Bio fuels: A green alternative for Energy Sustainability.

This article concentrates on need, types, and techniques of production, advantages and disadvantages of bio fuels. It also depicts the trends of use of bio fuel in India and future plans to adopt it as a blend in conventional petroleum fuel.

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1. What area Bio fuels?

Bio fuel is defined as any liquid made from biological source that can be used as a fuel. Bio fuels includes , most common Bio ethanol made from sugar cane extract or diesel-like fuel made from soybean oil, to less common such as dimethyl ether and Fischer-Tropsch liquids which are produced from lignocelluloses biomasses .

Bio fuels are attracting attention of scientific community worldwide as it has a potential to replace petroleum-derived transportation fuels to achieve energy sustainability, energy cost reduction, energy security, reduction in global warming and economic concerns associated with liquid fossil fuels. (Figure 1) depicts the substitutability of various bio fuels with common petroleum-derived fuels. Alcohol fuels can easily replace gasoline in spark-ignition engines, while biodiesel and fuel from various biological feedstock, green diesel and DME are used in compression ignition engines.

In spite of much attention on bio fuels for the transport sector and energy security the use of bio fuels in cooking (Figure 2), has a potential application, especially in developing countries.

In all cases, combustion of bio fuels for cooking will reduce pollutants that are safer than gaseous carbon emissions from cooking with solid fuels. People in developing countries cook food using solid fuels and suffer from severe health problems from indoor air pollution.

Figure 1. Substitutability of biofuels with common petroleum-derived fuels

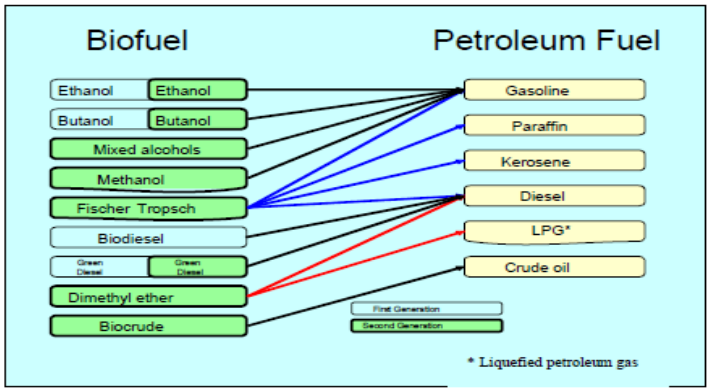
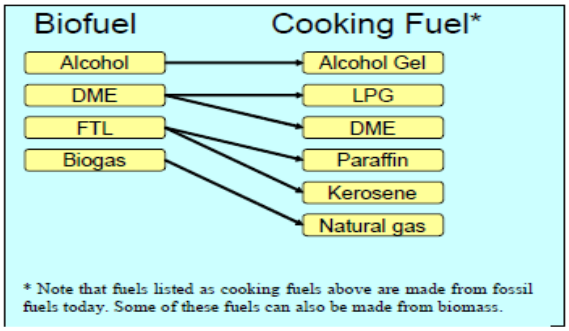


Figure 2. Substitutability of biofuels for clean fossil fuels used for cooking



2. Reasons for promoting Bio fuels?

Bio fuels may prove to be hotspot in research areas especially in many developing countries for several reasons. Some of them are:

- ✓ First and foremost reason for their promotion is depletion of non renewable conventional fossil fuels, But along with this there are further mire reasons to promote and encourage biofuels production.
- ✓ Climates conditions are favorable to grow biomass in significant quantity usable for production of Bio fuel
- ✓ Biomass production on a large scale can generate opportunities of employment in rural areas.
- ✓ Restoration of barren lands for production of biomass can reverse the soil fertility.
- ✓ The potential for producing good economic output from biomass & liquid fuel is lucrative in rural areas.
- ✓ The aim of earning foreign currency by exporting liquid crude fuel is a beneficial business.
- ✓ In addition, pollutants from crude petroleum oil i.e. carbon emissions can be further reduced with utilization of Bio fuels.

3. Energy Crops for Bio fuels

Plant species that are efficient users of solar energy for converting CO2 into biomass, and which can be used as a source of solid energy are called as energy crops. The nature of biomass obtained from these crops is of following types may be one of the following.

Table 2: A list of some energy crops and predominant mode of their utilization

Nature of Biomass	Plant Species	Estimated Yearly Production	Predominant mode of energy usage
Wood (Ligno cellulose)	*Butea monosperma, Casurina equisetifolia, Eucalyptus globules, Tamarix diocia*	1.3×10^{10}	Firewood
Starch	Cereals, millets,root and tuber crops i.e potato	1.9×10^{9}	Bioethanol
Sugar	Sugarcane , Sugarbeet	1.2×10^{8}	Bioethanol , Biodiesel
Hydrocarbons	*Euphorbia lathyris, Asclepia speciosa, Copaifera multijuga*	-	Biogas
Organic Wastes	Crop Residues, animal refuge, sewage	-	Biogas
Hydrogen	Algae like *Chlamydomonas*, anaerobic bacteria – *Clostridium*	-	Stored as metal hydride used as H_2

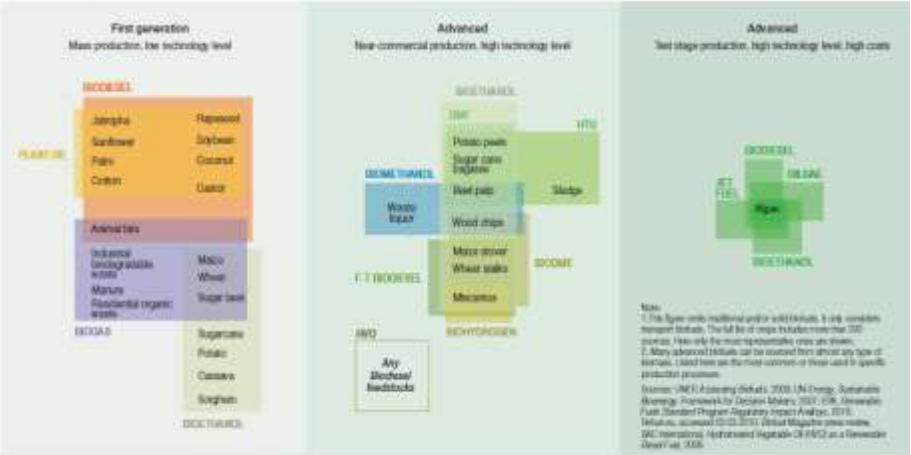
Recently , researchers have expanded their focus areas and deputation of resources to study feasibility of producing bio-diesel from tree-borne oilseeds (TBOs) from crops such as such as Pongamia (*Pongamia pinnata*), Neem (*Azadirachta indica*), Kusum (*Schleichera oleosa*), Mahua *(Madhuca longifolia*), and waste edible oils.

4. Types of Bio fuels

Basically Bio fuels are classified into first-generation and second-generation fuels. The main difference between them is the source used to produce the fuel. A first-generation fuel is generally prepared from a specific (often edible) portion of the above-ground biomass produced by a plant, following simple processing to produce a finished clear fuel. Various parts used in production of fuel are Grains, Sugar etc.

Many countries are producing First-generation fuels in significant quantities. Second-generation fuels are generally prepared from from non-edible lignocelluloses biomasses , which may be either non-edible residues of food / staple crop (e.g. corn stalks or rice husks) or non-edible whole-plant biomass (e.g. grasses or trees grown specifically for energy).

Figure 3: Table depicting various generations (types) of Bio fuel Family.



Thus, bio fuels could play a critical role in improving the health and economic conditions of billions of people especially in developing countries. It is fact that the volumetric demand of bio fuel production required to meet cooking energy needs is far smaller or negligible than that for meeting transportation fuel needs across the globe.

Many industrialized and developed countries are increasing support for the development of expanded or new bio fuels industries for the transport sector, energy sector and energy sustainability in many developing countries for similarly modernizing the use of biomass to provide a greater access to cleaner and safer liquid fuels. A basic comparison of both the types of fuels is illustrated below in table 01.

Table 1. Biofuel classification

First-generation biofuels *(from seeds, grains or sugars)*	**Second-generation biofuels** *(from lignocellulosic biomass, such as crop residues, woody crops or energy grasses)*
• Petroleum-gasoline substitutes – Ethanol or butanol by fermentation of starches (corn, wheat, potato) or sugars (sugar beets, sugar cane) • Petroleum diesel substitutes – Biodiesel by transesterification of plant oils, also called fatty acid methyl ester (FAME) and fatty acid ethyl ester (FAEE) ▪ From rapeseed (RME), soybeans (SME), sunflowers, coconut, palm, jatropha, recycled cooking oil and animal fats – Pure plant oils (straight vegetable oil)	• Biochemically produced petroleum-gasoline substitutes – Ethanol or butanol by enzymatic hydrolysis • Thermochemically produced petroleum-gasoline substitutes – Methanol – Fischer-Tropsch gasoline – Mixed alcohols • Thermochemically produced petroleum-diesel substitutes – Fischer-Tropsch diesel – Dimethyl ether (also a propane substitute) – Green diesel

4.1 First-generation Bio fuels

The most popular and extensively produced first-generation bio fuel is Bio ethanol produced by fermenting sugar extracted from sugar cane or sugar beets, or starch from maize or other starch abundant cereal crops. With the similar processing and using different fermenting micro organisms, an another alcohol, butanol can be generated. Commercialization efforts for butanol production are ongoing, while ethanol is already a well-established industry in various countries.

Seeing the depletion of fossil fuels and with a focus on fuel sustainability many countries are expanding their first-generation ethanol production, with Brazil and the United States having by far the largest expansion plans for future. First generations fuels are also bound with some limitations Some are depicted below in table 3.

Table 3: First Generation Fuels

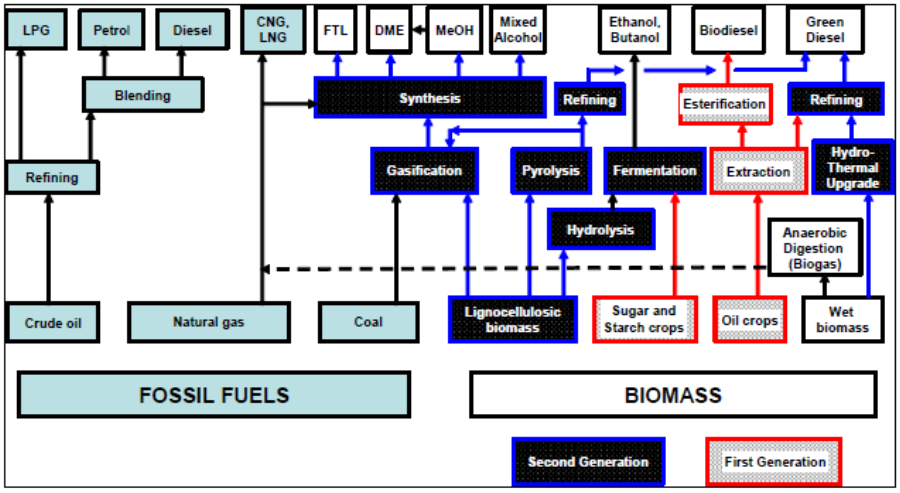
Pros	Cons
• Simple and well-known production methods • Familiar feedstocks • Scalable to smaller production capacities • Fungibility with existing petroleum-derived fuels • Experience with commercial production and use in several countries	• Feedstocks compete directly with crops grown for food • Production by-products need markets • High-cost feedstocks lead to high-cost production (except Brazilian sugar cane ethanol) • Low land-use efficiency • Modest net reductions in fossil fuel use and greenhouse gas emissions with current processing methods (except Brazilian sugar cane ethanol)

4.2 Second-generation Bio fuels

Second-generation bio fuels are different in feature of being produced from lignocelluloses biomass, enabling the utilization of lower-cost, non-edible feedstock, thereby reducing direct food vs. Fuel competition. Second-generation bio fuels can be further classified on the basis of the process used to convert the biomass into fuel: **biochemical or thermo chemical**. Second-generation bio ethanol or butanol are produced using biochemical processing, i.e. using biological machinery of microorganisms ,while all other second-generation fuels are produced using physical process like thermo chemical processing.

Researched have revealed that mixed alcohols can also be produced from fossil fuels, but there is no large scale commercial production in place as of now due to the immature state of some components of systems for producing these fuels . Another thermo chemically produced bio fuel is green diesel used in engines. Unrefined fuels, including pyrolysis oils, are produced thermo chemically, but these require considerable down streaming and refining before they can be used in engines.

Figure 4: Production pathways to liquid fuels from biomass and, for comparison, From fossil fuels



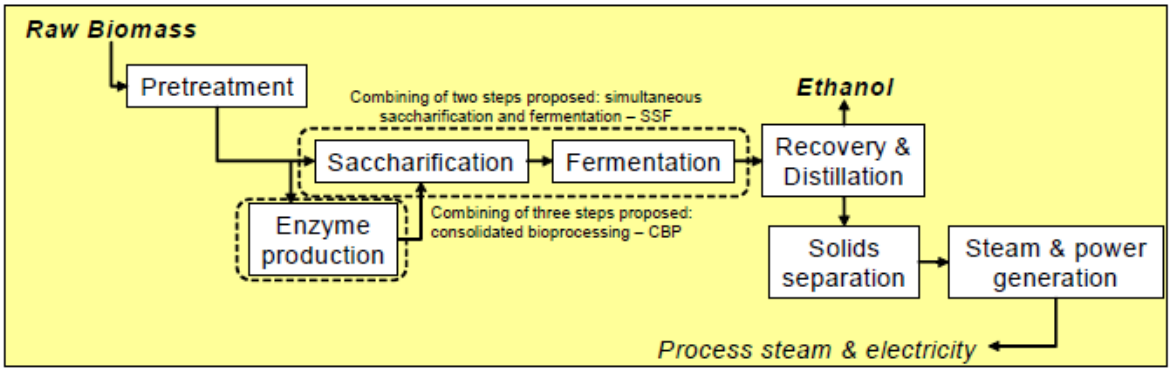
4.2.1 Second-generation- Biochemical Bio fuels

Although the characteristic fuel properties of second-generation fuels are identical to first generation equivalents, but differs with processing and feedstock used for their production. Second-generation biochemically-produced alcohol fuels are also named as "cellulosic ethanol" and "cellulosic bio butanol" because of the raw material used. The basic steps in producing these fuels include pre-treatment of biomass used , saccharification (conversion of the solid complex bio molecules carbohydrates into simple sugars for fermentation, fermentation profile for production of alcohol , and distillation for refining the alcohol produced which are depicted in (Figure 5).

Pre-treatment includes loosening or dissociation of complex bio molecules like cellulose, hemicelluloses, starch and lignin into simple accessible monomer of sugars using industrial enzymes
Cellulose which is one of the most abundant bio molecules present on this earth is a long chain polymer of 6-C glucose which is readily fermented to alcohol by microbes.
Hemicelluloses are made up of 5-C sugars and are easily broken down into its constituent sugars such as xylose and pentose using enzymes as depicted in (Figure 5).

Another well-defined approach for ethanol production is the use of separate enzymatic hydrolysis (saccharification i.e. conversion from non fermentable to fermentable sugar) following fermentation steps and distillation which is costlier and incur good losses. (Figure 5).Thus major focus is to first convert complex bio molecule to a form that is readily utilized by fermenting microbe to produce alcohol.

Figure 5: Simplified depiction of process steps for production of second-generation fuel ethanol



4.2.2 Second-generation - Thermo chemical Bio fuels
Thermo chemical biomass conversion as the name suggest is a process of conversion of biomass to liquid fuel at high temperature with a chemical process instead of a biological mechanism.

Key intrinsic characteristics of thermo chemical processing includes

- Flexibility in feedstock / biomass used for production of the fuel.
- The diversity of finished fuels produced.

The very first step in thermo chemical production of bio fuels is gasification or pyrolysis.
Gasification of solid biomass is more capital-intensive and requires larger scale for best economics returns, but the final product is a cleaner, safer and environment friendly fuel that can be used directly in combustion engines. A variety of different bio fuels can be produced using gasification, including Fisher-Tropsch liquids (FTL),dimethyl ether (DME), and various higher alcohols.

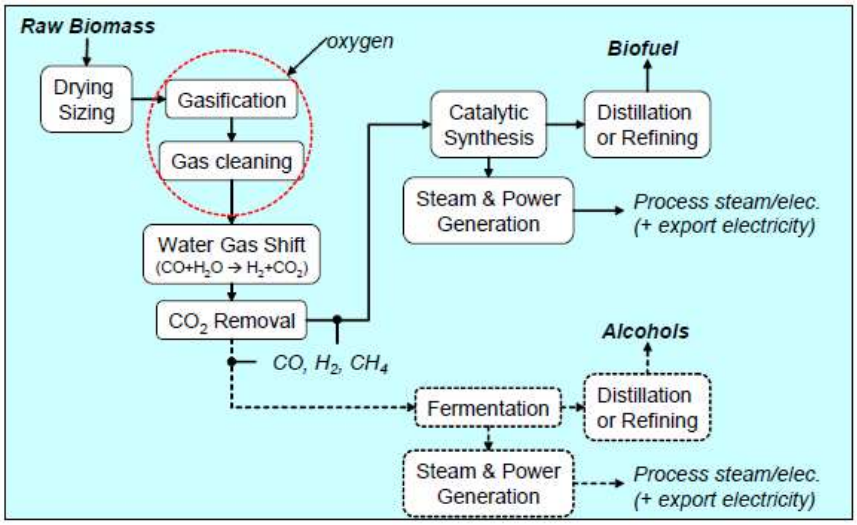
Gasification : Gasification is a chemical process of conversion of solid biomass or feedstock into gaseous form using various chemical catalysts at high temperatures and pressures.
The steps are illustrated as

1. During gasification, biomass having 10-20% moisture is heated in presence of oxygen to cause it to be burned and converted into a mixture of combustible & non-combustible gases.
2. Contaminants in the gases so produced are removed, using chemical adjustments like "water-gas

shift" reaction to get a intermediate composition of the gas (also called synthesis gas, or syngas) for further downstream processing and purification as illustrated in (Figure 8).

3. Carbon dioxide (CO2) is an impurity in the syngas and need to be removed to facilitate subsequent reactions downstream.
4. The major components of the now-clean, catalysed and concentrated syngas are carbon monoxide (CO), hydrogen (H2), with a small amount of methane (CH4) which is combustible in nature.
5. The Carbon monoxide CO and Hydrogen (H2) react when passed over a catalyst to produce liquid fuel. The design of the catalyst determines what type bio fuel is produced.
6. The unconverted syngas so produced is burned to make electricity provide captive power needed to run the facility so that total expenditure of power can be minimized.

Figure 6: Simplified depiction of process steps for Thermochemical Biofuels production



4.3 Third Generation Fuels

The third and recently emerging generation fuels are derived from microalgae, which give high biomass yield and do not compete with agricultural production system. These are in trial version and in coming days are expected to support an increase in the bio fuel production volume in future. Basically microalgae are like planktons in sea which grow very fast covering a huge area in minimal time so biomass produced is huge and is beneficial in production of bio fuels.

4.4. Fourth Generation Fuels: They are likely to involve harvesting of solar energy to produce hydrogen or electricity by making an ingenious use of photosynthetic apparatus. It is also proposed to engineer algae to produce sugars for easy production of cheap bio fuel. It has been estimated that ratio between energy obtained from energy crop and non-renewable energy for its production will be 5 or above for the crop to be used economically.

5. **India Present Status & Vision**

Biofuel production and expansion in India concentrates around the cultivation and processing of Jatropha plant seeds rich in oil (40%) and oil is used to produce bio fuels. Jatropha oil is widely used in India for years as biodiesel to fulfil the requirements of rural and forest communities of India. Jatropha has the potential to provide economic benefits as:

- ✓ The potential to grow in dry and barren lands with a minimal requirement of water, thus it can be a source of income generation.
- ✓ With an increased Jatropha oil production India marks economic benefit at macroeconomic or national level as it reduces the nation's fossil fuel import bill for diesel production.
- ✓ Jatropha oil is carbon-neutral, clear safer and environment friendly fuel and its large-scale production will improve the country's carbon foot print.

- ✓ Finally, as no food producing fertile agricultural farmland is used so it is also a good step to utilize barren lands and no competition between food and fuel occurs.

Currently, India is equipped with 5-6 large capacity plants for producing (10,000 to 250,000 MT per year) while currently we are utilizing only 28 percent of the installed capacity. We produce 125-140 million liters of biodiesel from multiple feed-stocks such as inedible vegetable oils, unusable edible oil waste (used-once), and animal fats.

The bio fuel thus produced is purchased by

- ✓ small and medium organizations,
- ✓ sold to experimental projects carried out by various automobiles and transport companies
- ✓ majorly sold to organized consumers such as cellular communication towers, brick kilns,
- ✓ progressive farmers, and
- ✓ to institutions that run diesel generators as source of power back-up.

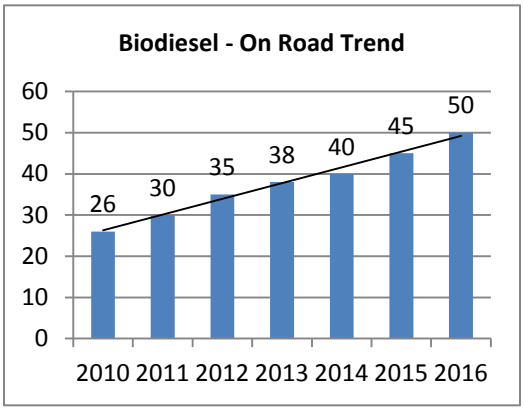
5. Way Forward & Potential in India.

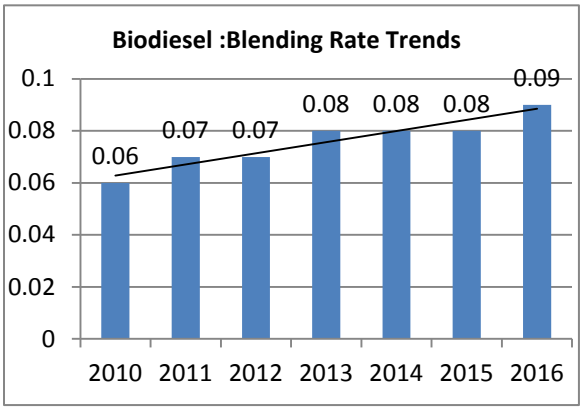
This below table illustrates bio fuel production in India from various feed stocks as compared to other fuels

Calendar Year	2010	2011	2012	2013	2014	2015	2016
Beginning Stocks	45	38	42	45	45	50	45
Production	90	102	115	120	130	135	140
Imports	0	0	0	0	0	0	0
Exports	0	0	0	0	0	0	0
Consumption	52	60	70	75	80	90	100
Ending Stocks	38	42	45	45	50	45	40
Production Capacity							
No of Biorefineries	5	5	5	6	6	6	6
Nameplate Capacity	450	450	460	465	480	480	500
Capacity Use (%)	20.0%	22.7%	25.0%	25.8%	27.1%	28.1%	28.0%
Feedstock Use (1,000 MT)*							
Used Cooking Oil	38	42	48	49	50	50	52
Animal Fats & Tallow's	6	6	7	7	6	5	6
Other Oils	50	58	65	70	75	85	85
Market Penetration							
Biodiesel, on-road use	26	30	35	38	40	45	50
Diesel, on-road use	42,625	45,520	49,343	49,354	49,605	53,284	57,244
Blend Rate (%)	0.06	0.07	0.07	0.08	0.08	0.08	0.09
Diesel, total use	71,041	75,866	82,238	82,256	82,674	88,807	95,407

Source: Industry and Post estimates - Biofuels Annual_New Delhi_India_7-1-2015

CY 2016 is projected





Graph 1: Trends and projection usage of biodiesel on road in India from 2010-2016.
Graph 2: Trends and projection of blend rates biodiesel with petroleum fuel from 2010-2016.

But seeing the vision of GOI to increase the blending of the bio fuel with conventional fuel by 2016 at a blending rate of 0.09 we need to focus more on the sustainable production of the bio fuel in our country .Some of the steps taken by GOI and other reputed stakeholders are presented below.

- ✓ Recently, the State Bank of India signed a MoU with D1 Mohan, a joint venture of D1 Oils plc, to give loan of 1.3 billion rupees to local farmers in India for the Jatropha seeds cultivation.
- ✓ In India, oil marketing companies plan to buy a total bulk volume of 20 million liters of UCO biodiesel to begin blending as first steps towards ~ 5% blending by 2020.
- ✓ In India, the government plans to make a large investment of $74.8 million in a second generation ethanol plant (IOC, Panipat) using crop residues as feedstock.
- ✓ In India, the Central Salt and Marine Chemicals Research Institute attracts farmers back to Jatropha production to boost oil supplies allowing it to use its patented bio fuel production technology.
- ✓ A $75 million second-generation ethanol plant using MSW and agricultural waste as feedstock has been announced for Kochi, at the BPCL-Kochi Refinery in collaboration with Praj Industries.
- ✓ In order to enhance ethanol availability in the country for blending with petrol, Indian Oil is developing and promoting 2G ethanol production infrastructure worth 30 billion using ligno-cellulosic biomasses as feedstock.

5. Advantages of Bio fuels:

1. Most of the Bio fuels are derived from biomass, which is renewable, low cost and environment friendly.
2. In general, they lead to relatively low CO2 emission than do fossil fuels.
3. They are less harmful as compared to conventional fossil fuel due to carbon emissions during their combustion.
4. The substrate is often a waste, including municipal waste. Use of such materials for Bio fuel production not only generate a more valuable product from lo cost substrate but also helps in cleaning up the environment.

6. Undesirable Features of Bio Fuels

- ✓ Very large volumes of bio fuels are required. Therefore production has to be taken up on a very large scale, and usually near to the site of use to minimise transportation costs.
- ✓ The substrate requirement is very large, to produce which large areas of land would be needed.
- ✓ The product is generally of low value and rather low profit margin, the cost of production being over 75% of sale price. As a result they are not attractive commercially, and continued production is driven by huge government subsidies.
- ✓ Diversion of food grains like maize for Bio fuel production has led to increased food grain prices and may lead to even global shortage of food grain.
- ✓ Posses lower energy content than fossil fuels.
- ✓ Costlier than fossil fuels as their production and storage requires additional inputs.
- ✓ Cultivation of bio fuel crops will promote mono cropping , increase the use of chemical fertilizers , encourage soil erosion and causes a decline in soil fertility.
- ✓ Increased agriculture of weedy crop may cause ecological disturbances.
- ✓ Most of the energy crops for bio fuel have toxicity and allergy problems.
- ✓ Increased use of chemical fertilizers for more biomass may cause a potential threat for biomagnifications.
- ✓ Added pressure on ground and surface water resources for growing bio fuel feedstock's is also of concern in many areas of the world.

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