BIOFUELS – A NEW AVENUE FOR FARMERS

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India has a tremendous biomass potential which could easily be relied upon to fulfil most of our energy needs. An estimated 5 crore metric tonnes of liquid fuels are consumed annually in India, but with the actual biomass potential and its full utilization, India is capable of generating almost double that amount per annum.

The term 'Biofuel' refers to liquid or gaseous fuels for the transport sector that are predominantly produced from biomass. A variety of fuels can be produced from biomass resources including liquid fuels such as ethanol, methanol, biodiesel, Fischer-Tropsch diesel, and gaseous fuels such as hydrogen and methane.

The **first-generation** liquid biofuels are made from sugar, starch, vegetable oils or animal fats using conventional technology. The basic feedstocks for the production of first-generation biofuels come from agriculture and food processing. The **second-generation** technologies use a wider range of biomass resources – agriculture, forestry and waste materials. **Third-generation** biofuels may include production of bio-based hydrogen for use in fuel cell vehicles, e.g. algae fuel, also called oilgae.

Globally, liquid biofuels are most commonly used to power vehicles, heat homes and for cooking. Biofuels offer many benefits including sustainability, less greenhouse gas emissions, regional development, wasteland agriculture and security of supply.

The **biomass resource** base is composed of a wide variety of forestry and agricultural resources, industry residues and municipal solid and urban wood residues. The **forest resources** include residues produced during the harvesting of forest produce, fuel wood etc. Some forest resources also become available through initiatives to reduce fire hazards and improve forest health.

The **agricultural resources** include grains used for biofuels production, animal manures and crop residues derived primarily from corn and small grains (e.g., wheat straw). A variety of regionally significant crops such as cotton, sugarcane, rice and orchards can also be a source of crop residue. Municipal and urban wood residues are also widely available.

Other advanced biofuel feedstocks include non-plant sources such as fats, manure and the organic material found in urban waste. In addition, algae production has great promise because algae generate higher energy yields and require much less space to grow than conventional feedstocks. Also, algae would not compete with food crops for land and could be grown with minimal inputs using a variety of methods.

Jatropha Plant

Biofuel Feedstock

First-generation biofuels (produced primarily from food crops such as grains, sugar, beet and oil seeds) are limited in their ability to achieve targets for oil-product substitution, climate change mitigation and economic growth. Their sustainable production is under review, as is the possibility of creating undue competition for land and water used for food and fiber production.

These concerns have increased the interest in developing biofuels produced from non-food biomass. Feedstocks from **ligno-cellulosic materials** including cereal straw, bagasse, rice husk, forest residues and purpose-grown energy crops such as vegetative grasses and short rotation forests. These second-generation biofuels could avoid many of the concerns facing first-generation biofuels and potentially offer greater cost reduction potential in the longer term.

Forest Resources

Primary

- Logging residues from conventional harvest operations and residues from forest management and land clearing operations
- Removal of excess biomass (fuel treatments) from timberlands and other forestlands
- Fuel wood extracted from forestlands

Secondary

- Primary wood processing mill residues
- Secondary wood processing mill residues
- Black liquor

Tertiary

- Urban wood residues — construction and demolition debris, tree trimmings, packaging wastes and consumer durables

Agricultural Resources

Primary

- Crop residues from major crops — corn stover, small grain straw and others
- Grains (corn and soybeans) used for ethanol, biodiesel and bioproducts
- Perennial grasses
- Perennial woody crops

Secondary

- Animal manures
- Food/feed processing residues
- Tertiary
- Post-consumer residues and landfill gases

In countries like India, human demand for food and feed oilseed crops (e.g. soybean, sunflower) exceeds supply, so it is not desirable to divert large quantities of these crops for biofuels **However large wasteland areas are available that might be cultivated with non-conventional oilseed species that are not consumed by humans but can withstand such rugged conditions, e.g. Pongamia and Jatropha**. In recent years, juice from sweet sorghum (*Sorghum bicolor*) stalks is emerging as a viable source for bioethanol production. Sweet sorghum grows rapidly, is photosynthetically efficient due to its C4 metabolism, and is widely adaptable.

The Government of India approved the National Policy on Biofuels in December 2009. The biofuel policy encouraged the use of renewable energy resources as alternate fuels to supplement transport fuels (petrol and diesel for vehicles) and proposed a target of 20 percent biofuel blending (both bio-diesel and bio-ethanol) by 2017. The government launched the National Biodiesel Mission (NBM) identifying *Jatropha curcas* as the most suitable tree-borne oilseed for bio-diesel production.

Bioethanol or Cellulosic Ethanol

Cellulosic ethanol (or bioethanol) technology is one of the most commonly discussed second-generation biofuel technologies worldwide. The largest potential feedstock for bioethanol is lignocellulosic biomass, which includes materials such as agricultural residues (corn stover, crop straws, husks and bagasse), herbaceous crops (alfalfa, switchgrass), short rotation woody crops, forestry residues, waste paper and other wastes (municipal and industrial). Bioethanol production from these feedstocks could be an attractive alternative for disposal of these residues in developing countries such as India. Lignocellulosic feedstocks do not interfere with food security and are important for both rural and urban areas in terms of energy security reason, environmental concern, employment opportunities, agricultural development, foreign exchange saving, socioeconomic issues etc.

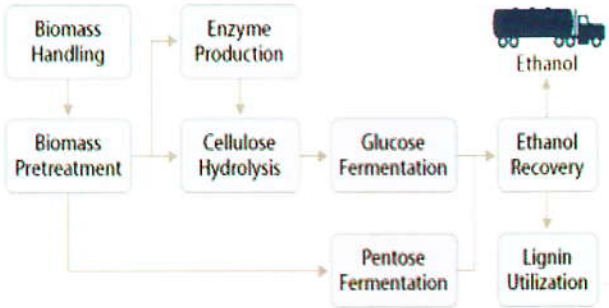
The production of ethanol from lignocellulosic biomass can be achieved through two different processing routes. They are:

- Bio-chemical – in which enzymes and other micro-organisms are used to convert cellulose and hemicellulose components of the feedstocks to sugars prior to their fermentation to produce ethanol;
- Thermo-chemical–where pyrolysis/gasification technologies produce a synthesis gas ($CO + H_2$) from which a wide range of long carbon chain biofuels, such as synthetic diesel or aviation fuel, can be reformed.

Compared with the production of ethanol from first-generation feedstocks, the use of lignocellulosic biomass is more complicated because it contains polysaccharides. These polysaccharides are more stable and the pentose sugars are not readily fermentable. So polysaccharides must first be hydrolysed, or broken down, into simple sugars using either acid or enzymes.

Ethanol from lignocellulosic biomass is produced mainly via bio-chemical routes. The three major steps involved are pretreatment, enzymatic hydrolysis and fermentation. Biomass is pretreated to improve the accessibility of enzymes. After pretreatment, biomass undergoes enzymatic hydrolysis for conversion of polysaccharides into monomer sugars such as glucose and xylose. Subsequently, sugars are fermented to ethanol by the use of different microorganisms.

Schematic of a Biochemical Cellulosic Ethanol Production Process



The world's largest demonstration facility of lignocellulose ethanol (from wheat, barley straw and corn stover), with a capacity of 25 lakh litres, was established by Iogen Corporation in Ottawa, Canada. Many other processing facilities are now in operation or planning throughout the world.

Biodiesel

Biodiesel in India is mostly produced from the oils extracted from the seeds of *Jatropha*, mainly because of the fact that edible oil is scarce and the country already depends on huge quantity of imported oils for edible purposes. **Apart from *Jatropha*, *Pongamiapinnata*, Mahua, Neem and Castor are also considered as good source of non-edible oil-based biodiesel in India.** In Western countries, biodiesel is typically made from vegetable oil (rapeseed oil, sunflower oil and palm oil), animal tallow and used cooking oil. Rapeseed oil has 82 percent of the share of the world's biodiesel feedstock followed by sunflower oil, soybean and palm oil.

Jatropha is a genus of nearly 175 species of shrubs, low-growing plants, and trees. However, discussions of Jatropha as a biodiesel plant actually means a particular species of the plant, *Jatropha curcas*. The plant is indigenous to parts of Central America, however it has spread to other tropical and subtropical regions in Africa and Asia. *Jatropha curcas* is a perennial shrub that, on average, grows approximately three to five meters in height. It has smooth grey bark with large and pale green leaves. The plant produces flowers and fruits in winter or throughout the year depending on temperature and soil moisture. The *curcas* fruit contains 37.5 percent shell and 62.5 percent seed. *Jatropha curcas* can be grown from either seed or cutting.

By virtue of being a member of the *Euphorbiaceae* family, *Jatropha* has a high adaptability for thriving under a wide range of physiographic and climatic conditions. It is found to grow in almost all parts of the country up to an elevation 3000 feet. *Jatropha* is a perennial plant, suitable for all soils including degraded and barren lands. It occupies limited space hence is highly suitable for intercropping. Extensive research has shown that Jatropha requires low water and fertilizer for cultivation, is not grazed by cattle or sheep, is pest resistant, is easily propagated, has a low gestation period and has a high seed yield and oil content. It also produces high protein manure.

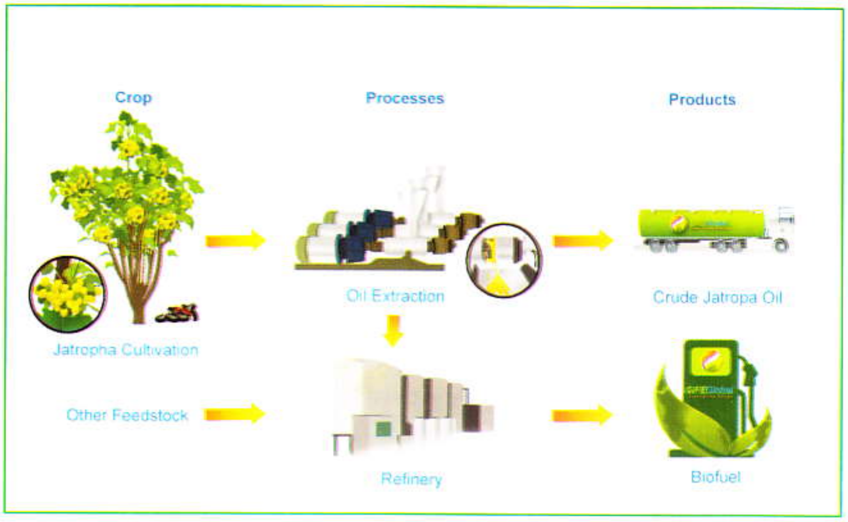
Pongamiapinnata or *Karanj* is another promising non-edible oil seed plant that can be utilized for oil extraction for biofuels. The plant is a native to India and grows in dry places, far in the interior and up to an elevation of 1000 meters. *Pongamia* plantation is not much known as like *Jatropha*, but the cost effectiveness of this plant makes it more preferred than other feedstock. *Pongamia* requires about four to five times lesser inputs and gives two to three times more yield than *Jatropha*. This makes it quite suitable for small farmers in India. However, *Pongamia* seeds have about 5-10 percent less oil content than *Jatropha* and the plant requires longer period to grow as the gestation period is about 6-8 years for *Pongamia* against 3-5 years in *Jatropha*.

There are three major steps in biodiesel production:

(i) plantation—production of oil seeds,

(ii) oil extraction—production of straight vegetable oil (SVO), and

(iii) trans-esterification— production of biodiesel.



Biorefinery Prospects in India

Biorefinery is analogous to the traditional petroleum refineries employing fractional distillation process for obtaining different fractions or components from the same raw material, i.e. the crude oil. Biorefinery involve the integration of different biomass treatment and processing methods into one system, which results in the production of different components from the same biomass. This makes the entire chain more viable economically and also reduces the waste generated.

India has a tremendous biomass potential which could easily be relied upon to fulfil most of our energy needs. An estimated 5 crore metric tonnes of liquid fuels are consumed annually in India, but with the actual biomass potential and its full utilization, India is capable of generating almost double that amount per annum. These biomass estimates only include the crop residues available in the country and essentially the second-generation fuels since the use of first-generation crop based fuels in such food-starved nations is a criminal thought.

Currently, there are various technologies available to process such crop-residues and generate value products from them. However, essentially, they all revolve around two main kinds of processes, either bio-chemical or thermo-chemical. The bio-chemical process involves fermentation to produce ethanol or trans-esterification to produce biodiesel. Alternatively, the thermo-chemical processes involve heat-based processes like combustion (to produce heat), gasification (to produce gas) or pyrolysis techniques (to produce liquid fuels). These products can be used as such, or could be further processed to generate high quality biofuels or chemicals.

Biorefineries can help in utilizing the optimum energy potential of biomass wastes in India and may also help in climate change mitigation to a certain extent. Biomass can be converted, through appropriate enzymatic/chemical treatment, into either gaseous or liquid fuels. The pre-treatment processes involved in biorefining generate products like paper-pulp, solvents, acetate, resins, laminates, adhesives, flavour chemicals, activated carbon, fuel enhancers, undigested sugars etc. which generally remain untapped in the traditional processes. The suitability of this process is further enhanced from the fact that it can utilize a variety of biomass resources, whether plant-derived or animal-derived.

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