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Review on Alternate Fuels: Need for Cleaner Fuels to Meet Future Energy Demands

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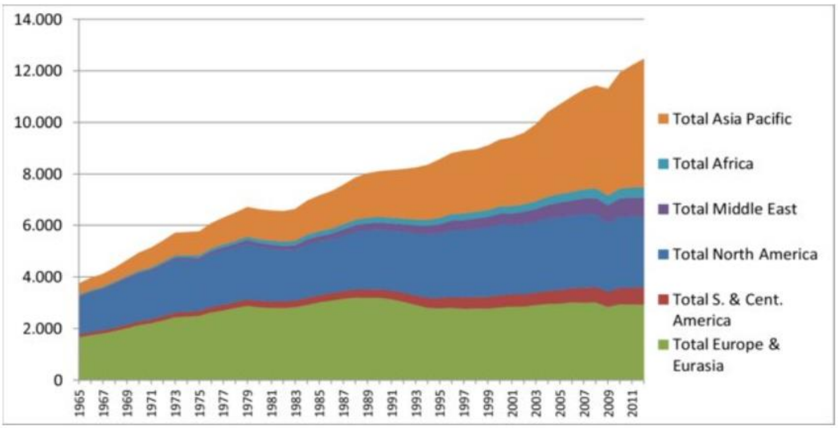
Abstract. On comparison with the current usage of fossil fuels, it is estimated that by the year of 2040, the requirement for global oil will increase to 5.7 million barrels per day for diesel fuel alone. The use of fossil fuels leads to high emissions of Carbon dioxide (CO_2), Nitrous Oxides (NO_x), Carbon Monoxide (CO) and Particulate Matter (PM). The release of Particulate matter (PM) from these vehicle sources is one of the major concerns to human health and linked with antagonistic health effects. There particulate matter (PM) emitted from the combustion of conventional fuels leads to diseases related to cardiopulmonary mortality and sickness which also includes cancer. This rapid diminution of readily available conventional fuels, environmental concerns, has led to the increasing demand for energy towards clean alternative renewable fuels. Depletion of fossil fuels and the toxic emissions from it has made us to look for alternatives. Biodiesels are one effective greener alternative out of the biofuels compared to the conventional fossil fuels. They also have a decreased effect on health, environment and no uncertainties related to the unstable costs of the fossil fuels. This review shows the importance of immediate change in the use of fossil fuels, comparison of various alternate fuels for engines and the challenges faced to implement alternate fuels in real time.

Keywords: Clean Energy, Alternate Fuels, Eco-friendly, Biofuel, Environmental impact assessment

1. Introduction

Alternative fuels differ in origin and manufacturing technique, but they all have one thing in common: they are generated in a sustainable and clean manner, with no additional carbon dioxide emissions (CO2). The direct use of excess power and thermochemical conversion of raw material are the two primary methods for the synthesis of alternative fuels. For the former, the term "electro fuels" was recently used to underline the manufacturing method and application of electricity.[1] Electro fuels are carbon-neutral fuels made from VRES energy excess in the form of a gas or a liquid, with carbon neutrality accomplished by closing the loop such that utilized CO_2 is collected from exhaust gases or straight from the air. Furthermore, electrolysis, which is a critical technology for the synthesis of electro fuels, may be run in a flexible mode in line with renewables output, boosting overall system efficiency while also permitting greater penetration of VRES.[2] Figure 1 shows the increase in the energy demands.

Figure 1. Illustration of tremendous increase in energy demands from 1965-2011 [3]



Depending on the use and manufacturing methods, alternative fuels can be produced in a liquid, gaseous, or solid state. The most viable answer for the transportation sector is liquid and certain gaseous fuels, whereas solid fuels are more likely to be employed for stationary demands in power plants. Furthermore, fuels that can be used in many forms while also serving as an energy transporter or storage will be implemented on a larger scale.[4,5]

Cross-sectoral integration is required to optimise fuel and overall system efficiency. This entails not only the production of combined heat and power (CHP), but also a greater integration of transportation and industry within the power generation sector.

Cogeneration facilities are more efficient than traditional power plants, and as a result, they will be favoured in the future energy system. Furthermore, waste heat can be used for district heating, industrial applications, or the direct generation of alternative fuels. To prevent any misunderstanding, the term alternative fuels will be used for all fuels evaluated in this analysis, including electro fuels.[6,7]

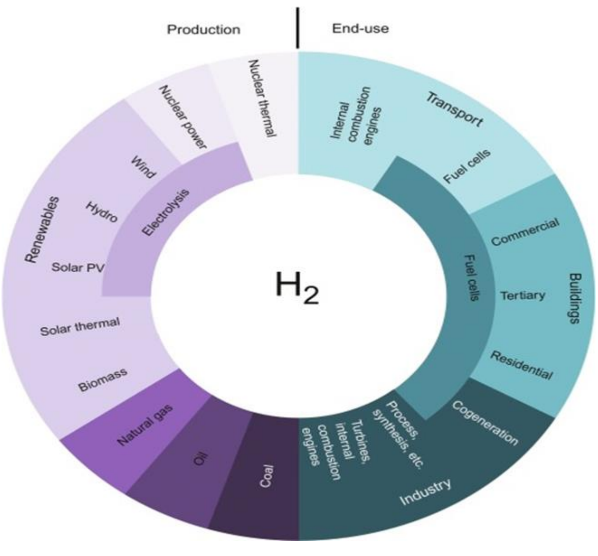


Figure 2. Schematic of applications of H_2 [8]

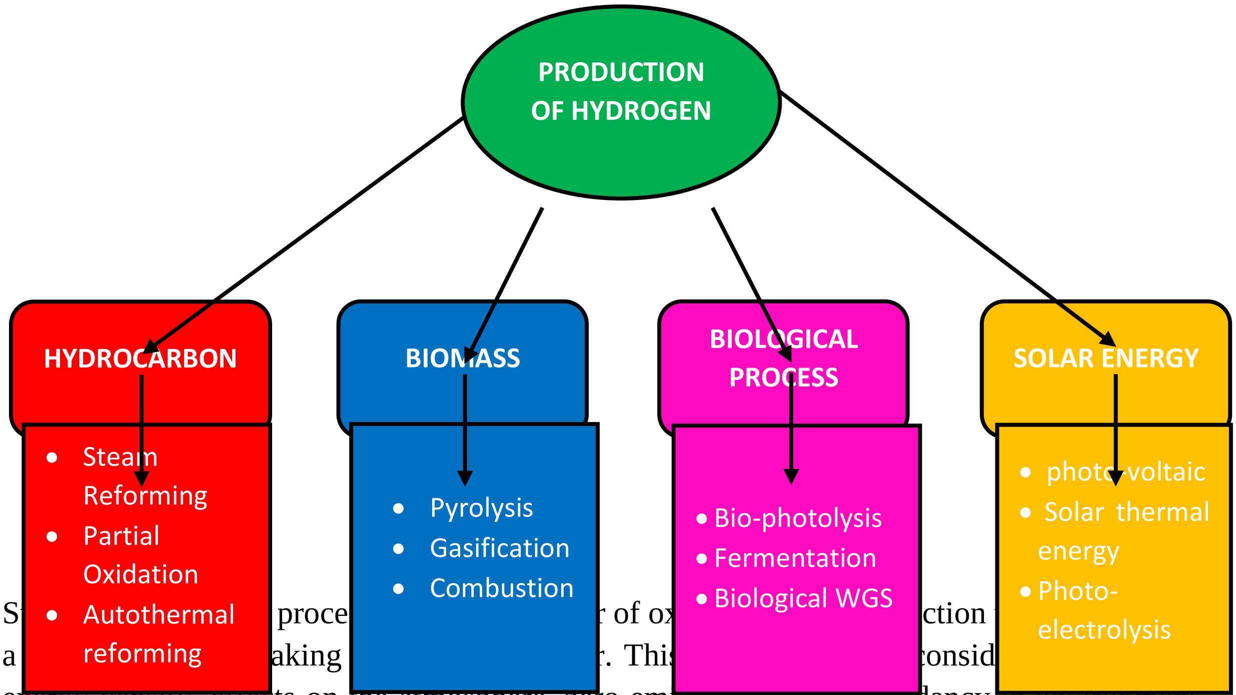
Figure 2. shows various applications of hydrogen (H2) which is one of the clean fuels. This review illustrates the various methods for various alternate fuels, production of cleaner fuel, ranking of the best production methods, applications of alternate fuels in industries and IC engines, current challenges and overview on improvement of cleaner fuel for the betterment of our environment. [9]

2. Alternative Fuels

2.1 Hydrogen

Energy obtained from production of hydrogen is non-toxic, eco-friendly as well as an infinite form of energy. Due to its abundance and eco-friendly product that is 'water' it is relied on to be one of the sources of alternative fuels. Hydrogen fuels do not produce any harmful greenhouse gases and hence considered to be zero emission of greenhouse gases. In general, manufacture of hydrogen (H2) is done by steam reforming, electrolysis as well as thermolysis. [10,11]

Figure 3. Flowchart of various methods used for production of hydrogen



S[illegible] proce[illegible] of ox[illegible]ction [illegible] a [illegible]aking [illegible]. Thi[illegible]onsid[illegible] energy density, effects on the atmosphere, zero emission and its abundancy in environment. Production of hydrogen can be from 3 forms.[12] Hydrogen can be obtained from hydrocarbons by partial oxidation (POX), Autothermal reforming (ATR) as well as Steam methane reforming (SMR). From biomass, production of hydrogen can be from pyrolysis and gasification.[13]

Hydrogen can also be produced through biological process at ambient pressure and temperature. Some of the common biological processes to obtain hydrogen are fermentation, bio-photolysis and indirect bio-photolysis.[14] These processes are controlled by H2 producing enzymes such as hydrogenase and nitrogenase. photovoltaic, solar thermal energy, photo-electrolysis and bio-photolysis are few processes from which production of hydrogen can be obtained from direct solar energy. The following table 1, shows the merits and demerits of various production processes of hydrogen for clean fuel along with the efficiency of yield.[15]

Table 1. Merits and Demerits of Production Processes [16]

RANK	PROCESS	YIELD (%)	MERITS	DEMERITS
1.	Steam Reforming	70 – 85	• No requirement of O2 • Used in industrial sectors. • Less operating Temperature	• Emission of carbon dioxide (CO_2)
2.	Partial Oxidation (POX)	60 – 75	• No Catalyst is required • Low methane slip • Desulphurization is low	• Less H2/CO ratio • Operating temperature range is high • Complex process
3.	Auto-thermal Reforming (ATR)	60 – 75	• Low methane slip • Lower partial temperature	• Less Air/O_2 is less • Not used in commercial sectors
4.	Biomass Pyrolysis	35 – 50	• Inexpensive • Biodegradable feedstock • CO_2 neutral	• Slow process • Formation of Tar • H2 yield depend on feedstock
5.	Gasification	35 -50	• Inexpensive • Biodegradable feedstock • CO_2 neutral • Good for small scale use	• Slow process • Formation of Tar
6.	Bio-photolysis	0.5	• By product are not toxic • Require mild environment	• H2 yield is very less • Requires sunlight • Sensitive to presence of O2
7.	Photo-electrolysis	0.06	• By-product is not toxic • Feedstock is readily available	• Yield percent is less • Slow process • Requires constant sunlight

2.2 Biodiesel

Biofuels are fuels that are made from plants and crops. Biodiesel and bioethanol are the most common biofuels. Plant-based fuels are a renewable resource that can be grown everywhere. Biofuels emit fewer carbon emissions than fossil fuels. Biofuels also aid in the reduction of greenhouse gas emissions. Biofuels, on the other hand, offer their own set of benefits and drawbacks.[17]

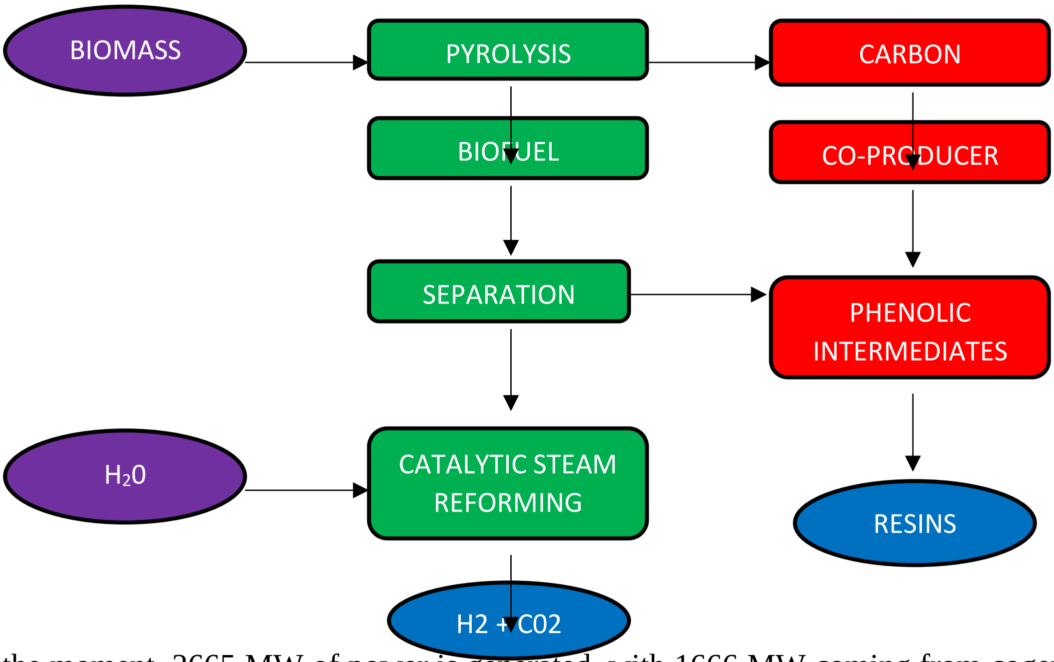
Biofuels are a renewable source of energy, making them preferable to fossil fuel-derived fuels due to the scarcity of fossil fuels. Biofuels are more environmentally friendly than petroleum-based fuels because they produce less pollutants when burned.[18] A major issue with burning fossil fuels is that a large amount of Sulphur is emitted into the atmosphere, resulting in acid rain. Although burning a biofuel emits nitrogen into the atmosphere, the net acid rain generation is substantially decreased when biofuels are used. Biofuel production should be carried out properly since proper biofuel production may significantly reduce greenhouse gas emissions. Biofuels may be made from a variety of low-cost sources, such as agricultural waste, discarded vegetable oils, non-edible oils, animal fats, and so on.[19]

Due to their superior combustion profile and environmentally benign nature, biofuels are the greatest alternative to petroleum-based fuels. Furthermore, the feedstock's necessary to synthesis biofuels are readily available. Biofuels have an advantage over petroleum fuels since they may be made from waste items like discarded vegetable oils and less expensive sources like non-edible oils like neem oil and jatropha oil and so on. Algae and fungus can potentially be used as raw materials to make biofuels. Biofuels are better than regular gasoline and diesel because they are renewable, thus they may be utilized instead of nonrenewable fossil fuels.[20] Despite the benefits of biofuels over gasoline and diesel, they have a number of drawbacks, although the overall impacts of biofuels are superior than conventional gasoline and diesel. Many nations, such as India, Brazil, and Indonesia, are involved in the production of biofuels. Engines benefit from the usage of biofuels because the lubricating properties of biofuels are improved. Biofuels primarily consist of biodiesel and bioethanol, which are generated by transesterification and fermentation processes, respectively. The ethanol yield can be raised by using different raw materials in the fermentation process, and the biodiesel output can be enhanced by changing the transesterification method. Biofuel yields can also be improved through molecular and genetic engineering approaches. Making genetic changes to the raw materials used in biofuel production can be beneficial. Microwave irradiations, ultrasounds, and other alternative methods have been developed for the generation of biofuels. In conclusion, biofuels can be a valuable approach to minimize reliance on non-renewable fossil fuels while also being environmentally friendly.[21,22]

2.3 Biomass

Biomass is one of the most widely used renewable energy source, and its use is growing due to worries about the devastating effects of fossil fuel usage, such as climate change and global warming, as well as their detrimental effects on human health.[23] As a result, the current article examines the many types of biomass accessible, as well as their chemical makeup and characteristics. Following that, several conversion technologies (thermochemical, biochemical, and physicochemical conversions) and their associated products are examined and explained. The global position of biomass in comparison to other renewable energy is examined in the next section. Furthermore, biomass-derived energy generation was examined from both an economic and an environmental standpoint.[24]

Figure 4. Flow chart of hydrogen production by biomass pyrolysis [25]



At the moment, 2665 MW of power is generated, with 1666 MW coming from cogeneration. This study also discusses the many types of biomass in India. According to the report, India has a significant potential for bio mass feed supply from several sources. The Indian government implemented several policies and initiatives for biomass power generation. Such regulations have encompassed the whole biomass energy industry, including biogas, biodiesel, and other biofuels. [26]

High carbohydrate and moisture content vegetable and fruit wastes are excellent candidates for biogas generation. Animal waste contains a lot of organic matter and a lot of bacteria, both of which are crucial in biogas generation. Kitchen trash, a high-nutritive organic material, is also ideal for biomethanation. Uneaten food and food preparation leftovers from various households, restaurants, school cafeterias, and other sources are included in the food waste. These carbohydrate-rich food wastes and wastewater from food industry are appropriate for biomethanation. [27] Distillery effluent has a high BOD and COD content, which makes it a good candidate for biomethanation. Biogas production from nutrient-rich poultry sector wastes is also a viable option. Industrial wastes can also be used to produce bio-methane. The carbohydrate-rich, readily biodegradable organic portion of municipal solid trash can be used to generate renewable energy. Biomethanation of biomass, either alone or in conjunction with other agro-industrial wastes, looks to be a potentially economically feasible solution for producing renewable energy while reducing pollution.[28] To address the drawbacks of biomass, further research and new technologies need be created. Agricultural wastes should be available; therefore, basic crops should be cultivated. Biomass crops should be produced on a big scale. Biomass collection, harvesting, and storage technologies should be made more affordable. Biomass energy facilities should be able to use environmentally acceptable and safe exhaust gas cleaning technology. Biomass conversion initiatives should be supported in order to lower the cost of producing biomass-based fuels for renewable energy generation. [29]

3. Synthesis of Alternate Fuels

3.1 Hydrogen Production

The technique of producing hydrogen from fossil fuels, which employs natural gas or coal as a feedstock, is well-known. Hydrogen is most often generated nowadays by steam reforming methane, although it may also be produced via partial or auto thermal oxidation or gasification. Biomass pyrolysis or gasification, as well as water electrolysis utilising VRES, are all examples of renewable energy production. [30] One of the most promising ways for creating clean hydrogen is water electrolysis. Efforts are being made to commercialise this technology, and although though it only accounts for 4% of present output, the future seems promising. Electrolysers are divided into groups based on the type of electrolyte they use. The most popular electrolysers are polymer electrolyte membrane (PEM) electrolysers, alkaline electrolysers, and solid oxide electrolysers (SOE). Electrolysers can produce hydrogen with a high purity (99.999 vol percent) and efficiency of 70 to 85 percent. The load factor of renewables and the efficiency of the electrolyser are the primary determinants of the process' efficiency. [31] Since the water is carbon-free and the technology has matured, the procedure's economic competitiveness is the final step before it can be widely deployed. Since energy is the major cost driver in electrolysis ($3/kg), these prices are now twice as expensive as those from natural gas reforming ($1.2-1.5/kg). However, if VRES has a greater penetration, this technology will be entirely competitive with steam reforming of fossil fuels. [32] This will be especially important in the future energy system, since there will be more electrical surpluses that may be used for electrolysis. Grid stability, output curtailment avoidance, and, most importantly, clean hydrogen generation would all be assured. Additionally, hydrogen may be produced directly from solar, nuclear, or industry waste heat. Because greater temperatures are necessary to generate hydrogen directly from solar energy, concentrated solar power (CSP) appears to be the best option. Even if further study is needed, production utilizing nuclear energy Table indicates the incorporation of waste heat for high-temperature electrolysis. [33]

Table 2. Applications of hydrogen in industries [34]

S.NO	INDUSTRY	APPLICATIONS
01.	Oil Refining	• Removal of impurities
02.	Chemical factories	• Production of chemicals • Used in manufacturing fertilizers like ammonia • Produce polymers

03.	Food production	• Converting sugar – polycols • Converting edible oils
04.	Plastics	• Nylon synthesis • Recycling plastics
05.	Metals	• Used as reducing agent in steel industries • O2 scavengers • Welding • Heat treatment processes
06.	Electronics	• Vacuum tubes • Processing nuclear fuel • Heat bonding materials
07.	Glass manufacturing	• Polishing • Few heat-treatment processes • Cutting torches

3.2 Anaerobic Digestion

Anaerobic digestion is a process that transforms biodegradable waste as useful biogas, primarily methane, via four stages of bio-metabolism. The four stages are hydrolysis, acidogenesis, acetogenesis and methanogenesis. [35] Anaerobic Digestion is the most efficient method of dealing with a biodegradable component of MSW, farm waste, food sector waste or sewage sludge. Even if the bottom step takes more study, the four-step approach may be used to multistage or single stage Anaerobic Digestion system. Complex relationships between numerous operational parameters, growth variables, system architecture, and reactor type influence the entire process. The feedstock type influences growth factors and operational parameters, as well as the system design and reactor type. [36] pH is strictly regulated throughout the procedure since it affects the bacteria's effectiveness and, as a result, the process's success rate. Nowadays, the majority of Anaerobic Digestion systems process different biodegradable wastes in a continuous single-stage manner. Despite the fact that anaerobic digestion is a complicated process with greater upfront and ongoing expenses, installation capacity has risen from 2 to 11 million tons in the previous two decades. [37] Since the creation of biodegradable waste is unavoidable, installed capacity are projected to rise even more, and Anaerobic digestion appears to be a viable waste management approach. However, more research should be focused on multi-stage Anaerobic Digestion, which can create high-quality biogas, as well as cost reduction to reach economically feasible production. [38]

3.3 Methanol Synthesis

The use of light to drive or help chemical reactions and processes in order to produce cleaner methanol is a unique notion that is gaining traction in the scientific community. The ability to synthesise methanol using solar energy, CO2, and water might lead to an economically viable technology capable of replacing fossil fuel-intensive sectors with sustainable alternatives. Light-assisted chemical products can be made in a variety of methods, including direct conversion of [39] CO2 and water via solar thermochemistry, photochemistry, or photo electrochemistry. Gasification of biomass feedstock to create syngas is another possible approach. Solar concentrators, when used in conjunction with complementary focusing components, increase the amount of sunlight that reaches the biomass gasification reactor. [40] The temperatures achieved should be sufficient to affect biomass gasification without the need of external heating (850 C). Solar-to-power technologies, such as ammonia, have low efficiency, which has a major influence on overall process efficiency. As a consequence, combining hydrogen from electrolysis with CCU technologies that take advantage of grid energy surpluses might be a viable option. Iceland's capital, Reykjavik, is a shining example of sustainable and environmentally friendly methanol production. [41] This industrial plant, which first opened in 2007, produces 4000 metric tonnes of methanol per year by collecting CO2 and H2 from the atmosphere. This translates to 5500 metric tonnes of CO2 being recycled each year. The facility's location allows it to create sustainable heat and energy using geothermal steam from the 75 MW power plant, while collected CO2 accounts for about 10% of total annual CO2 emissions. Electricity is primarily used to power alkaline water electrolysis to generate H2, which then lowers CO2 in the presence of a catalyst in a process running at 250 C and 5–10 MPa. [42]

3.4 Fuel Blend Pyrolysis for Biofuel

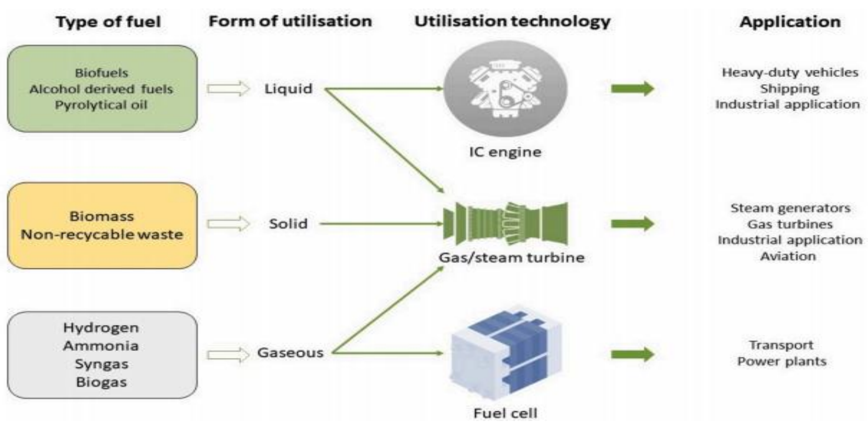
Pyrolysis is a thermochemical conversion process that involves heat breakdown without the need of oxygen. Carbonized residue, liquids, and gases are examples of derived products. Pyrolysis has recently been touted as a viable method for converting waste materials into useful fuels and chemicals. While higher manufacturing costs aren't an issue for this use, more cost savings are predicted if they're to be utilised as a fuel. In addition, the introduction of new fuels demands modifications to current usage technologies. Product yield is influenced by operating conditions and feedstock type, and finished products are usually refined before being used. Bio-oils, for example, have lower heating values and become unstable at higher temperatures, but pyrolysis gases might include a lot of CO_2. Recent scientific endeavours have focused on converting biomass feedstock into useful fuels and chemicals. Pyrolysis of waste materials such as sawdust, agricultural waste, various straws, energy crops, and other items is fascinating. [43] Despite the fact that pyrolysis has the potential to significantly enhance biomass properties, further research is needed to increase heating value, viscosity, acidity, and thermal stability. It's possible that the synergistic effect that occurs when biomass and waste plastics are co-pyrolyzed is fascinating. Plastic has a significant amount of carbon and hydrogen, as well as a heating value equivalent to that of fossil fuels. In addition, a lack of oxygen or a low proportion of oxygen in the elemental composition reduces the synthesis of oxygenated molecules, which is a key drawback of biofuels. Co-pyrolysis has been proven in several studies to enhance bio-oil properties such as heating value, thermal stability, and viscosity. Chemical and mechanical recycling of plastics is expensive, and in some cases impossible.

Because chemical and mechanical recycling of plastics is expensive, if not impossible in some situations, co-pyrolysis looks to be a viable waste management option. Other non-recyclable wastes, such as sewage sludge (SS), food waste, municipal solid waste (MSW), rubbers, and so on, can also be co-pyrolyzed with biomass. Despite the fact that research has shown that the co-pyrolysis process improves product characteristics significantly, additional work has to be done to minimize the production of different contaminants that limit immediate use. [44,45]

4. Results & Discussion

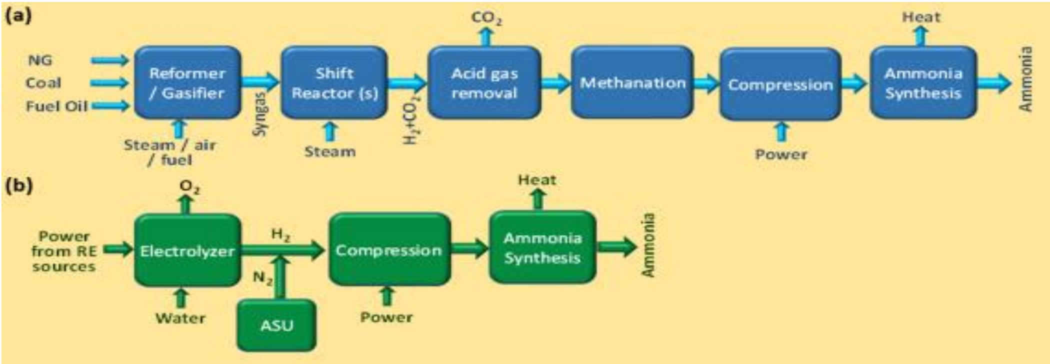
Currently, there are several barriers to expanding the use of alternative fuels. To begin with, alternative fuels find it difficult to compete on price due to the ample supply of fossil fuels. In the case of biofuels and waste fuels, quality standards are the most important consideration; lower heating value, higher acidity, thermal stability, and other characteristics limit the use of currently commercially available biofuels. However, research in this field has been ongoing for some time, and the continuous development of produced fuels suggests that the future importance of such fuel is unquestionable. Although they are mainly produced for industrial purposes, certain chemicals (H2, NH3, and alcohol-derived fuels, for example) have a well-known production method. While higher manufacturing costs aren't an issue for this use, more cost savings are predicted if they're to be utilised as a fuel. In addition, the introduction of new fuels demands modifications to current usage technologies. Figure 5, shows the various applications of alternate fuels in industries. [46]

Figure 5. Applications of various alternative fuels [47]



While biofuels and alcohol-derived fuels may be utilised in contemporary IC engines with just minor modifications, hydrogen and ammonia need the development of new technologies or significant alterations. Despite the fact that additional work is needed to optimise operating parameters and improve efficiency, fuel cells built for hydrogen usage have a bright future in both fixed and portable applications. Manufacturing, which must transition to more ecologically friendly and sustainable techniques, is the final hurdle to a widespread usage of alternative fuels.[48] This generally includes utilising discarded agricultural and industrial biomass leftovers to generate high-quality, clean fuels in the case of biofuels. Simultaneously, synthetic fuel production must shift to new technologies that do not require fossil fuels as a feedstock in order to achieve carbon neutrality. Furthermore, VRES should be coupled with alternative fuel synthesis to allow for wider penetration into the energy system while decreasing the carbon footprint of produced fuels. [49] Following figure 6, shows the production of ammonia from renewable and non-renewable resources.

Figure 6. Ammonia synthesis using (a)non-renewable resources and (b) renewable resources [50]



The direct use of solar energy for fuel synthesis in research is a significant trend. The major advantage of solar energy generation is that it does not require an external energy source. The poor conversion efficiency of solar energy, however, has a substantial influence on total process efficiency, making solar manufacturing commercially uncompetitive. Furthermore, significant research efforts are done to bring to market technologies that can operate in a flexible manner.[51] This is especially true for electrolysis and carbon capture technologies, which supply crucial feedstock (H2 and CO2) for alternative fuel generation. Combining these technologies with VRES would result in cheaper production costs, fewer power curtailments, and greater grid stability, among other benefits. When it comes to thermochemical conversion technologies for alternative fuel production, a lot of effort is invested into research in order to scale up and commercialise these processes[52]. Pyrolysis and gasification are particularly fascinating because they have the potential to convert a wide range of waste materials into valuable fuels or chemicals. The focus of research has recently shifted to enhancing biofuel properties by co-pyrolysis or co-gasification with high-calorie waste sources (i.e. end-of-life plastics). Not just for fuel generation, but also for waste management, this is critical. [53]

5. Conclusion

In a future decarbonized energy system, alternative fuels will be unavoidable. Alternative fuels are also critical for decarbonizing the transportation and manufacturing sectors, where electricity has a considerably smaller impact or is not appropriate as a replacement. The authors' major objective in this review is to highlight existing possible alternative fuels and their uses, as well as potential alternative manufacturing pathways. The conclusions that follows are taken.

- Biofuels, notably biodiesel and solid biomass, are now the only commercially available alternatives for transportation and industry. Because their usage is expected to increase significantly in the future, new methods for attaining sustainability must be developed.

Pyrolysis or gasification of raw feedstock, as well as anaerobic digestion of biodegradable waste, appear to be promising possibilities that merit further research. Waste management may also be effectively integrated into the production of better biofuels, solving environmental concerns while simultaneously improving biofuel characteristics.

- Alternative fuels like hydrogen and ammonia have been tested for a number of uses. Hydrogen has a high energy density, making it a feasible option for high-temperature industrial processes or transportation. However, because hydrogen is regularly used for other purposes, only a small quantity would be available for fuel uses. Furthermore, increasing hydrogen deployment necessitates the construction of a new distribution network, which is a considerable drawback.

  Ammonia, on the other hand, has a reduced heating value, a slew of safety issues, and poor combustion properties. As a result, ammonia looks to have little promise as an alternative fuel. Ammonia, on the other hand, has a high hydrogen gravimetric density and may be used as an energy transporter or storage since distribution is not an issue.
- Fuels made from alcohol have been around for a long time. Commercial usage on a wider scale, on the other hand, is improbable. Furthermore, lower heating values, which signal a larger fuel input, necessitate further modifications or the development of specialist IC engines in order to achieve higher efficiencies. However, such fuels offer fascinating characteristics when mixed with other fuels, particularly in terms of reducing pollutant emissions. Furthermore, as the simplest alcohol, methanol has been successfully examined for marine usage, with encouraging findings in terms of engine performance and pollution reduction.
- Expect a higher deployment of alternative fuels once cost-competitive manufacturing is established. Despite the fact that strategic opposition may have a significant influence, the price of produced fuels should ultimately be equivalent to traditional fuels. Because there would be longer periods of excess power output, which could be used to synthesis alternative energy, higher VRES penetration would allow for this cost reduction. At the same time, because the created alternative fuels may be used as energy storage, intermittent renewable energy sources might be used to a greater extent.

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