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Review Article

Biofuels as the Starring Substitute to Fossil Fuels

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Abstract: Energy is a vital infrastructure for economic development. Energy plays a vital role in human welfare as all important economic activities of present development are dependent on the use of energy. As on today, fossil fuels are still the main primary source of energy in the world. However, the use of these fossil fuels causes harm to the environment and the demand of energy is ever increasing at a faster rate due to increasing trend of modernization, industrialization, economic development and population growth. This increasing energy demand leads to energy (fuel) Crisis and rise in the price of petroleum thereby causing economic catastrophe. Most of all, Fossil fuels are non-renewable energy sources of energy, the total recoverable world reserves of the main fossil fuels are rapidly depleting at an alarming rate, as such, fossil fuels will surely be exhausted in not too distance future.

Keywords: Fuel, Fossil Fuel, Biofuel, Pyrolysis

1. Introduction

A fuel is any material that can be made to react with other substances in order to produce energy in the form of heat through a process called combustion. The heat energy release can be use directly or converted into another form such as mechanical or electrical energy. A fuel can be solid such as wood, charcoal, coal, peat, etc. It can be liquid such as diesel, gasoline, kerosene, coal tar, naphtha, ethanol, Liquefied Petroleum Gas (LPG), etc. Fuel can also appear as gaseous such as coal gas, water gas, hydrogen gas, propane, methane, Coke Oven Gas (CNG), etc. Apart from the solar energy in which all living things and non-living things in the universe depend on, fuel is the major form of energy needed in our daily activities. Depending on the source of the fuel, fuels are categorized into fossil fuels and biofuels [1].

1.1. Fossil Fuels

Fossils fuels are hydrocarbons primarily coal, petroleum and natural gas. Fossils fuels also include mineral fuels that are not derived entirely from biological sources such as tar sand and bitumen [1]. Fossil fuels are formed from the fossilized remains of plants and animals through exposure to heat and pressure in the earth's crust over millions of years. Petrol, Kerosene and propane are common derivatives of fossils fuels [2].

Fossil fuels are used to generate energy for use in almost all the human activities from cooking, farming, constructions, industrial processes, transportation, etc. fossil fuels (Oil, natural gas, and coal) are also used to produce chemicals which are used to make plastics, fertilizers, medicines, and many other materials. The use of fossils fuels in this processes had led to a serious side effects of global concern, which causes pollution of the environment through the emission of pollutants such as carbon monoxide, carbon dioxide, nitrogen oxide, Sulphur oxide, unburned hydrocarbons, particulate matter, etc. The carbon dioxide is a major greenhouse gas that contributes to global climate change. Also, the release of Nitrogen Oxide and Sulphur Oxide into the atmosphere from coal fired power plants has led to the formation of acid rain which consequently affect aquatic and terrestrial ecosystem. Nitrogen oxide also contributed to ozone pollution. Coal fired power plants also emit mercury which is starting to become a serious health concern due to the fact that it is a heavy metal [3].

Fossil fuels are non-renewable energy sources because they take millions of years to form and they are being consume faster than they are being generated. According to Udhan and Bhise [4], the total recoverable world reserves of the main fossil fuels namely Coal, Natural gas and Oil using the current technology and assuming continued consumption of present day rates, have been estimated to be about 100 years, 35 years and 20 years respectively. Thus, with the exponential increase in population, industrialization and urbanization, the fossils fuels are liable to be exhausted in a quite short time. This gradual depletion of fossil fuels and the fact that they are non-biodegradable, has led to the seeking of alternative source of energy for future use [4]. However, the shortage and high demand of fossil fuels around the world has led to several oil crises since the 1970s such as.

a. 1973 oil crisis: caused by the Organization of Arab Petroleum Exporting Countries (OAPEC) oil export embargo.
b. 1979 oil crisis: caused by the Iranian Revolution.
c. 1990 oil price shock: caused by the Gulf War.

These crises lead many countries, including Brazil and the USA, to begin the modern large-scale production of biofuels [5].

1.2. Biofuels

A Biofuel is any solid, liquid or gaseous fuel that is derived from biological materials or biomass. The biological material or organic matter that is converted to biofuels include food crops, dedicated bioenergy crops, (such as switch grass or prairie perennials), agricultural residues, wood/forestry waste and by-products, animal manure, algae, etc. The raw material or biomass used to manufacture the biofuel is called biofuel feedstock. The most primary common types of biofuels which are produce commercially are ethanol/ethanol blends and biodiesel/biodiesel blends. They are liquid biofuels and are mostly used in transport industry [5].

Biogas is also a commonly used gaseous biofuel that is made from the anaerobic fermentation of biomass and used for cooking, heating, and in some natural gas vehicles. Solid biofuels, such as wood, charcoal and dried manure, are also used to produce energy for local use [5].

1.3. Classification of Biofuels

Biofuels can be categorised into current/conventional or advanced biofuels. Current or conventional bioenergy is often referred to as first generation whereas advanced bioenergy refers to second and third generation biofuels.

First generation biofuel refers to established technologies used to produce biofuels, in particular the use of food crops such as sugar cane and maize, but also including biogas. Conventional biofuels are well established and used on a commercial scale.

Second and third generation biofuel refers to bioenergy solutions that either make use of waste or rely on non-food crops that can be grown on marginal land. Feedstock typically used for advanced biofuels include woody biomass, grasses, agricultural by-products, algae and seaweed. Advanced biofuels, or “second/third generation” biofuels, are still in the research and development, pilot or demonstration phase. Advanced biofuels include lignocellulose biofuels, algae/microbes-based biofuels, biodiesel, and bio-synthetic gas.

Advanced bioenergy solutions hold the unique promise of being able to provide a sustainable alternative to current oil-based liquid fuels, particularly for aviation, shipping and haulage [6, 7].

2. Why Biofuels

While other technologies, such as electric or hydrogen vehicles, may someday replace the need for liquid fuels they are not a viable alternative at present. Electric vehicles may be excellent for short journeys, but the range provided by current battery technologies, and lack of infrastructure, make them impractical for longer journeys, haulage or aviation use, and hydrogen-based vehicles likewise still require technological and infrastructural developments.[7].

Biofuels said to have more advantages over fossil fuels and other renewable source of energy because it reduces dependency on foreign oil, it is produced domestically thereby creating employment and uplifting the economy, and finally it has zero or negligible emissions as such it is free from causing any pollution, global warming, etc. [8].

Bioenergy research focuses on sustainable energy (liquid fuels, heat and electricity) either from non-food feedstock or from inedible elements and waste from agriculture, food crops or food processing. Researchers should suggest a region that has enough land to grow the needed feedstock for renewable biofuels production without affecting food production. Changes in land use will inevitably affect the environment, for instance biodiversity, soil structure or water availability. Some changes may be positive while others may have negative impacts. The farmed and natural environment provide vital ecosystem services and it is important that proper assessments of environmental risks are carried out throughout the development of crops and new technologies before they make it to the farm.[7].

Future-generation biofuels, also known as advanced biofuels, are categorized as follows:

a. Current biofuels (ethanol, biodiesel) produced through new methods
b. New molecules produced through existing methods
c. New molecules produced through new methods

It will take a decade or longer to develop new sources of biofuel from research being carried out today. Research is currently focused on developing biofuels from plant sugars while future options may include using synthetic biology techniques and algae to produce biodiesel directly [7].

2.1. Biofuels as a Leading Substitute to Fossil Fuel

Some advantages and disadvantages of biodiesel production and usage indicated by different scholars' studies show that biodiesel, with both its advantages and disadvantages, has some good and some bad features [9]. Biodiesel has three major advantages over conventional petroleum diesel. First, it will reduce our dependency on foreign oil. Secondly, it is produced domestically; as such it creates employment and uplifts the rural economy. The third major advantage of biodiesel is zero or negligible emissions because the carbon dioxide produced due to combustion of biodiesel is recycled in the photosynthesis of the plants producing oil seeds for biodiesel production [8]. On the other hand, it is less suitable in low temperatures and attracts moisture. However, in general, the first generation biodiesel, produced from oil crop, waste cooking oil and animal fats is not able to replace fossil fuel [9].

Technologically, biodiesel can compete with petro-diesel, not requiring major engine modification. Biodiesel is also preferable as it has excellent lubrication properties and lower emission profile of most of the exhaust. But poor oxidation stability, high density and lower calorific value of biodiesel as compared to petro-diesel, has restricted its application directly in CI engine. Most of the problems associated with biodiesel may be minimize by adding suitable additives or by blending wit petro-diesel. It is reported earlier that the cost of raw material is the prime contributor to the biodiesel production cost. However, the choice of raw materials depends mainly on its availability [10].

The feedstock, which are cultivated as intensive monocultures, where the conversion of extensive agricultural systems and natural habitats such as grasslands into intensive monocultures is one of the major threats to biodiversity; non-native feed stocks are also potentially invasive and may have negative impacts on ecosystems; ecosystem services such as soil regeneration, carbon sequestration, natural chemical cycles, pollination and protection against flood may be affected [9].

2.2. Comparison Between Biofuels and Fossil Fuels

An analysis based on social, political, and economic factors of biodiesel with a named fossil fuel (petroleum based diesel) have prompted people to consider replacing petroleum-based diesel with biodiesel, and explore the potential for biodiesel adoption [11].

Table 1. *Differences between biofuels and fossil fuels.*

S/N	Property	Biodiesel	Petroleum Diesel
1	Cetane No	51-62	44-49
2	Lubricity	Greater than diesel	Lower
3	Biodegradability	Good	Poor
4	Toxicity	Non-toxic	Highly toxic
5	Oxygen	11% free Oxygen	Very low
6	Aromatics	No aromatics	18-22%
7	Sulphr	None	0.05%
8	Cloud Point	Slightly more	---
9	Flash Point	300-4000F	125
10	Spoil Point	None	High
11	Heating Value	2-3% higher than diesel	---
12	Renewable Supply	Renewable	Non renewable
13	Alternative Fuel	Yes	No
14	Production Process	Chemical reaction	Reaction

2.3. Production of Biofuels

Biofuels can be produce from any biomass such as animal dung, industrial residues, sewage/solid waste, agricultural/forest crops or residues, etc. The trees, shrubs and herbs available for biofuels generation are limitless. However, 26 species were found to be most suitable for use as biofuels and they met the biofuels standards of USA (ASTM D 6751-02, ASTM PS 121-99), Germany (DIN V 51606) and European Standard Organization (EN 14214) and are shown in the Table below [12].

Table 2. *Suitable biofuels feedstock showing their Saponification number (SN), Iodine value (IV) and Cetane Number (CN) of fatty acid methyl ester of the 26 selected seed oils (^{a}Percent oil content expressed in w/w, ^{e} Oil from seed, ^{d} oil from kernel).*

S/N	Source	Oil^{a}	SN	IV	CN
1	Anacardiaceae Rhus Succedanea Linn Annonaceae	39.5^{d}	204.0	92..6	52.2
2	Annona Reticulata Linn	42.0^{e}	203.6	87.2	53.37
3	Apocynaceae Erwatamia Coronaria Stapf	41.6^{e}	201.1	76.0	56.3
4	Thevetia Peruviana Merril	67.0^{d}	201.5	84.0	57.48
5	Basellaceae Basella rubra linn	36.9^{e}	202.9	85.3	54.0
6	Burseraceae Canarium commune linn	73.0^{d}	204.6	77.3	55.58
7	Celastraceae Celastrus paniculatus linn	52.0^{d}	236.6	77.5	51.9
8	Terminalia bellirica roxb	40.0^{e}	198.8	77.8	56.24
9	Vemonia cinera less	38.0^{d}	2905.2	68.5	57.5
10	Coryplus avellana	57.5^{d}	200.5	84.5	54.5

S/N	Source	Oil[a]	SN	IV	CN
11	Jatropa curcas linn	40.0[e]	202.6	93.0	52.3
12	Putranjiva roxburghii	41.8[d]	199.6	82.9	54.9
13	Calophyllum apetallum wild	47.4[d]	200.4	97.6	51.57
14	Calophyllum inophylum linn	65.0[d]	201.4	71.5	57.3
15	Mesua ferrea linn	68.5[d]	201.0	81.3	55.10
16	Azaradicta indica	44.5[d]	201.1	69.3	57.8
17	Moringa concanensis nimmo	35.5[e]	199.7	76.0	56.32
18	Motinga olifeira linn	35.0[d]	199.7	75.4	56.6
19	Pongamia pinnata pierre	33.0[e]	196.7	80.9	55.8
20	Rhamnaceae ziziphus mauritiana lam	33.0[e]	198.6	81.8	55.37
21	Sapindus trifoliatus linn	45.5[d]	195.0	64.5	59.7
22	Schleichera oleosa oken	40.0[e]	193.0	57.9	61.55
23	Madhuka indica JF gmel	40.0[e]	202.1	74.2	56.6
24	Mimusops hexendra roxb	47.o[d]	202.0	62.2	59.3
25	Pterygota alata rbr ulmaceae	35.0[e]	202.6	98.4	51.09
26	Holoptelia integrifolia	37.4[e]	208.7	49.9	61.2

However, each feedstock produces a particular family of a biofuel as describe below:

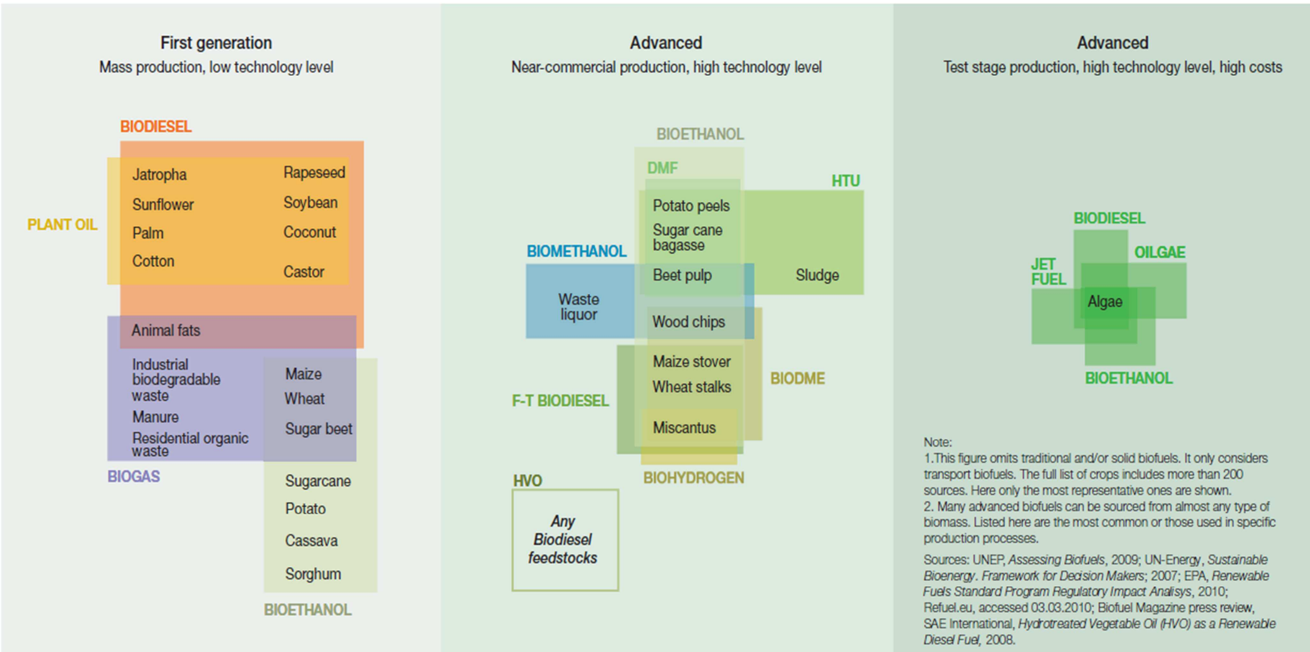

Figure 1. *Feedstock Produces a Particular Family of a Biofuel.*

This figure omits traditional and/or solid biofuels. It only considers transport biofuels. The full list of crops includes more than 200 sources. Here only the most representative ones are shown [6]

Biomass can be successfully converted into biofuels using two main processes. These are Thermo-chemical processes and Bio-chemical processes [13].

2.3.1. Thermo-Chemical Processes

Different methods are used in thermo-chemical processes for converting biomass into useful energy which includes

a. Combustion
b. Gasification
c. Liquefaction
d. Hydrogenation
e. Pyrolysis.

Out of all pyrolysis is advantageous than remaining processes because it can convert biomass directly into solid, liquid and gaseous products by thermal decomposition of biomass in the absence of air or oxygen. [13]

2.3.2. Pyrolysis

Pyrolysis is the conversion of one substance into another by means of heat with or without the aid of a catalyst. It involves heating in the absence of air or oxygen. Pyro gas, pyrolytic oil (bio oil) and char are the products of pyrolysis process. Pyrolysis process can be classified as slow pyrolysis or low temperature conversion and flash or fast pyrolysis. The pyrolytic breakdown of wood produces a large number of chemical substances. Some of these chemicals can be used as substitutes for conventional fuels.

2.3.3. Design and Fabrication of Pyrolysis Setup

In an experiment conducted by Prakash *et al.,* [13], a pyrolysis oil was obtained through vacuum pyrolysis process in a fixed bed reactor. Thick wood obtained from packing container box taken as sample, cut into small chips, washed and dried. The chips were fed into an externally heated mild steel reactor unit. The fed chips were heated up in the reactor unit in the absence of oxygen. The reactor used for production of wood pyrolysis oil is cylindrical in shape with inner diameter 200mm and outer diameter 250mm and a height of 250mm. The reactor is fully insulated by glass wool with thickness 50mm and refractory lining. The heat input to the electrical heater was 3kW. The temperature of the reactor was measured with the help of a temperature indicator provided in a temperature controller unit. The temperature of the reactor was controlled by a PID controller. The pyrolysis process for deriving wood pyrolysis oil was carried out at 5000C. The products of pyrolysis in the form of vapour were sent to a water cooled condenser and the condensed liquid was collected in a container. The schematic diagram of the pyrolysis process for deriving wood pyrolysis oil was given in Figure bellow.

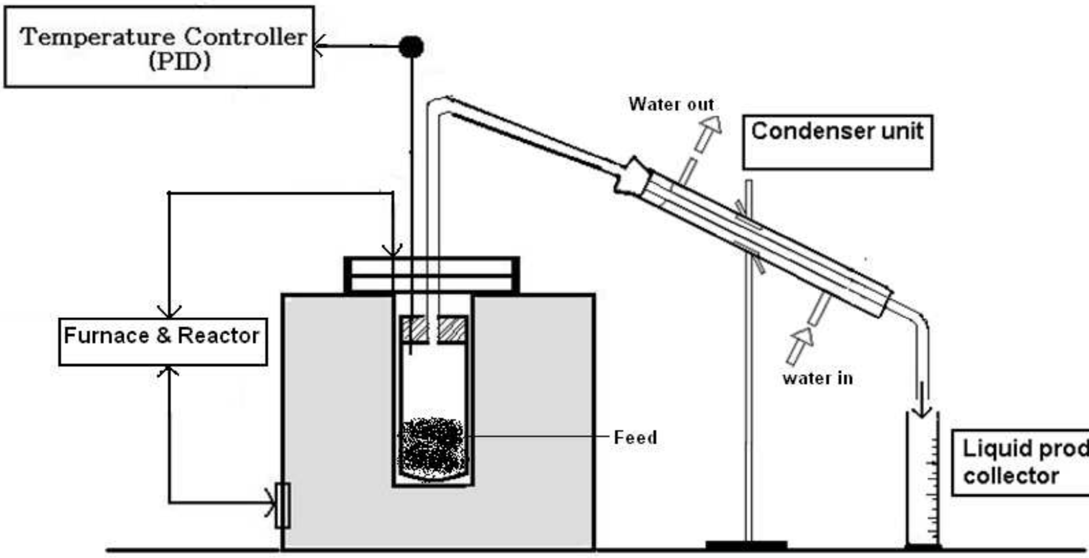

Figure 2. *Schematic diagram of pyrolysis setup (Prakash, et al., 2011).*

The properties of wood pyrolysis oil are compared with diesel fuel and given in Table below

Table 3. *Properties of Wood Pyrolysis.*

Properties	ASTM Standard	Diesel Fuel	WPO
Specific gravity at 15°C	ASTM D 4052	0.83	1.2
Net calorific value [MJ/Kg]	ASTM D 4809	43.8	18
Flash point [°C]	ASTM D 93	50	66
Pour point [°C]	ASTM D 97	30	−27
Kinematic viscosity at 40°C [cst]	ASTM D 445	2.58	13
Moisture content c	-	0.025	15-30
Ash (wt %)	-	0.13	0.01

Properties of Wood Pyrolysis Oil (WPO) as compared to diesel fuel [13].

3. Bio Oil

The liquid product from biomass pyrolysis is known as pyrolysis oil or bio-oil or bio crude oil. Bio-oil is not a product of thermodynamic equilibrium during pyrolysis but it is produced with short reactor times and rapid cooling or quenching from pyrolysis temperature (Prakash, et al., 2011).

3.1. Properties of Bio Oil

Bio-oil has high water content in the order of 15-30%. The presence of water in bio-oil lowers the heating value and flame temperature. But on the other hand presence of water reduces the viscosity and enhances the fluidity, which is good for atomization and combustion of bio-oil in engine. Bio-oil has 35-40% oxygen content distributed in more than 300 compounds depending on the biomass resource and pyrolytic process temperature, residence time and heating rate. The high oxygen content leads to the lower energy density than the conventional fuel by 50% and immiscibility with hydrocarbon fuels also. The viscosity of bio-oils varies depending on the biomass feedstock and pyrolysis process. Reduced viscosity is found with bio-oils with higher water content and less water insoluble compounds. Bio-oils contain carboxylic acids such as acetic acids and formic acids which leads to low pH values of 2-3. Acidity makes bio-oil very corrosive and extremely severe at high temperature which requires suitable materials when using bio-oil in transport application. Bio-oils have lower heating value than vegetable oils due to more water content present in the bio oil as such fuel consumption will be more to produce the same power output. Ash content in the bio-oil varies between 0-0.2%. The presence of ash in bio-oil can cause erosion, corrosion and kicking problems in the engines and the valves and even deterioration takes place when ash content is more than 0.1wt%. [13].

3.2. Upgrading Bio Oil

Due to the different properties of Bio oil, it requires upgrading in order to be use in place of petroleum oil. Bio-oil can be upgraded by any of the following method;

i. Hydro deoxygenation
ii. Catalytic Cracking of Pyrolysis Vapour
iii. Emulsification
iv. Steam Reforming
v. Chemicals Extraction

3.3. Factors Affecting Pyrolysis Reaction

i. Type of biomass feed stock
ii. Particle size
iii. Feedstock moisture
iv. Process parameters like vapour phase residence time, heating rate & temperature
v. Reactor and recovery unit design.

3.4. Bio-Chemical Processes

Anaerobic digestion and alcoholic fermentation are widely used in bio-chemical processes for obtaining energy from biomass. These processes are due to biological actions that convert semisolid or liquid biomass into a biogas or liquid fuel (i.e. ethanol and bio diesel) [13].

4. Conclusion

Energy is a vital infrastructure for economic development. Energy plays a vital role in human welfare as all important economic activities of present development are dependent on the use of energy. As on today, fossil fuels are still the main primary source of energy in the world. However, the use of these fossil fuels causes harm to the environment and the demand of energy are ever increasing at a faster rate due to increasing trend of modernization, industrialization, economic development and population growth. This increasing energy demand leads to energy (fuel) Crisis and rise in the price of petroleum thereby causing economic catastrophe. Most of all, Fossil fuels are non-renewable energy sources of energy, the total recoverable world reserves of the main fossil fuels are rapidly depleting at an alarming rate, as such, fossil fuels will surely be exhausted in not too distance future. Therefore, an urgent need to seek of alternative source of energy to fulfill world's energy demand becomes necessary. This energy has to be non-polluting, sustainable and renewable for it to be accepted globally. Many alternative source of energy were introduced, which included harnessing Biomass, Hydro, Tidal, Wave and Wind Power, capture of solar, geothermal energy supplies and also nuclear power. In contrast, biomass energy is available in a global scale; it is amenable to management and augmentation. It can be mobilized to produce a high quality energy like electricity at costs that are not exorbitant. Moreover, considering our present technology and engines, which makes use of liquid fuel (gasoline or diesel), in the absence of these fuels, there is need for a suitable fuel that can be use on the same engines. Solar, wind and hydro energy requires other technologies, such as electric or hydrogen vehicles, which may someday replace the need for liquid fuels, but they are not a viable alternative at present.

5. Recommendations

i. Production of large scale biofuels requires government initiatives. Therefore, the government should be ready to contribute towards the generation of the future energy.
ii. Production of biofuels from plants requires that the plants are particularly cultivated for that reason; otherwise it would result in food shortage and deforestation.
iii. Many publications should be made in order to enlighten the government and the citizen about the depleting of fossils fuels and to start producing biofuels. Most of the countries around the world are already into this.

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