The Effect of Use of Biofuels on Environmental Pollution - A Review

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Abstract- Considering the fulfilment of future energy requirement in the world with green energy, it is necessary to consider the environmental pollution due to the use of conventional fossil fuel sources. Present environmental pollution caused by different fossil energy sources are discussed in detail. Advancement of biofuels as a green energy source and the environmental pollution savings due to the use of biofuel life cycle greenhouse gas emissions in comparison to the fossil fuels are discussed in detail. Finally, emission due to transportation with biofuels is compared with relevant fossil fuels. It is evident that the atmospheric CO_2 and CH_4, emitted as a product of combustion of fossil fuel are the main sources for global warming. It is well understood that the usage of bioethanol as a substitute for gasoline is a green effect saving. Further, bioethanol produced using sugar cane, corn and sugar beet reduces greenhouse effect about one third, relative to gasoline. But, vice versa for biodiesel. Considering emission due to transportation with biofuels, compared with relevant fossil fuels, few positive and negative merits could be observed. It can be concluded that usage of bio ethanol as a substitute for gasoline should be promoted considering energy saving and greenhouse effect saving.

Keywords Biofuels, fossil energy, environment, pollution, global warming

1. Introduction

Global energy demand is continuously increasing due to rapid growth of population, industrialization, urbanization, etc. and thus the demise of natural energy resources is the biggest challenge to be faced by the world [1]. Conventional energy sources such as coal, petroleum, and natural gas are not enough to overcome the future energy needs. World energy consumption is estimated to grow by 28% between 2015 and 2040 [2], but petroleum sources are estimated to decay daily and depleted by 2050 [3, 4]. Moreover, the world population is estimated to increase from 7.6 billion people today to 8.5 billion people in 2030 [5]. Major energy consumption is by the transport sector. Globally, the consumption of liquid fuels in the transportation sector alone is estimated to grow from 110.3 quintillion Joules in 2015 to 144.3 quintillion Joules in 2040 [6].

The global energy demand has been fulfilled by different energy sources out of which fossil energy sources are the majour contributor. In 2005, 81% of the global energy requirement has been fulfilled by fossil fuel while 10% by bio energy, 0.5% by other renewable energy sources (wind and solar energy sources), 6.3% by nuclear power, and 2.2% by hydropower [7, 8]. The production of global bio energy such as wind energy and solar energy has been gradually increasing over two decades [9, 10]. Today, the global energy production by conventional energy sources is almost fully used. Thus, the growing demand can only be met with additional energy sources [8, 11].

Considering the increase in energy demand with prices and the depletion of the conventional energy sources, non-conventional sources such as wind, solar, hydro, biomass, etc. has gained a wide attention over many years [12]. Although wind, solar, and hydro are the best non-conventional energy sources, usage of them, however, in mass scale is impracticable in the current context [7, 13]. Biomass simply is the plant matters such as agricultural crops, municipal wastes, agricultural and forestry by products, and plant matter residues. Biomass has been used from ancient times as a fuel for cooking and keeping warmth in houses [14, 15]. The amount of energy that a plant contains mainly depends on the amount of energy it absorbs from solar energy and the amount of carbohydrate stored in the plant [16, 17]. The produced carbohydrate substance makes up bulk tissues with a proportion of the solar energy trapped in their chemical bonds. During the process of making biomass into biofuels, these chemical bonds are broken through chemical reaction and thereby the binding energy that holds electrons to a nucleus in the organic molecules is released to produce work and heat [18, 19, 20]. The conversion of biomass into bioenergy involves several processes which cause environmental pollution. Solid biomass is converted into heat energy by burning biomass with smoke. Solid biomass is converted into bio gas by gasification and into biofuel by hydrolysis and then by fermentation. Wet biomass such as organic wastes, manure, sewage, etc. is converted into biogas by fermentation under anaerobic condition. Starch rich crops, is converted into bioethanol, can be obtained by fermentation of the biomass while oil crops are converted into biodiesel by crushing and refining [21]. All the processes contribute to the environmental pollution in a small extent compared to the emission due to burning of fossil.

Therefore, this paper is a review of environmental issues related to fossil fuels, evolution of biofuel resources, the life cycle assessment of biofuels, emissions of biofuel as a product of combustion, energy saving and reduction of environmental pollution due to the use of biofuel.

2. Environmental problems due to fossil energy

Energy is interrelated with environmental pollution. Fossil energy is highly responsible for creating several environmental issues throughout its life cycle starting from production, transportation, refining and finally combustion that caused higher impact [22]. Emission due to combustion of fossil fuel contributes to increase in global warming potential, volatile organic compounds (VOC), NO_x and SO_x, unburnt carbon, ozone in ground level, etc. [23, 24]. Biofuels also contribute to GHG emissions from its combustion stage. The production stage of biofuels can generate relatively high GHG emissions due to the use of fossil fuels [25].

2.1 Global Warming

Global warming is the gradual increment in the earth's atmospheric temperature due to the greenhouse effect caused by the increase in the levels of the greenhouse gasses such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), fluorinated gases, etc. The current global warming is caused mainly due to anthropogenic CO_2, NO_x and CH_4 [26, 27]. As given in Table 1, global warming potential (GWP) of CH_4 is 28 times greater higher than that of CO_2 and it is of N_2O is 265 times greater than that of CO_2. Considering the concentration of these gases in the atmosphere, concentration of CO_2 is in the atmosphere is relatively high, amounting to 403 ppm in 2016 whereas the concentrations of CH_4 and N_2O are 114 ppm and 6.48 ppm respectively in 2016. Considering both GWP and the concentration in atmosphere of the main gases, CO_2 and CH_4 are the main sources for global warming. By considering the GWP and concentration of both N_2O and fluorinated gases, although GWP is high, concentration in the atmosphere is quite low. [28- 30].

Reference to the statistics in Table 1, CO_2 concentration in the atmosphere has been increased about 125 ppm from pre-industrial period to 2016 and it has been further increased up to 403 ppm with a gradient of 2-3 ppm annually [29]. Reference to Table 2, 49.04 % GHG emission is due the production of electricity in 2014.

Table 1. Basic greenhouse gases in atmosphere (during pre-industrial period and in 1998), sources of gases, and global warming potential (GWP) of gases [30-32]

Greenhouse gas	Concentrations /ppm (pre industrial)	Concentration in the atmosphere / ppm (in 2016)	Source	GWP (100 years)
Carbon dioxide (CO_2)	278	403	Fossil-fuel combustion, land-use changes, cement production	1
Methane (CH_4)	0.7	114	Fossil fuels, rice paddies, waste dumps, livestock	28
Nitrous oxide (N_2O)	0.27	6.48	Fossil-fuel combustion, fertilizer, industrial processes	265
Fluorinated gases (F- gases)	0	1.43	Electronics, refrigerants, industrial processes	Very high

Table 2. Energy type, main energy sources, and percentage greenhouse gas emission in 2014 [33]

Type of energy	Main energy source	% Emission
Electricity and heat production	Fossil + renewable	49.04
Transportation	Fossil + renewable	20.45
Manufacturing industry	fossil	19.96
Residential buildings	fossil	8.6
Other sectors	Fossil + renewable	1.96

Average global temperature, in 2018 has been increased by 1.16 °C (2.09 °F) above the average temperature of the late 19th century [34]. Increment in the atmospheric temperature has changed the global climate drastically and it directly and indirectly given adverse effects on human life in economic, social, and geopolitical (local politics & lifestyles of people, etc.) aspects [35, 36]. 150,000 deaths have been reported due to increasing poverty, flood, water scarcity, and malaria resulting 150,000 deaths every year [37].

Considering CO_2 emissions of three different fossil fuels sources, coal has the highest carbon intensity of 43%. Second (36%) and third CO_2 emissions (20%) sources are from oil and gas, respectively [35, 38] All fossil fuels emit

Nearly 40% of coal in the world are mined from underground and the rest from the surface. Underground coal mining is a dangerous occupation because mining has to be done in contact with dirt and most often without room to stand up in dusty environment. It is reported that around 100 coal miners die annually per year due to the bad impact on health and having the lung disease called black lung disease. Coal has to be washed outside the mine to remove foreign materials.

Along with washing, these waste materials are piled up in large quantities in thousands of acres. Normally these waste banks catch fire and burn caused to air pollution. The abandoned mines have an adverse environmental impact due to formation of acid drainage, water seeping, and reacts with sulphur compounds to produce sulphuric acid which then seeps out and gets into streams by making them acidic. This has a significant effect for usage in water for drinking, swimming, farming, and many industrial purposes. Often, this acidic water can harmful to the aquatic life. The other environmental impact of underground mining is moving the ground surface downward as the abandoned mines below are with caves inside. This may cause for buildings on the surface to crack or even to be completely destroyed. Another serious environmental impact of underground mining is accidentally catching fires and as a result, emitting a large smoke resulting air pollutants. The generated heat may damage the vegetation as well [39][40].

Globally 25 countries are account for emission of 83% of greenhouse gasses to the atmosphere. The highest share of about 21% is emitted by United States, followed by China with the second highest contribution of about 15% [31].

2.2 Volatile Organic Compound VOC)

Any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides/carbonates, ammonium carbonate, can volatize under normal indoor atmospheric conditions of temperature and pressure, and thus are referred to as Volatile Organic Compound [41]. VOC emitted from industrial processes and automobile exhaust emissions, specially from cars and gasoline-burning engines create a serious environmental problem. VOCs (Volatile Organic Compounds) are available in wide range of other sources such as household air fresheners, aerosol sprays cans, cleaners & disinfectants, paints, lacquers, varnishes, cleaning supplies, air fresheners, pesticides, building materials, and furnishings [42]. VOCs are released to the atmosphere while storing these products. Long-time exposure to some VOC may causes some minor healthcare issues such as eye, nose and throat irritation, frequent headaches, nausea. It can be possible to have some serious damage to the liver, kidney and central nervous system [42, 43]. Moreover, VOCs are key component in formation of ground level ozone and urban smog [44].

2.3 NO_x and SO_x

Fossil sources are the main source of emission of toxic greenhouse gases such as sulphur dioxide (SO_2), and nitrogen oxide (NO_2) [45]. Nitrogen and sulphur emissions cause for acid rains which can travel distances through wind and fall on the ground causing changes in the characteristics of the land [46, 47]. In addition, formation of aerosols (basically suspensions in the air as liquid or solid particles, black carbon which are visible as a cloud) is possible due to the emission of tiny particles caused by transformation of sulphate (SO_4) particles from emitted SO_2, nitrate particles from emitted NO_x, etc. [48, 49]. Globally black carbon emission from fossil fuel sources and residential combustion are about 24% and 58%, respectively. However, regionally these fractions change drastically [50] Formation of harmful tiny particle (PM: Particulate matter, diameter less than 2.5 μm) can be taken place due to chemical reactions involve with SO_2 in the atmosphere and formation of ground level ozone (O_3) and smog can also be taken place due to chemical reactions with NO_2 in the atmosphere [51]. Atmospheric air quality is strongly affected due to presence of aerosols, particulate matters, smog, etc., which has adverse effect on Health and welfare [44, 52].

2.4 Unburnt Carbon (PM2.5 and PM10)

Particulate matter (PM) is a general term for very small solid and liquid particles which are PM2.5 (fine particles): $d \leq 2.5$ μm and PM10 (coarse particles): $d \leq 10$ μm in the atmosphere. The primary sources of adding PM to the atmosphere are automobile emissions, emissions due to incomplete combustion, dust, dirt, soot, etc. [53]. The secondary sources are chemical reactions in the atmosphere due to presence of harmful pollutants such as SO_2, VOC, etc. PM is hazardous to human health in many ways creating an impact on human health and economy. When the PM solution is inhaled, it enters the deep into the lungs and thus caused lung diseases and heart disease. However, PM composition is 61 heterogeneous and includes both water-soluble and water-insoluble fractions, but these have 62 different fates and pathways while interacting with human physiological systems after inhalation [54].

2.5 Ground level Ozone

Creation of ground-level O_3 is hazardous to human health. The primary sources for creation of O_3 are VOC and NO_2 that emitted as a product of combustion from cars and gasoline vehicles. The sun's direct ultraviolet rays convert these emissions in to O_3 in the presence of heat [55]. The O_3 concentration in the atmosphere is depend on the same factors such as temperature, wind speed and direction, time of day, and driving patterns. In addition, O_3 is emitted from indoor office equipment such as photocopies and laser printers [41].

3. Biofuel generations and usage

Biomass is the mostly considered renewable energy source especially due to the availability in all over the world. It is an alternative source to replace fossil energy sources for energy-importing countries [56, 57]. Reference to Table 3, biofuels can be classified into three generations namely 1st, 2nd and 3rd generation biofuels depending on its evolution [15]. The first-generation biofuels are considered as traditional biofuels produced from specific sources such as seeds of selected plants. The 2nd generation biofuels are produced from lignocellulose such as all types of vegetation and all parts of the plant [8, 15, 58]. Biofuels, produced from waste materials are considered as 3rd generation bio fuels. Due to the more complex and expensive process, 2nd and 3rd generation biofuels are not available in the market in mass scale. [8, 15, 59]. The 4th generation biofuels are at the conceptual stage to produce biofuels by photosynthetic water splitting (water oxidation) into its constituents by solar energy. This method has been identified as the largest contributor for biofuel production in the near future on global scale [60]. Among the various biofuels, bioethanol is a widely available chemical compound that presents in a lot of things used in daily basis, ranging from perfumes to alcoholic beverages. Ethanol is abbreviated as EtOH and ethanol's chemical formula is C_2H_6O. This chemical formula of ethanol can also be written as CH3CH2OH. Here, there is a methyl group (which is the CH3-), a methylene group (which is the -CH2-), and a hydroxyl group (which is the -OH) in the chemical structure of ethanol [61].

3.1 Sources of biofuels

Different generations of biofuels are classified based on the sources used for the production. First-generation biofuels (bioethanol and biodiesel) are made mainly from food crops. Bioethanol is made from starchy foods such as cereals, sugar crops, and biodiesel is made from oil seeds. Some negative impacts of the 1st generation biofuel such as food security, land use, and environmental issues, etc. were addressed in

Table 3. Biofuel generations [15]

Biomass feedstock	**1st generation biofuels**	**2nd generation biofuels**	**3rd generation biofuels**	**4th generation biofuels**
Vegetable oil	Pure Plant Oil (PPO) Virgin Plant Oil (VPO) Straight Vegetable Oil(VGO) Fatty Acid Methyl Ester: FAME			
Fermentable biomass	Biogas Substitute Natural Gas			
Starch/sugar	Ethanol Ethyl Tertiary Butyl ether (ETBE)			
Lignocellulose		Ethanol Fischer-Tropsch (FT) diesel* Dimethyl Ether (DME)* Methanol* Mixed Alcohols (MA)* Substitute Natural Gas: (SNG)		
Waste material			Ethanol Bio gas	
Solar energy				biofuel production (in research level)
Biofuels indicated with * are produced with synthesis gas (syngas, mainly H_2 and CO) as intermediate.				

the 2nd generation biofuels, produced from lignocellulosic materials using advanced technologies. These feedstocks include wood, wood wastes, crop residues, and energy crops such as switchgrass. Although these non-food crop feedstocks address the food security issue, arise in 1st generation biofuel, second generation biofuel was not attracted due to the complex process which is not economical. The 3rd generation biofuels, produced from waste materials are also still under developing stage for efficient biofuel generation [62]. The 4th generation biofuels are still under conceptual stage, to produce biofuels using inexhaustible, cheap and widely available raw materials.

3.2 Biofuel and conversion process

As stated above, biofuel was developed in several generations as gasoline substitute and diesel substitute fuels. The 1st generation bioethanol or butanol as a substituent for gasoline is produced from starch-based feedstocks such as starches (corn, wheat, potato) or sugars (sugar beets, sugar cane) by fermentation followed by filtration and distillation to obtain fuel. 1st generation biodiesel as a substitute for petroleum diesel is obtained through transesterification of plant oils. These plant oils are named as fatty acid methyl ester (FAME) and fatty acid ethyl ester (FAEE) and collected oil plants such as rapeseed (RME), soybeans (SME), sunflowers, coconut, palm, jatropha and also from recycled cooking oil and animal fat [63, 64].

2nd generation biofuel is produced using lignocellulosic materials such as crop residues and woody crops or energy grasses. Bioethanol production from cellulosic materials is a multi-step process. First the hard bonds of the cellulosic materials have to be broken down by two process: high temperature and/or low temperature deconstruction. In high temperature process, three of primary routes which are pyrolysis, gasification, and hydrothermal liquefaction are followed. In low temperature process enzymes are used as biological catalysts to breakdown feedstocks. Before adding the catalyst, a pretreatment process has to be followed in order to opens the physical structure of plant for the enzyme to react with polymers like cellulose. Next the broken particles have to subjected fermentation using microorganisms to convert into fuel [3, 65]. Third generation biofuel production technologies are still under development. 4th generation biofuels are under conceptual stage to produce biofuels by photosynthetic water splitting (water oxidation) into its constituents by solar energy [66]. This method has been identified as the largest contributor for biofuel production in the near future on global scale. Two methods have been developed as artificial photosynthesis and direct solar biofuel production technologies to realize the above concept. Production of reduced carbon-based biofuels using atmospheric CO_2 is expected to be launched and the necessary technologies are yet to be developed [67].

Biofuel is a green energy source considering several merits. Reference to Figure 01, production of biofuel is a sustainable cyclic process. It reduces greenhouse gas emission since the emitted CO_2 during the production and combustion of biofuel is absorbed by the plants during the growth. Similarly, the byproducts produced during the production of biofuel are utilized by the plant as fertilizer during the growth [15]. Biofuel is a very good substitute for the fossil fuel with improved emission characteristics with less greenhouse gas emission. Biofuel blended with gasoline and diesel called flex fuel that reduce greenhouse gas emission substantially [68]. Many countries are legislated to include the minimum percentage of biofuel in their fossil fuel considering the requirement of reducing GHG emission with flex fuels [69].

4.0 Environmental advantages of biofuels.

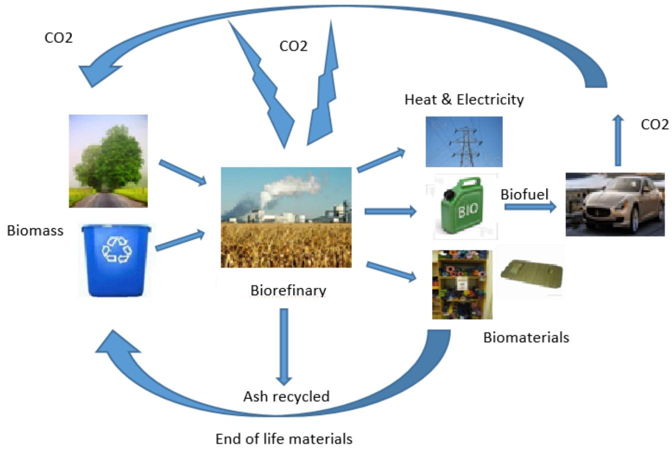

Fig. 1. Biofuel-biomaterial- bio power cycle for sustainable technologies [8]

Presently, increase in waste is a considerable environmental issue and the biofuel can be produced using those waste materials which provides many environmental benefits. Table 4 includes the data on energy saving and green effects of biofuels and fossil fuels. Reference to the same table, highest energy savings could be observed using bioethanol, produced using sugar cane as a substitute for gasoline. The highest energy savings are due to the lesser energy requirement for production. Considering green effect, usage of all bioethanol as a substitute for gasoline is a green effect saving and specially bioethanol, produced from sugar cane and sugar beet reduces green effect by one third. But reference to the same table, usage of bio diesel as a substitute for diesel is not a green effect saving.

5. Environmental pollution due to biofuels

Environmental pollution caused by biofuel is inter-linked with two considerable areas: emission due to production of biofuels and product of combustion of biofuels. Emission due to production of biofuels generates the greenhouse gases that are emitted during processing of biofuel feedstock such as plantation, usage of fertilizers, pesticides, farming with machineries, and waste removal process. Due to the increase of production of biofuels, agriculture greenhouse gas emissions have been increased by 10% from 1990 to 2000; CH_4 and N_2O emissions have been increased by 17% from 1990 to 2005 [23]. It has been estimated that 88% of these emissions are due to biomass burning, fermentation and N_2O emissions from soil [72].

Table 4. Energy saving and green effects of bio-fuels and fossil fuels [70, 71].

Biofuel (produced from different feedstocks)	Energy saving / (GJ/hectare)	Greenhouse effect /(g CO_2/ MJ)	Comparative fossil fuel and GHG emission	
			Fossil fuel	Greenhouse effect /(g CO_2/ MJ)
Ethanol-sugar cane	150-200	33.6	Gasoline	96.9
Ethanol-beet	30-150	32.4		
Ethanol-wheat	10-50	49.0		
Ethanol-corn	25-50	84.9		
Biodiesel–sunflowers	25-70	82.5	Diesel	82.3
Biodiesel -rapeseed	25-55	87.6		
Biodiesel -palm oil	17.5-22.5	104.6		
Biodiesel –soy bean	10-22.5	102.3		

The amount of GHG emission due to production of biofuels varies depending on type of bio fuel, production process, type of feedstock, etc. The major activities that contribute to environmental pollutant loads are farming activities including fertilizers and agrochemicals. In addition to the use of diesel by tractors and other agricultural machineries [73]. The amount of GHG (Green House Gas) emission during the production different biofuels and the energy density of each biofuel are given in Table 5. Based on the data shown in Table 5, GHG emission varies from 1.0 to 4.0 CO_2 (kg/kg) for different biofuels and highest emission is recorded for the production of green diesel produced by hydrocracking oil and fat feedstock. Reference to Table 6, environmental pollution due to biofuels can be categorized further due to the several steps involved in the biofuel production processes. Reference to the proportion of GHG emission, production of ethanol using sugarcane in Brazil is given in Table 6 [74]. The highest proportion of emission (33%) is caused by soil emission and the second highest (19%) is due to the trash burning and the third proportion, third highest (11%) is due to the fertilizer production with small other contributions.

6. Greenhouse effect saving due to use of biofuels

Considering the environmental pollution caused by biofuel, it is necessary to compare the greenhouse effect saving and energy saving between biofuels with similar type of fossil fuel. The data shown in Table 7 [15][76][77] are the results of a comparative study on energy saving and greenhouse effect saving of different bio fuels. Accordingly, both greenhouse effect saving and energy saving vary with different biofuel due to the different feedstock used for producing them. Comparatively, highest energy saving and greenhouse effect saving is recorded for bioethanol produced from sugar cane, corn and sugar beet [15][76][77]. In general, many biofuels perform better at reducing GHG [78].

Considering the GHG emission of biofuel during the combustion stage, the level of GHG emissions varies with different factors such as the type of biofuel, type of vehicle, type of fuel blends, proportion in fuel blends, type of additives, engine speed, etc.

Commonly bioethanol, methanol, and biodiesel are used for fueling vehicles with different proportion of fuel blends with fossil fuel [79, 80]. Row details on emission with different biofuel and fuel blends are shown in Table 8. The information is not given with numbers as the data is quite variable with different application. Reference to the formation in Table 8, ethanol and ethanol blended with gasoline is appeared to have low CO emissions compared to gasoline. However, CO_2, THC, and NO_x emissions are unpredictable but possible to presest aldehydes in the emissions [81, 82].

Since ethanol is an oxygenated fuel, adding oxygenates generally reduces many GHG emissions. Emissions with ethanol including fuel blends vary with engine operating conditions, ethanol content, additive, and ignition improver. [80-84]. At higher loading conditions, ethanol blended diesel fuels have a higher emission of smoke, NO_x, acetaldehyde, acetaldehyde, and unburned ethanol emissions are increased and unburnt ethanol. By increasing the proportion of ethanol, smoke, NO_x, and CO_2 emissions are decreased whereas CO, proper additive and ignition improver, CO, acetaldehyde, and under most of the operating conditions. At low loads, there is a smoke reduction and quite low THC emission. Using proper additive and ignition improver, CO, acetaldehyde and unburned emissions can be diminished [85, 86]. Considering emission with diesel and diesel blends, improved emission characteristics could be observed with biodiesel and biodiesel blends comparative to diesel.

Table 5. GHG emission and energy density of different biofuels, produced by different feedstocks [75]

Generation of bio fuel	Type of fuel		GHG/ CO_2 (kg/kg)	Energy Density (MJ/kg)	Type of feedstock
First generation	**Bio alcohol**	Ethanol (C_2H_5OH)	1.91	30	Starches from wheat, corn, sugar cane, molasses, potatoes, other fruits
		Propanol (C_3H_8OH)	-	34	
		Butanol (C_4H_9OH)	2.37	36.6	
	Biodiesel		2.85	37.8	Oils and fats including animal fats, vegetable oils, nut oils, hemp, and algae
	Green Diesel		3.4	48.1	Made from hydrocracking oil and fat feedstock
	Biogas (CH_4)		2.74	55	Methane made from waste crop material through anaerobic digestion or bacteria
	Solid Biofuels	Wood	1.9	16-21	Everything from wood, sawdust, garbage, agricultural waste
		Dried plants	1.8	10-16	
		Bagasse	1.3	10	
		Manure	-	10-15	
		Seeds	-	15	
	Vegetable Oil	Castor Oil	2.7	39.5	Unmodified or slightly modified
		Olive Oil	2.8	39	
		Fat		32	
		Sunflower Oil	2.8	40	
	Bio ethers		-	-	Dehydration of alcohols
Second Generation	**Cellulosic ethanol**		-	-	Usually made from wood, grass, or inedible parts of plants
	Algae - based biofuels		-	-	Multiple different fuels made from algae
	Bio hydrogen (H_2)		-	(compressed to 700 atm) 123	Made from algae breaking down water.
	Methanol (CH_3OH)		1.37	19.7	Inedible plant matter
	Dimethyl furan		-	33.7	Made from fructose found in fruits and some vegetables
	Fischer-Tropsch Biodiesel		2.85	37.8	Waste from paper and pulp manufacturing

Table 6. Greenhouse gases emissions during bioethanol production from sugarcane in Brazil [74]

Method of emission	Proportion of GHG emission / (%)
Soil emission	33
Trash burning	19
Fertilizers production	11
Cane transportation	7
Harvesting	7
Chemical and lubricants	5
Agricultural operations	3
Lime, insect, herbic	2
Input transportation	2
Seeds	1
Machinery	1
Equipment	1
Other activities	8

Table 7. The range of energy saving and green effect savings of different biofuels [13][76][77]

Biofuel (produced from different feedstocks)	Energy saving / (GJ/hectare)	Average Greenhouse effect saving /(CO_2 equivalent per hectare)
Ethanol-sugar cane	150-200	71
Ethanol-beet	30-150	52
Ethanol-lingocellulostic	25-90	41
Ethanol-wheat	10-50	23
Ethanol-corn	25-50	56
Ethanol-potatoes	10-45.5	23
ETBE – sugar beets	80-240	130
ETBE-wheat	30-110	35
ETBE-potatoes	25-100	32
Bio methanol - lingocellulostics	60-150	202
Biodiesel –sunflowers	25-70	58
Biodiesel -rapeseed	25-55	45
Biodiesel - canola	17.5-22.5	10
Biodiesel -coconut	20-25	15
Biodiesel –soy bean	10-22.5	40
Vegetable oil-rapeseed	25-50	25
Vegetable – sun flowers	25-45.5	13
Bio Gas – cultivated bio mass	25-75	36

7. Conclusion

Biofuel is an excellent substitutor for fossil fuel since it contributes biofuel-biomaterial-bio power cycle for sustainable energy. Among the various biofuels, bioethanol is is the best substitutor for gasolin. Specially, bioethanol produced using sugar cane, con and sugar beet reduces green effect about one third, relative to gasoline. Few drawbaks of using biofuels such as food protection, land use, etc. have to be addresed positively by applying necessary regulations. Considering negligable amount of GHG emissions and variations of emissions of exhaust gases, it is possible to improve by extending research that will cover the areas of modifications in fuel production process, operating conditions of engines, and engines condtions.

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Table 8. Emission caused by different biofuels and fuel blends

Biofuel	Fuel type	Reference	CO	CO_2	NO_x	HC	Comments	Ref
Ethanol	100% Eethanol	gasoline	substantial reduction	increases	reduction	reduction	high air fuel ratio	[83]
	Methanol gasoline blends	gasoline	decrease	increase	NO_x emission increases	decreases with increasing methanol percentage	CO_2 increases due to better combustion. high air fuel ratio	[84] [82]
	Ethanol gasoline blends	gasoline	very less	increase	reduction	vary	high air fuel ratio	[83]
Bio diesel	Ethanol diesel	diesel	decrease	increase	increase	low	Considerable smoke	[84]
	Ester ethanol diesel blends	diesel	decrease	increase	decrease	decrease	increase air fuel ratio, decrease PM emission	[84]
	100% Vegetable oil	diesel	decrease	similar	substantially smaller	substantially less	smoke increase with higher loads	[85]
	Vegetable oil diesel blends	diesel	low emission for less than 20% blends	increase	considerable increment	considerable reduction	smoke increase with higher loads	[86]

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