BIOFUEL: PROSPECTS AND CHALLENGES AS CLEANER ENERGY SOURCE

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Abstract

The consumption of energy has ever-increasing trend due to change in the lifestyle and significant growth of population. Two of the main contributors are the transportation and the basic industry sectors. This increase of energy demand has been supplied using fossil resources (fossil fuel, natural gas and coal). Fossil fuels are extensively used due to its high power output, availability and quality combustion characteristics. At present, as almost all the energy required by the transportation sector is met by fossil fuel, rapid depletion of fossil fuel reserve is considered as the foremost problem for this sector. In addition, problem associated with combustion of fossil fuel is accountable for harmful emissions that are causing global warming. These problems have intensified research into identifying suitable alternative fuels for internal combustion engines. Biofuels are one of the most promising alternatives of fossil fuels. Their acceptance as energy source in transportation sector increasing rapidly due to ease in adaptation, environmental benefits and prospects in energy security. Biofuel has similar working properties as of petroleum fuel. In addition, there is no need of engine modification to operate it with biofuel. Key advantage of using biofuel is it has higher lubricity index compared to petroleum fuel, which extends engine life. Even a small percentage of biofuel means cleaner emissions and better engine lubrication. In contrast, disadvantages of biofuel include limited feed stock availability, higher production cost, inferior oxidative and storage stability and lower volumetric energy content. Application problems evolved from these issues include- lower power output; corrosive wear to engine parts like piston ring, piston liner etc. due to formation of oxidation products like aldehydes, ketones, acids and oligomers; clogging of the injection pumps and filters; carbon deposits on piston and head of engine etc. These problems need to be resolved for its widespread applicability.

Keywords: Biofuel; Transport; Renewable Energy; Lubricant; Oxidation Stability.

1. Introduction

Energy plays the foremost important role in the advancement of all commercial sectors, including agricultural, transportation, telecommunication and industrial sectors. With the development of the world's economy, worldwide energy consumption is expected to grow in a faster rate than the population growth [1]. According to a recent report of U.S. Energy Information Administration (EIA) one-fourth of the total delivered energy consumption globally is consumed by transportation sector [2]. International Energy Agency (IEA) reported that, petroleum fuel supplies 93.5% of the total fuel consumed by transportation sector [3]. Transport sector heavily depends upon petroleum due to their adaptability, high combustion efficiency, availability, reliability as well as the handling facilities. However, petroleum fuelled engine has

recently been besieged with concerns over its contribution to the atmospheric emissions inventory due to less emission reduction. Emissions which are produced from burning petroleum derived fuels have a serious effect on both the environment as well as human health [4, 5]. One of the main sources of an increase in CO_2 emission is the burning of fossil fuels. This is largely responsible for an increase in global warming. It has been suggested that, if strict regulation concerning fossil fuel's emission is not taken soon, by 2030, an increase of 39% of GHG emission from fossil fuel will be observed. In these consequences a strong worldwide drive towards alternative fuels for transportation mainly driven by emissions reduction, energy security concerns, volatility in the fuel price and the search for renewable fuels to compliment the dwindling world fuel supplies. Targets of improving air quality and diversifying energy resources have intensified research into identifying suitable alternative fuels for cleaner combustion [6, 7]. Biofuels can be a practical replacement for fossil fuels in the transport sector. There is no requirement of engine or fuelling process modification to use biofuel, thus simplifies their adoption. Due to these reasons, biofuels are considered as one vital alternative to diminish CO_2 emissions and decrease reliance on petroleum oil. There are various advantages of biofuel e.g. it is renewable so it will replenish as soon as it is consumed, can provide energy security to a country and decrease reliability on imports or foreign volatile markets, and production process can eliminate the unemployment problem. Fig. 1 illustrates energy demand until 2030, from this it can be seen that, by 2030, the demand will be a significant amount which will be one of the key player to meet the future energy demand [8].

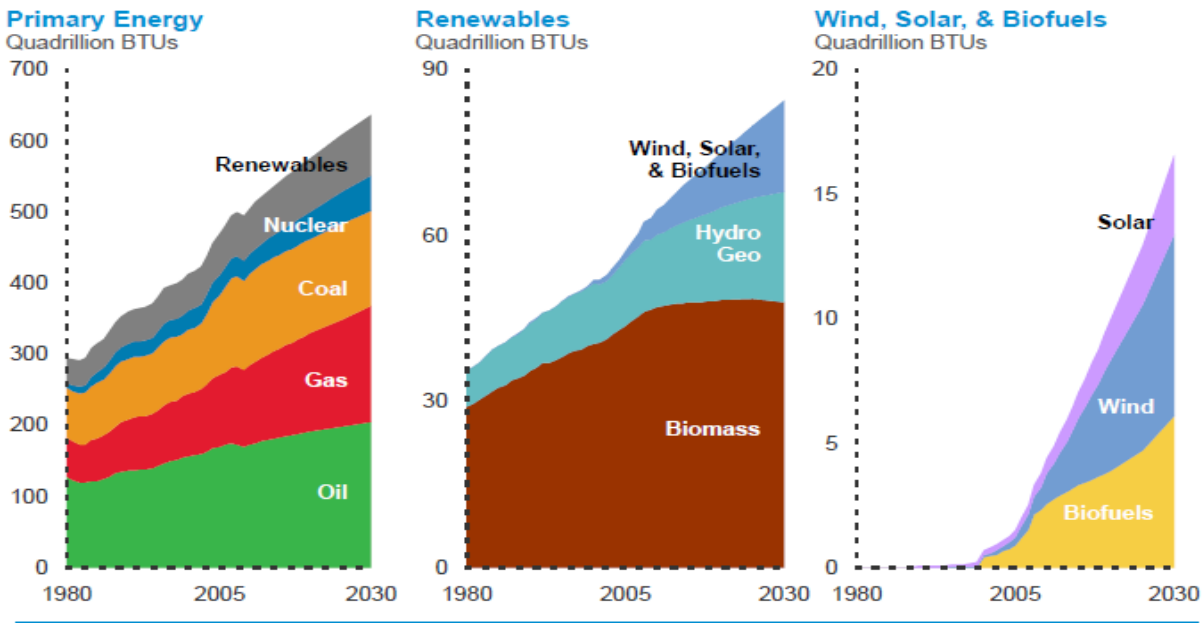

Fig 1. Energy demand until 2030[8]

As biofuel is non-toxic and have good safety and environmental characteristics, it can be an attractive alternative to petroleum-based oil used in automobile lubrication. On the other hand, the use of crude vegetable oils as fuel may give rise to a variety engine problem, such as carbon deposits on piston and head of engine, coking of injectors on piston and head of engine, and also extreme engine wear [9-11]. In order to make biofuel the most promising alternative of petroleum, these problems need to be solved as soon as possible.

2. Biofuel and its feedstock

Fuel derived from organic matter such as plants, agriculture, domestic, industrial, and/or commercial wastes, are known as biofuel. It has several advantages, such as renewability, biodegradability, non-toxic, emits fewer pollutants, etc. Currently, the most popular biofuels are-biodiesel and bioethanol.

Biodiesel are mono alkyl esters and generally derived from fatty ester of vegetable oil or animal fat through chemical treatment. Biodiesel production is more appropriate as an energy substitute due to its widespread accessible resources. Depending on country's dependency on husbandry and geographical locations biodiesel feedstock differs from country to country. Worldwide, there are more than 350 oil-bearing crops that were identified as potential feedstock for biodiesel. Feedstock of biodiesel can be divided into 4 categories[12]. They are as below:-

a. Edible vegetable oil—soybean, rapeseed, palm, coconut, and sunflower.
b. Non-edible vegetable oil—karanja, jatropha, Calophyllum inophyllum, Moringa oleifera, algae, halophytes and sea mango.
c. Waste or recycled oil.
d. Animal fats—by-products from fish oil, yellow grease, tallow, and chicken fat.

Bioethanol, also known as only 'ethanol', is an energy source prepared from sugar and starch components of plant by-products by fermenting process using yeast. Sometimes, potatoes, corn, potatoes, rice, milk, beetroot and lately dates, banana and grapes are also used depending on agricultural strength of the country. Today, bioethanol has many uses: It is blended with petrol to make a truly sustainable transport fuel. Bioethanol feedstocks can be conveniently classified into three types [13]:

a. sucrose-containing feedstocks (e.g. sugar beet, sweet sorghum and sugar cane),
b. starchy materials (e.g. wheat, corn, and barley), and
c. lignocellulosic biomass (e.g. wood, straw, and grasses).

3. Biofuel policies of different countries

Around the world, many countries have set their biodiesel policy and standards. Targets or mandates concerning an increase in biofuel consumption and utilization of biofuel in the energy mix has been announced. In this section, biofuel policies, targets and its standardization of Malaysia and Indonesia has been presented. Figure 2 shows the ASEAN biofuel flagship roadmap. [12].

Malaysia: On 21st march 2006 by the Ministry of Plantation Industries and Commodities of Malaysia introduced the “National Biofuel Policy”. It contains five strategic thrusts:

i. Biofuel for transport,
ii. Biofuel for industry,
iii. Biofuel technologies,
iv. Biofuel for export and
v. Biofuel for a cleaner environment.

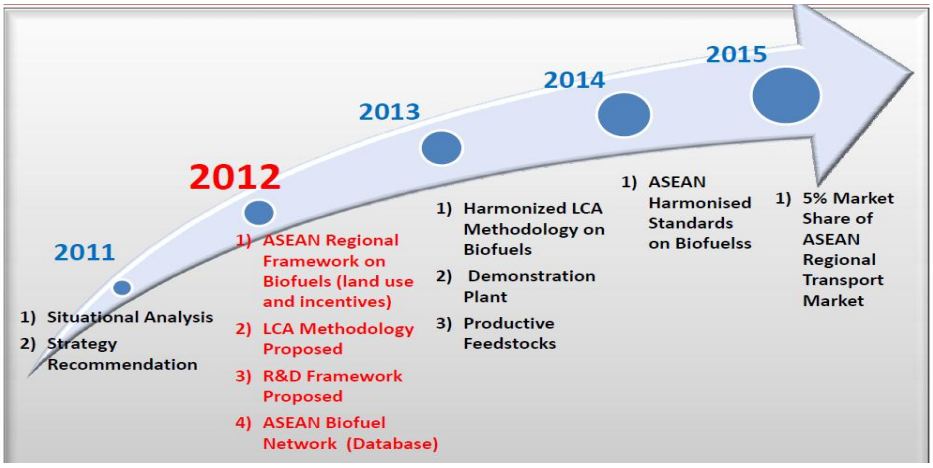

Fig 2 ASEAN biofuels flagship roadmap.

However, government has aborted the Envo Diesel (5% Palm Methyl Ester and 95% Diesel) due to failing to market it in 2008 according to "The National Biofuel Policy."

Indonesia: In 2006, Government of Indonesia announced its first national biofuel policy. According to the policy, it set a target of achieving 10% replacement of transport fuel with biofuel within 2010. The national oil company Pertamina has suffered a severe financial loss from selling of the B5 biodiesel blends commercially due to high feedstock price. For these problems, the Indonesian government has changed their target to replacement of 3% gasoline by ethanol and 2.5% diesel excision by biodiesel within 2010.

4. Impact of biofuel on transport sector

Main reason of using biofuel is that it is supposed to be carbon neutral. Compared to petroleum fuels, biofuel can significantly reduce GHG emissions. Various scientific shows that using biodiesel instead of diesel and bioethanol instead of gasoline helps reduce GHG emission (Fig 3 and Fig 4) [14]. According to recent UK Government publication, biofuels can reduce 50-60% carbon emissions [15].

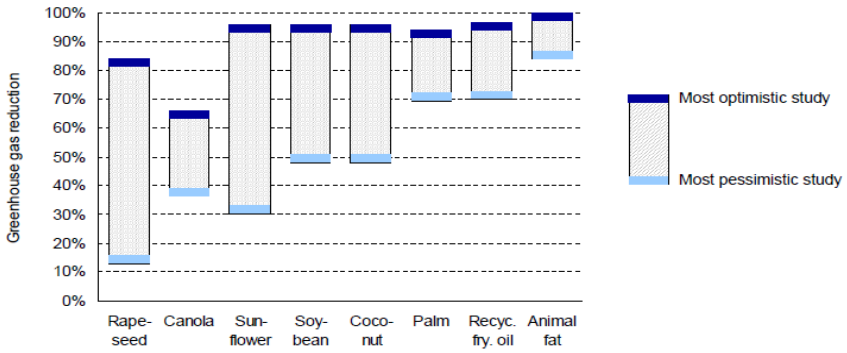

Fig 3. Greenhouse gas savings achieved by substituting a liter of diesel with biodiesel

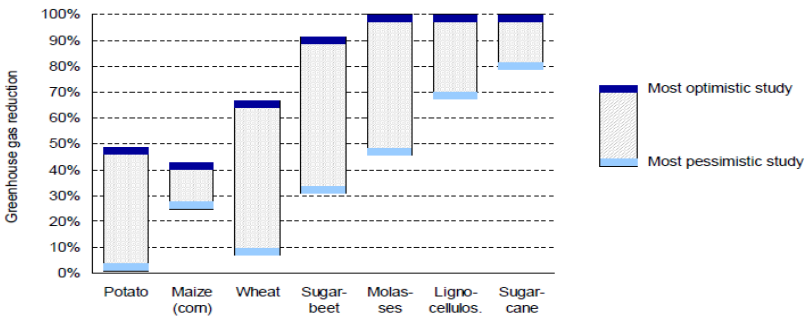

Fig 4. Greenhouse gas savings achieved by substituting a liter of gasoline with bioethanol

Advantage of biodiesel is that compared to diesel it has higher oxygen content. Studies suggest that, use of biodiesel in the diesel engine significantly decreases CO, sulfur, PAH, PM, noise and smoke emission [16]. As the flash point of biodiesel is much higher than diesel, there are fewer possibilities of burning after an accident and thus increasing safety of the engine [17].

Because of the regenerative and biodegradable characteristics of ethanol, it is widely used as an alternative fuel at present. The use of gasoline containing 3–10 vol% bioethanol is being promoted in many parts of the world for last few years [18]. Ethanol burn reduces greenhouse gas emission significantly [4]. Ethanol provides high quality, high octane for excellent engine performance and reduced emissions [19]. Ethanol has much higher octane number compared to gasoline, which enables it to keep engines running smoothly making it highest performance fuel on the market currently. As Ethanol-blended fuel does not leave tacky deposits, it keeps the fuel system clean for optimum performance.

In near future, with the discovery of new feedstock for biofuel production countries energy security will rise since dependency on imports or foreign volatile markets will decrease.

5. Drawbacks and remedies of biofuel

Although biofuels have many positive impacts, it also has some negative characteristics too. Compared to petroleum fuels, biofuels have a lower energy output. As a result, to produce same power output as petroleum fuel it requires greater quantities of biofuels to be consumed. Though emission from burning of biodiesel is cleaner, but production process of biofuel which includes machineries might have hefty carbon emissions. Production process of biofuel is also very much costly. Producing biofuel from edible feedstock may raise the prices for essential fundamental food crops. Using land to produce fuel crops can have a severe impact on food price and might lead to food shortages. There can be massive draining of the water resources, as a huge amount of water is needed for the production process of biofuels.

Lower energy content, higher viscosity, higher cloud point and pour point, lower oxidative stability, higher nitrogen oxides emissions, lower engine power and speed, injector coking, engine compatibility, high price and higher engine wear- these are the disadvantages of using biodiesel in a diesel engine [20, 21]. Biodiesels are more susceptible to degradation compared to fossil diesel. The mechanisms of degradation are: (a) autoxidation in presence of atmospheric oxygen; (b) thermal or thermal-oxidative degradation from excess heat; (c) hydrolysis in presence of moisture or water during storage and in fuel lines; and (d) microbial contamination from contact with dust particles or water droplets containing fungi or bacteria into the fuel [22]. Oxidation of biodiesel results in the formation of hydroperoxides. Once the hydroperoxides are formed, they decompose and inter-react to form numerous secondary oxidation products,

including higher molecular weight oligomers often called polymers. Oxidation products cause corrosive wear to engine parts like piston ring, piston liner, etc. and may lead to clogging of the injection pumps and filters [23]. Physical properties that are sensitive to the effects of biodiesel oxidation include cetane number, kinematic viscosity, flash point, refractive index, and di-electric constant [22, 24]. Cetane number and kinematic viscosity are the most important properties that affect the combustion of fuel in engines. Significant operational disadvantages of biodiesel in comparison with diesel are cold start problems, higher copper strip corrosion and fuel pumping difficulty from higher viscosity [25].

Although several researchers have suggested various solutions to these problems, without a biofuel dedicated engine definite solution may not be possible. A dedicated biofuel engine is quite attainable by altering the fuel supply system (fuel pump, fuel tank, injector, filter, fuel lines and injection controller). Problems regarding poor oxidation stability can be safeguarded using antioxidants. They significantly slow down the biodiesel degradation process and hence increase its stability. According to their mode of action, antioxidants are classified as free radical terminators, metal ion chelators capable of catalyzing lipid oxidation, or as oxygen scavengers that react with oxygen in closed systems [26]. These are primary antioxidants, which react with high-energy lipid radicals to convert them to thermodynamically more stable products.

A modified and compatible biodiesel engine manufacturing is the only solution to compensate engine problems caused by the high viscosity and high cetane number of biodiesel. The fuel supply system also requires modification, especially, in the fuel filter and fuel pump. Adjustment of injection timing is also needed as biodiesel have a higher cetane number where the injection timing should be retarded a little. Even though biodiesel has lower energy content where the engine may loses some power, but it can runs quieter and the fuel burns cooler, thus reducing NO_x emissions. Fuel Injection Equipment (FIE) Manufacturers (Delphi, Stanadyne, Denso, Bosch) showed their concern on following fuel properties of biodiesel**:**

- Free methanol: Corrosion of fuel injection equipment
- Dissolved and free water: It causes reversion of biodiesel to fatty acid and finally results to filter plugging
- Free glycerin: Free glycerin corrodes non-ferrous metals, soaks cellulose filters, Sediments on moving parts and Lacquering which causes filter clogging, injector Coking.
- Mono and di-glycerides
- Free fatty acids: Provides an electrolyte and hastens the corrosion of zinc, salts of organic acids, Organic compounds formed. Final result is corrosion of fuel injection equipment, Filter plugging, sediments on parts.
- Total solid impurity levels
- Alkaline metal compounds in solution
- Oxidation and thermal stability

The following table no 1 shows the effect of impurities on engine components

Table no 1: Problems with impurities in biofuel [35]

Fuel Characteristic	Effect	Failure Mode
Fatty acid methyl esters (general)	Causes some elastomers including nitrile rubbers to soften, swell, or harden and crack	Fuel leakage
Free methanol in FAME	Corrodes aluminium & zinc Low flash point	Corrosion of fuel injection equipment
FAME process chemicals	Potassium and sodium compounds Solid particles	Blocked Nozzles
Dissolved water in FAME	Reversion of FAME to fatty acid	Filter Plugging
Free water in mixtures	Corrosion Sustains bacteria Increases the electrical conductivity of fuel	Corrosion of fuel injection equipment Sludging
Free glycerin	Corrodes non-ferrous metals Soaks cellulose filters Sediments on moving parts Lacquering	Filter clogging Injector Coking
Mono- & di-glyceride	Similar to glycerin	
Free fatty acid	Provides an electrolyte and hastens the corrosion of zinc Salts of organic acids Organic compounds formed	Corrosion of fuel injection equipment Filter plugging Sediments on parts
Higher modulus of elasticity	Increases injection pressure	Potential of reduced service life
High viscosity at low temperature	Generates excessive heat locally in rotary distributor pumps Higher stressed components	Pump seizures Early life failures Poor nozzle spray atomization
Solid impurities	Potential lubricity problems	Reduced service life

Even though various research approaches on troubleshooting the problems of biodiesel have been carried out, a definite solution for all of these may not be possible without a dedicated standardized biodiesel engine as if petro-diesel. For instance, the Brazil's flex-fuel vehicle which has a modified petrol engine that can use different gasoline-bioethanol blends (i.e. E5 to E20).

Some suggestions on modifications of a diesel engine to build a dedicated biodiesel automotive engine are listed below:

a. Fuel Pump: Pump material (like aluminum alloy, iron based alloy) should be changed to a more corrosion resistant material. To reduce the seizure of the pump, a heating system can be run by radiator's heat.

b. Fuel Filter: As prescribed by many automobile manufacturer and researchers, engine requires more frequent change of fuel filter while running on biodiesel. But this will incurs extra cost to user and also require regular inspection as well. So a reinforced fuel filter container (to prevent the crash of highly viscous biodiesel) and a smaller meshed fuel filter can provide a good solution to this problem (Figure 5).

Fig 5 External view of a new fine porous filter element (a) that was damaged during experiments by pure rapeseed oil (b) in comparison with reinforced fielem (c) suitable to withstand oil pressure.

c. Fuel Injectors: Jones et al. [23] have recommended that fuel injectors should be checked at least twice as often for biofuel user than that of diesel because of their coking and rapid ageing. Carbon deposition on the tip of injector is obvious (as shown in Figure 5), if the fuel used contains biodiesel even in minor proportions.

d.

Fig 6. Carbon depositions in Injector tip after using a) No. 2 Diesel b) 95% No. 2 diesel & 5% palm olein.

e. To avoid plugging and coke formation, the temperature of the nozzle has to be measured and kept (acting on the cooling water flow rate) below 250 $^{\circ}$C. Such a nozzle design is proposed by Sgroi et al.[27].

The disadvantages of bioethanol are that it is very corrosive. It can easily absorb water and dirt. Failing to successfully filtering these contaminants out of engine, may cause serious damage and corrosion inside the engine. Ethanol use can enhance corrosion on ferrous components such as fuel tank [28]. Lower vapor pressure of ethanol can contribute to produce unregulated pollutants like aldehydes [29].

6. Biopro diesel and Biolubricant

BioPro diesel is derived from palm oil waste through bioprocess, i.e. using enzymes in a low pressure, low temperature process. Malaysia currently has about 420 palm oil mills mostly located in Johor, Sabah and Selangor; the potential is huge. UM scientists estimated that based on BioPro price of RM1.50/liter, total revenue from these palm oil mills could be up to RM40 billion per annum. RM12 million is needed for a palm oil affluent process plant to produce 25 tonnes of BioPro diesel daily. The byproducts created during the extraction process can be used as fertilizer and water, which can then be reused in other industry applications. Saving up to 45% is achievable but engine rpm is lowered by 500 rpm when using BioPro Diesel. Others advantages are: a) lesser soot, less polluting; b) will not clog fuel filters; c) can be used in any diesel engines with no modification needed.

Lubricants based on mineral, and synthetic oil are widely used in transport industry. These lubricants are toxic and non-biodegradable. Due to these petrochemical based lubricants poses a continuous threat to ecosystem and ground water reserves [30]. Hefty proportions of lubricant, such as 50-60% of the synthetic lubricants, lost into the environment, directly comes into the contact with water, air and soil, thus creating a potential threat to ecosystem [31]. To mitigate these problems, there is an increase awareness to develop new techniques and environmentally friendly products. As a product from vegetable oils contains high content of oleic acid, they are being considered as prospective alternatives to conventional lubricants. Eychenne and Mouloungui [32] have reviewed the developments in ecofriendly lubricating oils based on neopentylpolyols such as pentaerythritol, neopentyl glycol, and trimethylolpropane. Other researchers have worked on engine oil prepared from a mixture of trimethylolpropane esters having both sufficiently high viscosity and low pour point. The TMP (trimethylolpropane) ester is produced from a palm oil methyl ester through the transesterification process which eliminates the hydrogen molecule on the beta carbon position in the palm oil substrate. As a result, the thermal stability and oxidative stability of TMP ester improve [33]. TMP esters also have decent friction-reducing properties and satisfactory anti-wear properties [34].

7. Conclusion

Present energy consumption trends are neither sustainable nor secured economically, socially or environmentally. An approaching energy crisis may grasp social and economic growth if there is no change in practice and selection of energy sources. Coupled with drastic environmental consequence severe shortage of petroleum fuels is anticipated as inevitable. Hence, the quest for an ‘alternative clean fuel’ is vital. To date, wind, solar, tidal and fusion energies are all very prospective types of renewable-energy resources. However, as demand of transport fuel grows rapidly, there is an urgent need for an alternative fuel that can be easily adapted with the present supply and storing system. Biofuel can become the most suitable alternative for petroleum fuel for having numerous advantageous. However, research has shown that internal-combustion engines designed for petroleum fuel's usage are not suitable for long time operation on biofuel.

Hence, the high-quality biofuel along with a little modification to the engine can give a comprehensive solution for engine compatibility. Therefore, a mass production along with utilization necessitates a dedicated engine that could be done by modifying present day engines on a fuel supply system only.

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PROCEEDINGS

ABSTRACTS

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Abstract

The consumption of energy has ever-increasing trend due to change in the lifestyle and significant growth of population. Two of the main contributors are the transportation and the basic industry sectors. This increase of energy demand has been supplied using fossil resources (fossil fuel, natural gas and coal). Fossil fuels are extensively used due to its high power output, availability and quality combustion characteristics. At present, as almost all the energy required by the transportation sector is met by fossil fuel, rapid depletion of fossil fuel reserve is considered as the foremost problem for this sector. In addition, problem associated with combustion of fossil fuel is accountable for harmful emissions that are causing global warming. These problems have intensified research into identifying suitable alternative fuels for internal combustion engines. Biofuels are one of the most promising alternatives of fossil fuels. Their acceptance as energy source in transportation sector increasing rapidly due to ease in adaptation, environmental benefits and prospects in energy security. Biofuel has similar working properties as of petroleum fuel. In addition, there is no need of engine modification to operate it with biofuel. Key advantage of using biofuel is it has higher lubricity index compared to petroleum fuel, which extends engine life. Even a small percentage of biofuel means cleaner emissions and better engine lubrication. In contrast, disadvantages of biofuel include limited feed stock availability, higher production cost, inferior oxidative and storage stability and lower volumetric energy content. Application problems evolved from these issues include- lower power output; corrosive wear to engine parts like piston ring, piston liner etc. due to formation of oxidation products like aldehydes, ketones, acids and oligomers; clogging of the injection pumps and filters; carbon deposits on piston and head of engine etc. These problems need to be resolved for its widespread applicability.

KEYWORDS: BIOFUEL; TRANSPORT; RENEWABLE ENERGY; LUBRICANT; OXIDATION STABILITY.

1. INTRODUCTION

Energy plays the foremost important role in the advancement of all commercial sectors, including agricultural, transportation, telecommunication and industrial sectors. With the development of the world's economy, worldwide energy consumption is expected to grow in a faster rate than the population growth [1]. According to a recent report of U.S. Energy Information Administration (EIA) one-fourth of the total delivered energy consumption globally is consumed by transportation sector [2]. International Energy Agency (IEA) reported that, petroleum fuel supplies 93.5% of the total fuel consumed by transportation sector [3]. Transport sector heavily depends upon petroleum due to their adaptability, high combustion efficiency, availability, reliability as well as the handling facilities. However, petroleum fuelled engine has recently been besieged with concerns over its contribution to the atmospheric emissions inventory due to less emission reduction. Emissions which are produced from burning petroleum derived fuels have a serious effect on both the environment as well as human health [4, 5]. One of the main sources of an increase in CO_2 emission is the burning of fossil fuels. This is largely responsible for an increase in global warming. It has been suggested that, if strict regulation concerning fossil fuel's emission is not taken soon, by 2030, an increase of 39% of GHG emission from fossil fuel will be observed. In these consequences a strong worldwide drive towards alternative fuels for transportation mainly driven by emissions reduction, energy security concerns, volatility in the fuel price and the search for renewable fuels to compliment the dwindling world fuel supplies. Targets of improving air quality and diversifying energy resources have intensified research into identifying suitable alternative fuels for cleaner combustion [6, 7]. Biofuels can be a practical replacement for fossil fuels in the transport sector. There is no requirement of engine or fuelling process modification to use biofuel, thus simplifies their adoption. Due to these reasons, biofuels are considered as one vital alternative to diminish CO_2 emissions and decrease reliance on petroleum oil. There are various advantages of biofuel e.g. it is renewable so it will replenish as soon as it is consumed, can provide energy security to a country and decrease reliability on imports or foreign volatile markets, and production process can eliminate the unemployment problem. Fig. 1 illustrates energy demand until 2030, from this it can be seen that, by 2030, the demand will be a significant amount which will be one of the key player to meet the future energy demand [8].

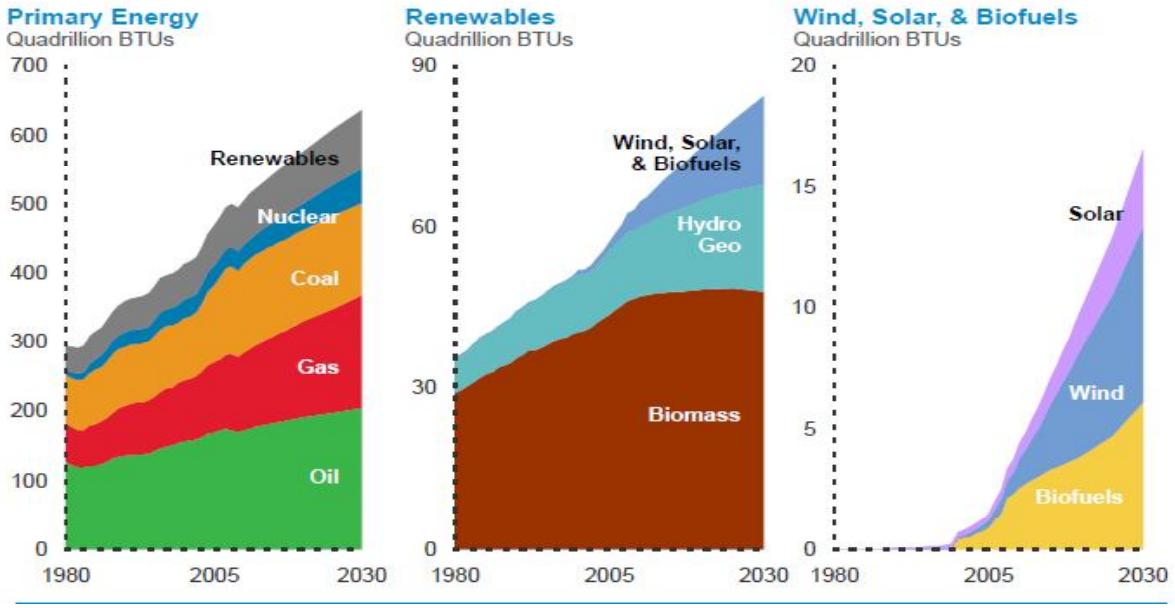

Fig 1. Energy demand until 2030[8]

As biofuel is non-toxic and have good safety and environmental characteristics, it can be an attractive alternative to petroleum-based oil used in automobile lubrication. On the other hand, the use of crude vegetable oils as fuel may give rise to a variety engine problem, such as carbon deposits on piston and head of engine, coking of injectors on piston and head of engine, and also extreme engine wear [9-11]. In order to make biofuel the most promising alternative of petroleum, these problems need to be solved as soon as possible.

2. Biofuel and its feedstock

Fuel derived from organic matter such as plants, agriculture, domestic, industrial, and/or commercial wastes, are known as biofuel. It has several advantages, such as renewability, biodegradability, non-toxic, emits fewer pollutants, etc. Currently, the most popular biofuels are- biodiesel and bioethanol.

Biodiesel are mono alkyl esters and generally derived from fatty ester of vegetable oil or animal fat through chemical treatment. Biodiesel production is more appropriate as an energy substitute due to its widespread accessible resources. Depending on country's dependency on husbandry and geographical locations biodiesel feedstock differs from country to country. Worldwide, there are more than 350 oil-bearing crops that were identified as potential feedstock for biodiesel. Feedstock of biodiesel can be divided into 4 categories[12]. They are as below:-

a. Edible vegetable oil—soybean, rapeseed, palm, coconut, and sunflower.

b. Non-edible vegetable oil—karanja, jatropha, Calophyllum inophyllum, Moringa oleifera, algae, halophytes and sea mango.

c. Waste or recycled oil.

d. Animal fats—by-products from fish oil, yellow grease, tallow, and chicken fat.

Bioethanol, also known as only 'ethanol', is an energy source prepared from sugar and starch components of plant by-products by fermenting process using yeast. Sometimes, potatoes, corn, potatoes, rice, milk, beetroot and lately dates, banana and grapes are also used depending on agricultural strength of the country. Today, bioethanol has many uses: It is blended with petrol to make a truly sustainable transport fuel. Bioethanol feedstocks can be conveniently classified into three types [13]:

a. sucrose-containing feedstocks (e.g. sugar beet, sweet sorghum and sugar cane),

b. starchy materials (e.g. wheat, corn, and barley), and

c. lignocellulosic biomass (e.g. wood, straw, and grasses).

3. Biofuel policies of different countries

Around the world, many countries have set their biodiesel policy and standards. Targets or mandates concerning an increase in biofuel consumption and utilization of biofuel in the energy mix has been announced. In this section, biofuel policies, targets and its standardization of Malaysia and Indonesia has been presented. Figure 2 shows the ASEAN biofuel flagship roadmap. [12].

Malaysia: On 21st march 2006 by the Ministry of Plantation Industries and Commodities of Malaysia introduced the "National Biofuel Policy". It contains five strategic thrusts:

i. Biofuel for transport,

ii. Biofuel for industry,

iii. Biofuel technologies,

iv. Biofuel for export and

v. Biofuel for a cleaner environment.

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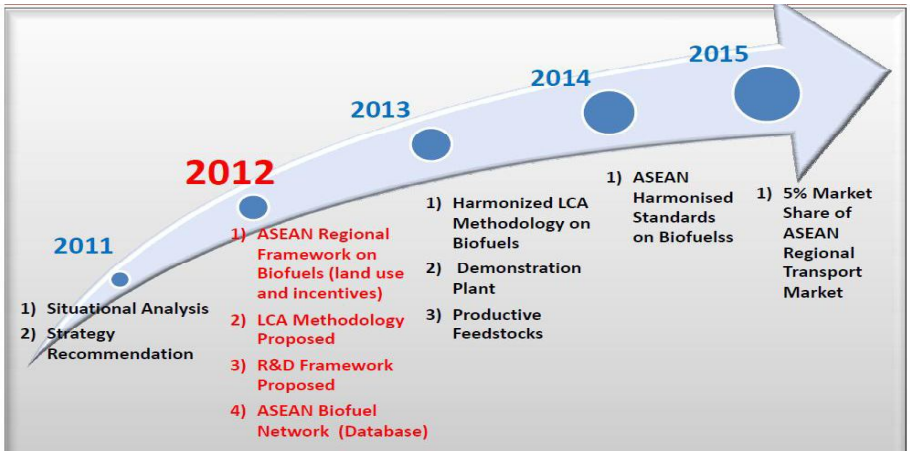

Fig 2 ASEAN biofuels flagship roadmap.

However, government has aborted the Envo Diesel (5% Palm Methyl Ester and 95% Diesel) due to failing to market it in 2008 according to "The National Biofuel Policy."

Indonesia: In 2006, Government of Indonesia announced its first national biofuel policy. According to the policy, it set a target of achieving 10% replacement of transport fuel with biofuel within 2010. The national oil company Pertamina has suffered a severe financial loss from selling of the B5 biodiesel blends commercially due to high feedstock price. For these problems, the Indonesian government has changed their target to replacement of 3% gasoline by ethanol and 2.5% diesel excision by biodiesel within 2010.

4. Impact of biofuel on transport sector

Main reason of using biofuel is that it is supposed to be carbon neutral. Compared to petroleum fuels, biofuel can significantly reduce GHG emissions. Various scientific shows that using biodiesel instead of diesel and bioethanol instead of gasoline helps reduce GHG emission (Fig 3 and Fig 4) [14]. According to recent UK Government publication, biofuels can reduce 50-60% carbon emissions [15].

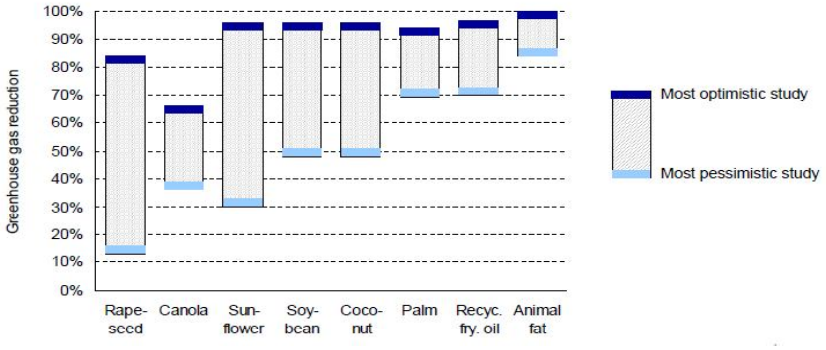

Fig 3. Greenhouse gas savings achieved by substituting a liter of diesel with biodiesel

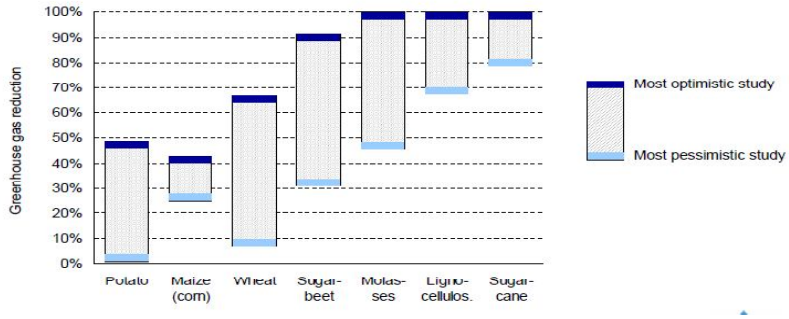

Fig 4. Greenhouse gas savings achieved by substituting a liter of gasoline with bioethanol

Advantage of biodiesel is that compared to diesel it has higher oxygen content. Studies suggest that, use of biodiesel in the diesel engine significantly decreases CO, sulfur, PAH, PM, noise and smoke emission [16]. As the flash point of biodiesel is much higher than diesel, there are fewer possibilities of burning after an accident and thus increasing safety of the engine [17].

Because of the regenerative and biodegradable characteristics of ethanol, it is widely used as an alternative fuel at present. The use of gasoline containing 3–10 vol% bioethanol is being promoted in many parts of the world for last few years [18]. Ethanol burn reduces greenhouse gas emission significantly [4]. Ethanol provides high quality, high octane for excellent engine performance and reduced emissions [19]. Ethanol has much higher octane number compared to gasoline, which enables it to keep engines running smoothly making it highest performance fuel on the market currently. As Ethanol-blended fuel does not leave tacky deposits, it keeps the fuel system clean for optimum performance.

In near future, with the discovery of new feedstock for biofuel production countries energy security will rise since dependency on imports or foreign volatile markets will decrease.

5. Drawbacks and remedies of biofuel

Although biofuels have many positive impacts, it also has some negative characteristics too. Compared to petroleum fuels, biofuels have a lower energy output. As a result, to produce same power output as petroleum fuel it requires greater quantities of biofuels to be consumed. Though emission from burning of biodiesel is cleaner, but production process of biofuel which includes machineries might have hefty carbon emissions. Production process of biofuel is also very much costly. Producing biofuel from edible feedstock may raise the prices for essential fundamental food crops. Using land to produce fuel crops can have a severe impact on food price and might lead to food shortages. There can be massive draining of the water resources, as a huge amount of water is needed for the production process of biofuels.

Lower energy content, higher viscosity, higher cloud point and pour point, lower oxidative stability, higher nitrogen oxides emissions, lower engine power and speed, injector coking, engine compatibility, high price and higher engine wear- these are the disadvantages of using biodiesel in a diesel engine [20, 21]. Biodiesels are more susceptible to degradation compared to fossil diesel. The mechanisms of degradation are: (a) autoxidation in presence of atmospheric oxygen; (b) thermal or thermal-oxidative degradation from excess heat; (c) hydrolysis in presence of moisture or water during storage and in fuel lines; and (d) microbial contamination from contact with dust particles or water droplets containing fungi or bacteria into the fuel [22]. Oxidation of biodiesel results in the formation of hydroperoxides. Once the hydroperoxides are formed, they decompose and inter-react to form numerous secondary oxidation products, including higher molecular weight oligomers often called polymers. Oxidation products cause corrosive wear to engine parts like piston ring, piston liner, etc. and may lead to clogging of the injection pumps and filters [23]. Physical properties that are sensitive to the effects of biodiesel oxidation include cetane number, kinematic viscosity, flash point, refractive index, and di-electric constant [22, 24]. Cetane number and kinematic viscosity are the most important properties that affect the combustion of fuel in engines. Significant operational disadvantages of biodiesel in comparison with diesel are cold start problems, higher copper strip corrosion and fuel pumping difficulty from higher viscosity [25].

Although several researchers have suggested various solutions to these problems, without a biofuel dedicated engine definite solution may not be possible. A dedicated biofuel engine is

quite attainable by altering the fuel supply system (fuel pump, fuel tank, injector, filter, fuel lines and injection controller). Problems regarding poor oxidation stability can be safeguarded using antioxidants. They significantly slow down the biodiesel degradation process and hence increase its stability. According to their mode of action, antioxidants are classified as free radical terminators, metal ion chelators capable of catalyzing lipid oxidation, or as oxygen scavengers that react with oxygen in closed systems [26]. These are primary antioxidants, which react with high-energy lipid radicals to convert them to thermodynamically more stable products.

A modified and compatible biodiesel engine manufacturing is the only solution to compensate engine problems caused by the high viscosity and high cetane number of biodiesel. The fuel supply system also requires modification, especially, in the fuel filter and fuel pump. Adjustment of injection timing is also needed as biodiesel have a higher cetane number where the injection timing should be retarded a little. Even though biodiesel has lower energy content where the engine may loses some power, but it can runs quieter and the fuel burns cooler, thus reducing NO_x emissions. Fuel Injection Equipment (FIE) Manufacturers (Delphi, Stanadyne, Denso, Bosch) showed their concern on following fuel properties of biodiesel**:**

- Free methanol: Corrosion of fuel injection equipment
- Dissolved and free water: It causes reversion of biodiesel to fatty acid and finally results to filter plugging
- Free glycerin: Free glycerin corrodes non-ferrous metals, soaks cellulose filters, Sediments on moving parts and Lacquering which causes filter clogging, injector Coking.
- Mono and di-glycerides
- Free fatty acids: Provides an electrolyte and hastens the corrosion of zinc, salts of organic acids, Organic compounds formed. Final result is corrosion of fuel injection equipment, Filter plugging, sediments on parts.
- Total solid impurity levels
- Alkaline metal compounds in solution

- Oxidation and thermal stability

The following table no 1 shows the effect of impurities on engine components

Table no 1: Problems with impurities in biofuel [35]

Fuel Characteristic	Effect	Failure Mode
Fatty acid methyl esters (general)	Causes some elastomers including nitrile rubbers to soften, swell, or harden and crack	Fuel leakage
Free methanol in FAME	Corrodes aluminium & zinc Low flash point	Corrosion of fuel injection equipment
FAME process chemicals	Potassium and sodium compounds Solid particles	Blocked Nozzles
Dissolved water in FAME	Reversion of FAME to fatty acid	Filter Plugging
Free water in mixtures	Corrosion Sustains bacteria Increases the electrical conductivity of fuel	Corrosion of fuel injection equipment Sludging
Free glycerin	Corrodes non-ferrous metals Soaks cellulose filters Sediments on moving parts Lacquering	Filter clogging Injector Coking

Mono- & di-glyceride	Similar to glycerin	
Free fatty acid	Provides an electrolyte and hastens the corrosion of zinc Salts of organic acids Organic compounds formed	Corrosion of fuel injection equipment Filter plugging Sediments on parts
Higher modulus of elasticity	Increases injection pressure	Potential of reduced service life
High viscosity at low temperature	Generates excessive heat locally in rotary distributor pumps Higher stressed components	Pump seizures Early life failures Poor nozzle spray atomization
Solid impurities	Potential lubricity problems	Reduced service life

Even though various research approaches on troubleshooting the problems of biodiesel have been carried out, a definite solution for all of these may not be possible without a dedicated standardized biodiesel engine as if petro-diesel. For instance, the Brazil's flex-fuel vehicle which has a modified petrol engine that can use different gasoline-bioethanol blends (i.e. E5 to E20).

Some suggestions on modifications of a diesel engine to build a dedicated biodiesel automotive engine are listed below:

a. **Fuel Pump:** Pump material (like aluminum alloy, iron based alloy) should be changed to a more corrosion resistant material. To reduce the seizure of the pump, a heating system can be run by radiator's heat.

b. Fuel Filter: **As prescribed by many automobile manufacturer and researchers, engine requires more frequent change of fuel filter while running on biodiesel. But this will**

incurs extra cost to user and also require regular inspection as well. So a reinforced fuel filter container (to prevent the crash of highly viscous biodiesel) and a smaller meshed fuel filter can provide a good solution to this problem (Figure 5).

II

III

Fig 5 External view of a new fine porous filter element (a) that was damaged during experiments by pure rapeseed oil (b) in comparison with reinforced fielem (c) suitable to withstand oil pressure.

c. **Fuel Injectors:** Jones et al. [23] have recommended that fuel injectors should be checked at least twice as often for biofuel user than that of diesel because of their coking and rapid ageing. Carbon deposition on the tip of injector is obvious (as shown in Figure 5), if the fuel used contains biodiesel even in minor proportions.

d.

Fig 6. Carbon depositions in Injector tip after using a) No. 2 Diesel b) 95% No. 2 diesel & 5% palm olein.

e. To avoid plugging and coke formation, the temperature of the nozzle has to be measured and kept (acting on the cooling water flow rate) below 250 °C. Such a nozzle design is proposed by Sgroi et al.[27].

The disadvantages of bioethanol are that it is very corrosive. It can easily absorb water and dirt. Failing to successfully filtering these contaminants out of engine, may cause serious damage and corrosion inside the engine. Ethanol use can enhance corrosion on ferrous components such as fuel tank [28]. Lower vapor pressure of ethanol can contribute to produce unregulated pollutants like aldehydes [29].

6. Biopro diesel and Biolubricant

Fig. 1. BioPro diesel is derived from palm oil waste through bioprocess, i.e. using enzymes in a low pressure, low temperature process. Malaysia currently has about 420 palm oil mills mostly located in Johor, Sabah and Selangor; the potential is huge. UM scientists estimated that based on BioPro price of RM1.50/liter, total revenue from these palm oil mills could be up to RM40 billion per annum. RM12 million is needed for a palm oil affluent process plant to produce 25 tonnes of BioPro diesel daily. The byproducts created during the extraction process can be used as fertilizer and water, which can then be reused in other industry applications. Saving up to 45% is achievable but engine rpm is lowered by 500 rpm when using BioPro Diesel. Others advantages are: a) lesser soot, less polluting; b) will not clog fuel filters; c) can be used in any diesel engines with no modification needed.

FIG. 2. Lubricants based on mineral, and synthetic oil are widely used in transport industry. These lubricants are toxic and non-biodegradable. Due to these petrochemical based lubricants poses a continuous threat to ecosystem and ground water reserves [30]. Hefty proportions of lubricant, such as 50-60% of the synthetic lubricants, lost into the environment, directly comes into the contact with water, air and soil, thus creating a potential threat to ecosystem [31]. To mitigate these problems, there is an increase awareness to develop new techniques and environmentally friendly products. As a product from vegetable

oils contains high content of oleic acid, they are being considered as prospective alternatives to conventional lubricants. Eychenne and Mouloungui **[32]** have reviewed the developments in ecofriendly lubricating oils based on neopentylpolyols such as pentaerythritol, neopentyl glycol, and trimethylolpropane. Other researchers have worked on engine oil prepared from a mixture of trimethylolpropane esters having both sufficiently high viscosity and low pour point. The TMP (trimethylolpropane) ester is produced from a palm oil methyl ester through the transesterification process which eliminates the hydrogen molecule on the beta carbon position in the palm oil substrate. As a result, the thermal stability and oxidative stability of TMP ester improve **[33]**. TMP esters also have decent friction-reducing properties and satisfactory anti-wear properties [34]**.**

7. Conclusion

Present energy consumption trends are neither sustainable nor secured economically, socially or environmentally. An approaching energy crisis may grasp social and economic growth if there is no change in practice and selection of energy sources. Coupled with drastic environmental consequence severe shortage of petroleum fuels is anticipated as inevitable. Hence, the quest for an 'alternative clean fuel' is vital. To date, wind, solar, tidal and fusion energies are all very prospective types of renewable-energy resources. However, as demand of transport fuel grows rapidly, there is an urgent need for an alternative fuel that can be easily adapted with the present supply and storing system. Biofuel can become the most suitable alternative for petroleum fuel for having numerous advantageous. However, research has shown that internal-combustion engines designed for petroleum fuel's usage are not suitable for long time operation on biofuel. Hence, the high-quality biofuel along with a little modification to the engine can give a comprehensive solution for engine compatibility. Therefore, a mass production along with utilization necessitates a dedicated engine that could be done by modifying present day engines on a fuel supply system only.

Acknowledgement

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