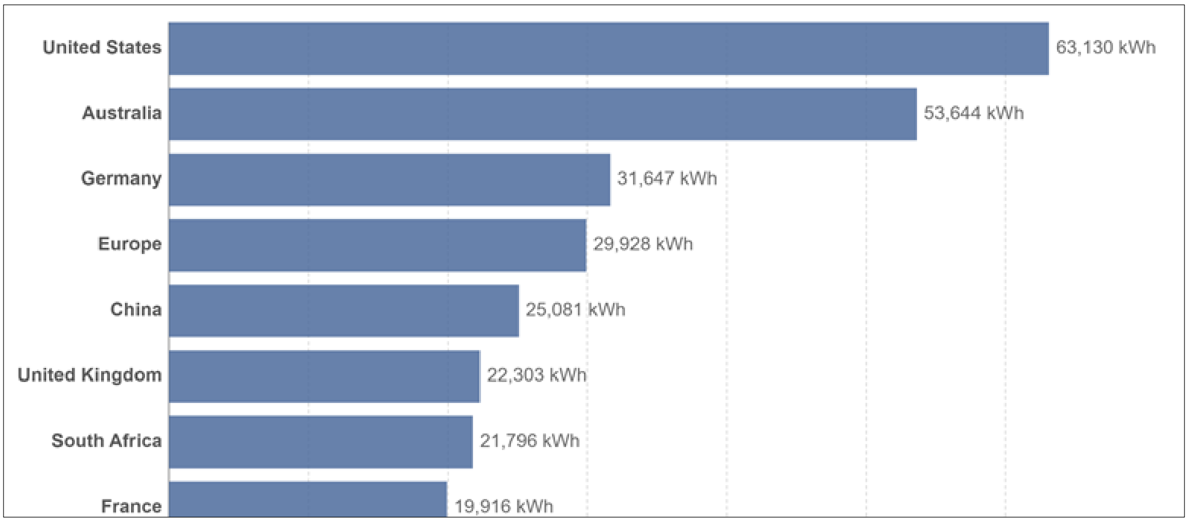

Figure 2 Fossil Fuel Consumption per capita, 2021 [7]

3. Evolving Energy Scenario

Energy is a fundamental requirement for any country's economic development. The geographical distribution of petroleum resources is changing as reserves are discovered and accessed using improved exploration technologies; however, this distribution of oil supply does not always correspond to where demand is located. This results in high fuel costs, which are primarily determined by the price of crude oil. Rising energy consumption has made India increasingly reliant on fossil fuels such as coal, oil, and gas. Fossil fuels provide more than 80% of global energy consumption and 95% of transportation energy (Fig. 3). Figure 3 shows that petroleum accounts for 95% of transportation energy, with the remainder supplied by natural gas, biofuels, and electricity. Light-duty vehicles (LDVs), which include light-duty trucks, light commercial vehicles, and minibuses, account for approximately 52% of fuel requirements, while trucks, including medium and heavy-duty, account for 17%. Buses (4%) and two/three-wheelers (3%) consume the remainder of road transport energy [9].

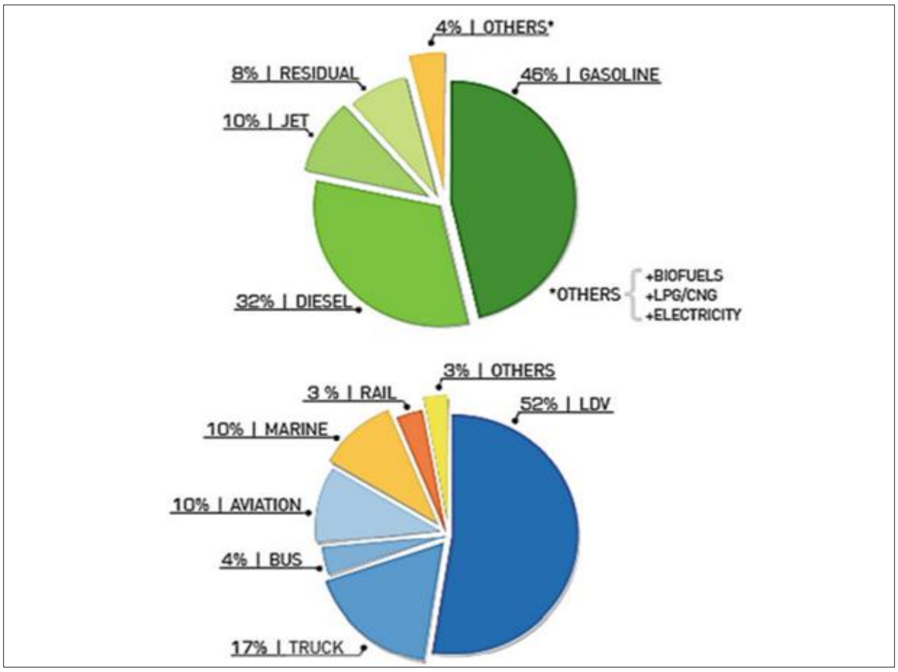

Figure 3 Current global transport energy sources and consumption trends (2011)

The global population was 7 billion in 2009, and it is expected to grow to 9 billion by 2050 and 10 billion by 2100 [10]. Another major factor affecting the energy sector is the rapidly growing population, which necessitates more energy, putting additional strain on global economic development. According to the International Energy Agency (IEA), global energy demand will rise from 12 billion tons of oil equivalents (TOE) in 2009 to 17 or 18 billion TOE by 2035 under the 'current policies' or 'new policies' scenarios [11]. This data shows that the world is already in an alarming situation, and these figures must be drastically reduced in order to improve human survival. Figure 4 depicts the significance of fossil fuels in the transportation and energy generation sectors. The transportation sector, which accounts for 95% of transportation energy, is driving the increase in the use of fossil fuels. Electricity generation is also heavily influenced by fossil fuels, with coal accounting for 48% of total generation, natural gas accounting for 19%, nuclear power accounting for 21%, renewables accounting for 10%, and oil accounting for 1%.

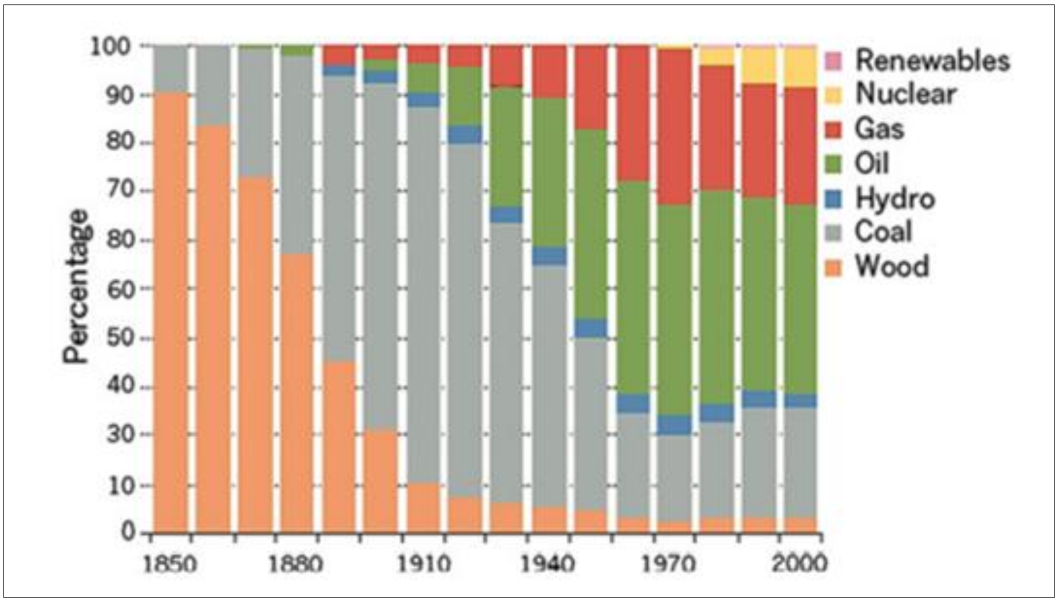

Figure 4 History of a relative mix of main energy resources used in the USA [12]

While global fossil fuel reserves are depleting, global energy demand is increasing due to the evolution of energy-intensive lifestyles. Experts predict that global energy demand will increase by more than 50% between 2009 and 2030, with oil production peaking around 2020-30. The combustion of fossil fuels produces CO_2, a greenhouse gas (GHG) that contributes to global warming. As a result, cleaner fuels that are not derived from fossil resources are required. Because pollutants are emitted at ground level, close to human breathing levels, vehicular pollution cannot be avoided. Increased human mortality and morbidity reflect the severity of vehicular pollution. The presence of carbon monoxide (CO), unburned hydrocarbons (HC), oxides of nitrogen (NO_x), suspended particulate matter (SPM), and aldehydes, among other things, in engine exhaust has a negative impact on human health. Aside from these harmful pollutants, CO_2 causes a variety of long-term global issues, including the greenhouse effect/global warming. To combat this threat, almost all countries are working on methods to reduce CO_2 emissions from engine tailpipes. Different air pollutants emitted by vehicles have negative effects at all levels: local (e.g., smoke reduces visibility and air quality), regional (e.g., smog, acidification), and global (i.e., global warming) [13].

4. Alternative Fuels Landscape

Table 1 Alternative fuels landscape [13]

Sr. No.	Fuel	Composition	Environmental Impact	Uses
1	CNG	Methane	Reduced CO_2, CO, and Hydrocarbon emissions	LCVs, HCVs, Three Wheelers
2	LPG	Propane Butane	Reduced CO_2, CO, and Hydrocarbon emissions	Three Wheelers Passengers Cars
3	HCNG	Blend of Hydrogen and Natural Gas	Reduced CO_2, CO, and Hydrocarbon emissions Increases Fuel Efficiency	Not commercially introduced Proposed for HCVs

4	LNG	Methane Ethane	Improves carrying capacity of the vehicle	Not commercially introduced Proposed for HCVs
5	Biogas	Methane	Reduced CO_2, CO, and Hydrocarbon emissions	Proposed for LCVs, HCVs
6	Alcohols	Blended with gasoline at a 5% blend	Reduced HC and particulate emissions	Used for some passenger cars and SUVs
7	Biodiesel	Esterified vegetable oils	Reduced HC emissions compared to conventional fuels.	Used for SUVs and HCVs
8	Hydrogen	-	No HC emissions	Under trial Proposed for Passenger cars and HCVs

5. Available Alternative Fuels

To meet increasingly stringent emission standards, researchers are investigating the use of alternative fuels that can be used in current-generation engines with minimal hardware modifications. Emissions from such alternative fuels are expected to be lower than emissions from conventional fuels. Several alternative fuels have been researched and developed in this quest. In order to reduce greenhouse gas emissions, researchers are primarily interested in low-carbon fuels. Several alternative fuels, including biodiesel, compressed natural gas (CNG), ethanol, hydrogen, vegetable oils, LPG, and hydrogen-CNG (HCNG) blends, have been studied for engine performance in order to determine their technical feasibility [13].

5.1. Natural Gas

Natural gas is a mixture of ethane, propane, butane, carbon dioxide, nitrogen, and other substances, with methane constituting 80-98% of the total, depending on the source of production [14] [15] [16]. Fossil natural gas can be found in conjunction with other fossil fuels (for example, crude oil in oil fields or coal in coal beds) or on its own. CNG has been used in buses, heavy-duty commercial vehicles, and light-duty personal vehicles. It provides several advantages in SI engines, including the possibility of increasing engine efficiency (with an associated reduction in CO_2 emissions) by increasing engine compression ratio due to the higher-octane rating of natural gas compared to gasoline, reduction in quantity and toxicity of HC emissions, reduction in CO emissions, and so on. decrease in the quantity and toxicity of HC emissions, decrease in CO emissions, and so on. It can also be used in retrofitted CI engines, which include modifications such as adding an ignition source, lowering the compression ratio, and retrofitting a fuel storage and delivery system, all of which reduce local pollution. The use of natural gas in SI engines results in a 10-15% reduction in power output compared to gasoline-fueled engines, which can be compensated for by direct injection of fuel, with special injectors expected to be available in the near future [14]. Natural gas is currently stored in cylinders at 200 bar pressures for vehicular use; however, the range of natural gas-powered vehicles remains significantly lower than that of gasoline and diesel-powered vehicles due to its lower energy storage density [14] [15]. According to the EIA world energy outlook, natural gas's share of global transport fuels will remain in the range of 3-3.7% through 2035.

While natural gas is a non-renewable resource, its main constituent methane can also be produced from biomass, which is a renewable resource [17]. Waste biomass can be used as a transportation fuel by converting it into natural gas, biomass-to-liquid (BTL), and ether. When compared to the Fischer-Tropsch process used in gas-to-liquid (GTL) and BTL processes, the process of collecting, purifying, and using methane obtained from biomass decomposition is relatively simple [14]. However, at the current stage of technological development, the well-to-wheel energy consumption of methane obtained from biomass (3.5 MJ/km) [18] is greater than that of fossil natural gas, gasoline, and diesel (2 MJ/km) [19]. Future advancements in natural gas engine technology and gas purification technology may result in more efficient use of renewable methane.

5.2. Liquified Petroleum Gas

Another gaseous, fossil-origin alternative fuel is liquefied petroleum gas (LPG), which is primarily a mixture of butane and propane. It is made from lighter hydrocarbon fractions produced during crude petroleum refining, as well as heavier components of natural gas that are removed before the gas is distributed [20]. Heavy gases, which comprise LPG, are separated prior to further processing and transportation of crude oil or natural gas. LPG is also produced during atmospheric distillation, crude oil reforming, and cracking.

The separation of propane and butane-like gases from crude oil is required for stabilization prior to distribution via pipeline or tanker [15]. Its engine utilization is similar to natural gas, with the added benefit of higher storage energy density due to its ease of liquefaction and storage as a liquid fuel at moderate pressures of 10-12 bars. However, LPG's cold-starting and cold-start emission characteristics are inferior to those of natural gas, which must be addressed technologically [15] [20].

5.3. Hydrogen

Hydrogen has emerged as a prominent alternate fuel candidate in the quest for improved engine efficiency and lower emissions. Several modifications must be made to existing engines in order to run the engine on hydrogen. Hydrogen is an energy carrier rather than an energy source because free hydrogen is not found in nature and the production of hydrogen requires the expenditure of some form of primary energy [20] [21]. Its utility as an energy carrier is limited by its low energy content in terms of volume, which limits its onboard storage. [20] The primary advantage of hydrogen over other fuels is that its exhaust is clean. Its oxidation produces no carbon dioxide or other harmful carbonaceous species. Hydrogen is employed as a mode of transportation via two routes: hydrogen fuel-cell (H_2 FC) vehicles and hydrogen vehicles. Vehicles with IC engines (H_2 ICE). Hybrid electric vehicle (HEV) technology is being added and enhances the fuel economy of both powertrains. At the moment, the efficiency and cost of the H_2 FC powertrain are more powerful than the H_2 ICE powertrain. [21] Hydrogen can be produced in general through electrolysis or thermal decomposition of water, steam reforming of natural gas and other hydrocarbons, and pyrolysis of biomass. Hydrocarbons, plasma refining, and so on. [15] [16] Natural gas is steam formatted into synthesis gas, from which CO_2 and other greenhouse gases are produced. CO has been removed [15].

Prior to production, an interim energy carrier such as electricity must be produced. The use of hydrogen has significant efficiency drawbacks. Abbott proposed using solar hydrogen generated by solar thermal collectors via the H_2 ICE route as a viable and promising future transport solution for large-scale applications [22].

5.4. HCNG

CNG, which is made from both fossil and natural resources, is a viable alternative to liquid fossil fuels. In comparison to hydrogen, it is relatively abundant and easily accessible. It does, however, have a lower flame speed, a shorter flammability range, and other limitations, making it a sub-optimal fuel for IC engines. Some of these issues may be addressed by hydrogen, which can also be produced from renewable resources. However, due to its low storage energy density, hydrogen has its own set of limitations. It takes up a lot of space as a gas, and storing it in liquid form requires a lot of energy. Because the vital properties of these two fuels differ significantly, many researchers proposed blending hydrogen and CNG for IC engine applications. Because of the higher H/C ratio, HCNG mixtures produce lower emissions. As a result, they have the potential to replace traditional liquid fossil fuels in an environmentally friendly way [23]. IIT Kanpur's Engine Research Lab (ERL) has conducted significant research on HCNG, including the development of HCNG engines and the development of laser ignited HCNG engines [24] [25].

6. Biofuels

Biofuels are gaining popularity among policymakers, industry, and researchers. Biofuels are combustible materials derived directly or indirectly from biomass, which is composed of plants, animals, and microorganisms derived from renewable organic wastes. Biofuels can be solid, liquid, or gaseous, and are derived from all types of biomass and derived products used for energy. Figure 5 depicts the biofuel production process and typical fuel classification.

6.1. Primary Alcohols

Methanol, ethanol, and butanol, as well as their gasoline blends, are used as alternative transport fuels in SI engines [26] [27] [28]. Because of its simple chemical structure and high oxygen content (50%), ethanol is the shortest carbon chain primary alcohol and burns cleanly. Ethanol is similar to methanol; however, it is cleaner, less toxic, and less corrosive than methanol [26]. Butanol is far less corrosive than other primary alcohols and can be distributed via existing pipeline networks and filling stations [27]. Lower gasoline-alcohol blends in SI engines reduce CO, HC, and NO_x emissions while producing nearly identical engine torque output [26] [28]. However, aldehyde emissions rise when IC engines are run on alcohol [26]. Higher alcohol blends require engine modifications to accommodate their higher-octane number, lower volatility, lower calorific value, and different chemical reactivity when compared to gasoline [26] [29]. Alcohol blends can also be used as supplemental fuels in CI engines [26] [15]. Fuel additives are required for the use of higher concentration ethanol blends (>20% v/v) in order to stabilize the mixture and achieve the desired cetane number [15]. A higher percentage of ethanol in diesel necessitates a double injection or fumigation system, which reduces emissions and noise while increasing control complexity. Alcohols can also be blended with pure vegetable oils, biodiesel, and mineral diesel. In CI engines, alcohol-biodiesel-diesel blends reduce NO_x particulate emissions. [30] [31] [32]

Methanol/ethanol and vegetable oils are used as process inputs in the transesterification process for biodiesel production. This method of using alcohol as a diesel engine fuel is superior because aldehyde emissions and alcohol corrosion of engine parts is greatly reduced [27].

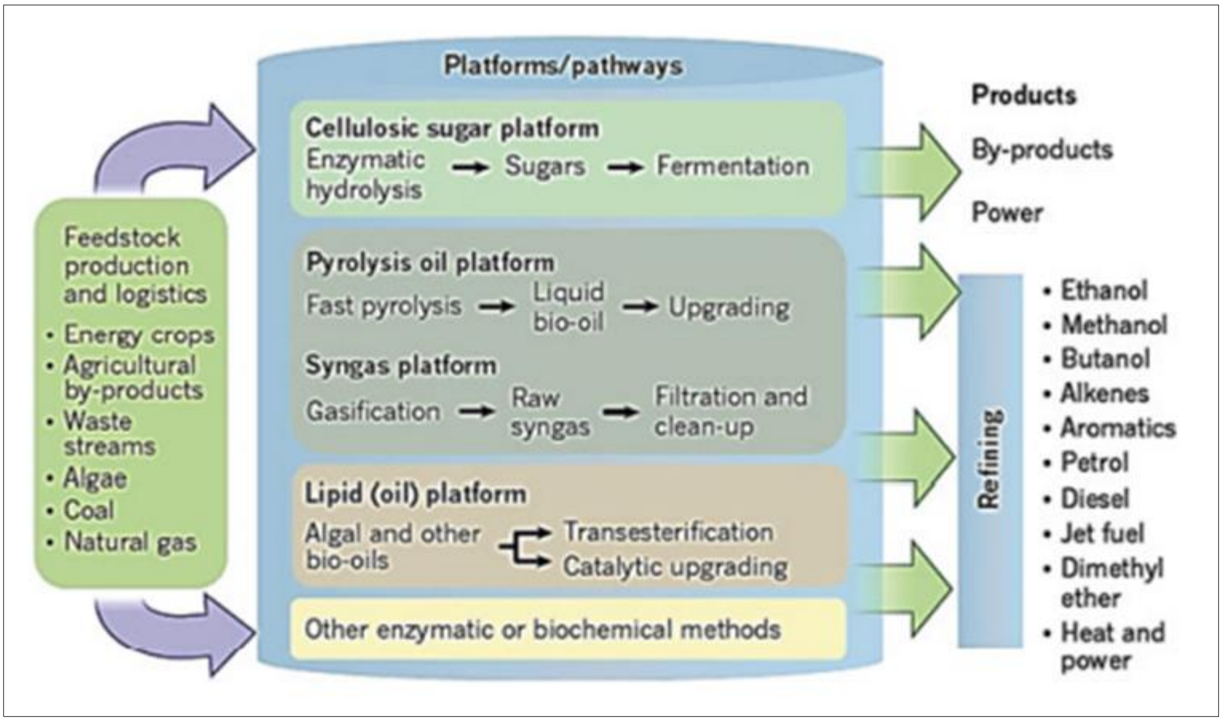

Figure 5 Methods of producing alternative fuels from various biomass feedstocks to products [12]

6.2. Straight Vegetable Oils and Derivatives

Several routes can be used to convert plant-derived oils, waste cooking oils, or any other waste/residue triglycerides into diesel-like fuels. Biodegradable, non-toxic vegetable oil-based fuels have the potential to significantly reduce environmental pollution. Vegetable oils contain 90% of the heat content of mineral diesel and have a favorable output/input ratio of 2-4: 1 for non-irrigated crops. In India, the current price of vegetable oils is nearly equal to the price of petroleum-derived fuel. If any specific oil needs to be adopted as a continuing energy crop from among a large number of vegetable oils available in the country, then this oilseed variety must have higher productivity and oil content. However, these vegetable oils have several drawbacks, including low volatility and the ability to polymerize (due to unsaturation). This causes problems like carbon deposits in the engine combustion chamber, injector coking, and piston ring sticking [26] [33]. To address these issues, straight vegetable oils are converted into biodiesel, which has properties very similar to mineral diesel and is currently one of the most widely accepted routes [34]. By hydro-deoxygenation of triglycerides, another fuel with properties and composition similar to mineral diesel can be produced. Hydrotreated vegetable oil (HVO), renewable diesel, or green diesel are all terms for it [34] [11] [35]. A feedstock containing double bonds and oxygen moieties can be converted into hydrocarbons via the hydro-de-oxygenation process by removing oxygen and saturating double bonds [34]. Renewable diesel has superior old flow properties to mineral diesel, but the commercial production technology is still in the works [34] [11].

6.3. Biodiesel

Vegetable oils cannot be used in CI engines in their raw form due to their inferior fuel properties; thus, they must be chemically modified to produce biodiesel, which has improved physical and chemical properties for use as a fuel. Biodiesel is a chemically modified alternative fuel for diesel engines made from fatty acids found in vegetable oils and animal fats. This is accomplished through the transesterification process, in which triglycerides present in vegetable oils react with primary alcohols in the presence of a catalyst, yielding primary esters (biodiesel) and glycerol [26]. Because it involves low reaction temperatures and pressures, low-cost construction materials, and high process yield for good-quality feedstock (low free fatty acid (FFA) and moisture content), base-catalyzed transesterification is the most commonly used process for producing biodiesel. In most ways, the resulting biodiesel is very similar to conventional diesel. Transesterification causes significant changes in the density and viscosity of vegetable oils. This biodiesel is completely miscible with mineral diesel in any proportion to produce a stable blend. Because the viscosity of biodiesel is very close to that of mineral diesel, problems with fuel handling systems are reduced. The transesterification process reduces the flash point of biodiesel while increasing the cetane number, which aids in reducing ignition delay. As a result, lower concentrations of biodiesel can improve the cetane of biodiesel blends. The heating value of biodiesel is comparable to that of mineral diesel. Because of these properties, biodiesel can be used in CI engines without requiring major hardware modifications [13].

7. Unconventional Fossil Fuels

Unconventional oils are fossil fuel resources whose extraction and conversion into liquid fuels is difficult and expensive. Unconventional oils are primarily derived from extra-heavy oil, natural bitumen (oil sands and tar sands), and oil shale [36]. Extra-heavy oils are significantly more difficult to recover than conventional petroleum. Heavy oil constituents have a significantly higher viscosity than conventional petroleum, and primary recovery of heavy oils typically necessitates reservoir thermal stimulation. Natural bitumen, also known as tar sand and oil sand, is a dense, viscous organic material impregnated with bitumen [16] [37]. Oil shales are fine-grained sedimentary rocks that can be destructively distilled to extract a significant amount of shale oil and combustible gas [36] [37]. The presence of a large amount of organic matter referred to as 'kerogen,' is the primary source of oil and gas in oil shales.

According to the EIA, the largest fractions of future unconventional liquid fuel production are 239 MTOE/year of Canadian oil sands, 69.7 MTOE/year of Venezuelan extra-heavy oils, and 194.2 MTOE/year of biofuels (109.6 and 84.7 MTOE/year of biofuels from the United States and Brazil, respectively) [12]. By 2035, unconventional fossil oils are expected to account for roughly 7% of the global liquid fuel supply [12].

8. Other Alternative Fuels

8.1. Fischer- Tropsch Liquids

The Fischer-Tropsch (F-T) process produces a variety of hydrocarbon fuels. The primary product is a diesel-like fuel derived from syngas (H_2/CO) produced by auto-thermal reforming of natural gas, biomass, or coal [20] [27] [38]. Depending on the starting material, the process may be referred to as coal-to-liquid (CTL), gas-to-liquid (GTL), or biomass-to-liquid (BTL). F-T liquid fuel contains no Sulphur, almost no aromatics, and has a high cetane number. These characteristics make it an appealing alternative fuel for CI engines [20]. In comparison to alcohols or oilseed-based fuels, the feedstock for BTL is renewable and can be produced with biomass residues from food crops with minimal interference to the food economy, as well as significantly less strain on land, air, and water resources. However, conversion technologies such as hydrolysis and gasification are still in the early stages of development [38].

8.2. Dimethyl Ether

At room temperature, dimethyl ether (DME: CH_3-O-CH_3) exists as a colorless gas with a faint odor. For normal use and distribution, it must be kept in tightly sealed containers [15]. DME has a vapor pressure between propane and butane [15]. DME is a clean-burning alternative fuel for CI engines that helps to reduce local air pollution. Because of its high cetane number, it is easily auto-ignited and produces practically soot-free combustion due to easy vaporization and the absence of carbon-to-carbon bonds [39]. It, like hydrogen and F-T liquids, does not exist in nature. Organic feedstocks such as biomass, coal, or natural gas are converted into synthesis gas, which is a mixture of carbon monoxide, hydrogen, and other gases, for DME production. Syngas is dehydrogenated into methanol, which is then converted into DME [15] [39]. DME-fueled engines produce less power than diesel-fueled engines due to significant differences in the properties of diesel and DME, such as DME's higher compressibility and lower heating value than mineral diesel.

Lower DME fuel lubricity and viscosity cause durability issues in fuel injection systems, which must be resolved before this wonderful fuel can be widely adopted [39].

9. Conclusion

The preceding discussions demonstrate that the twin crises of fuel scarcity and environmental degradation can be resolved by using sustainable and environmentally friendly alternative fuels. Biofuels can provide a viable solution to these crises in developing countries such as India. These biofuels could include alcohols, vegetable oils, biomass, biogas, and so on. Some of these biofuels can be used directly in IC engines, while others must be formulated to have properties similar to conventional fuels. There are several compelling reasons to use biofuels as alternative fuels, including the anticipated rise in the price of fossil liquid fuels in the near future, the gradual depletion of crude oil resources over the next 80-100 years, and so on. Biofuels emit significantly less harmful emissions in exhaust gas than conventional fuels. Mineral diesel currently meets the majority of agricultural and transportation energy requirements in India; therefore, alternatives to mineral diesel must be developed on a priority basis. Aside from renewable energy technologies, a number of steps should be taken to promote fossil fuel conservation. These include improving refinery energy efficiency, increasing fuel efficiency in the transportation sector, increasing the use of CNG as a fuel in the transportation sector, upgrading lubricants, and promoting fuel-efficient equipment and practices in the industrial sector.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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