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## REVIEW ARTICLE

# BIO FUELS: A NOVEL BIOMASS ENERGY TECHNOLOGY

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**ABSTRACT**

Bio energy provides an irreversible mitigation benefit when it displaces fossil fuels. Mitigation benefits of afforestation or forest protection will be lost if deforestation occurs. Non-commercial energy sources, predominantly fuel wood, chips and dung cakes, contribute around 30% of the total primary energy consumed. The overall trend in the last decade in primary energy consumption for cooking in rural areas exhibits that the number of households using firewood as primary cooking fuel is increasing steadily, while there is no significant transition with regards to Liquefied Petroleum Gas (LPG). Bio fuels can include relatively familiar ones, such as ethanol made from sugar cane or diesel-like fuel made from soybean oil, to less familiar fuels such as dimethyl ether (DME) or Fischer-Tropsch liquids (FTL) made from lignocellulosic biomass or Ethanol produced from the fermentation of sugar by enzymes produced from specific varieties of yeast.



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## INTRODUCTION

Biofuels are drawing increasing attention worldwide as substitutes for petroleum-derived transportation fuels to help address energy cost, energy security and global warming concerns associated with liquid fossil fuels (World Health Organization, 2006; International Energy Agency, 2006; Goldemberg *et al*., 2004). The term bio fuel is used here to mean any liquid fuel made from plant material that can be used as a substitute for petroleum-derived fuel. Biofuels can include relatively familiar ones, such as ethanol made from sugar cane or diesel-like fuel made from soybean oil, to less familiar fuels such as dimethyl ether (DME) or Fischer-Tropsch liquids (FTL) made from lignocellulosic biomass (Dupont, 2007). A relatively recently popularized classification for liquid biofuels includes "first-generation" and "second-generation" fuels. There are no strict technical definitions for these terms. The main distinction between them is the feedstock used. A first-generation fuel is generally one made from sugars, grains, or seeds, i.e. one that uses only a specific (often edible) portion of the above-ground biomass produced by a plant, and relatively simple processing is required to produce a finished fuel (Macedo, 2007; Collins, 2007; Coelho, 2006; http://www.ebb-eu.org/).

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First-generation fuels are already being produced in significant commercial quantities in a number of countries. Second-generation fuels are generally those made from non-edible lignocellulosic biomass, 1 either non-edible residues of food crop production (e.g. corn stalks or rice husks) or non-edible whole plant biomass (e.g. grasses or trees grown specifically for energy). Second-generation fuels are not yet being produced commercially in any country.

### Generation of Biofuels

#### *A. First-Generation Biofuel -Biomass Ethanol production*

The most well-known first-generation biofuel is ethanol made by fermenting sugar extracted from sugar cane or sugar beets, or sugar extracted from starch contained in maize kernels or other starch-laden crops. Similar processing, but with different fermentation organisms, can yield another alcohol, butanol (Bioproducts Alberta, 2006). The production of ethanol from corn is a mature technology that is not likely to see significant reductions in production costs. The ability to produce ethanol from low-cost biomass will be key to making it competitive as a gasoline additive. The production of ethanol from corn is a mature technology that is not likely to see significant reductions in production costs. Substantial cost reductions may be possible, however, if cellulose-based feedstock are used instead of corn. The ability to produce ethanol from low-cost biomass will be significant in making ethanol competitive with gasoline (Government of India Planning Commission, 2005; Renewable Fuels Association, 1999).

## Technology for Ethanol Production

Ethanol is produced from the fermentation of sugar by enzymes produced from specific varieties of yeast. The five major sugars are the five-carbon xylose and arabinose and the six-carbon glucose, galactose, and mannose (Stricklen, 2006). Traditional fermentation processes rely on yeasts that convert six-carbon sugars to ethanol. Glucose, the preferred form of sugar for fermentation, is contained in both carbohydrates and cellulose. Because carbohydrates are easier than cellulose to convert to glucose, the majority of ethanol currently produced in the United States is made from corn, which produces large quantities of carbohydrates (Energy Information Administration, 1998). Also, the organisms and enzymes for carbohydrate conversion and glucose fermentation on a commercial scale are readily available (www.ott.doe.gov/ biofuels/history.html). The conversion of cellulosic biomass to ethanol parallels the corn conversion process. The cellulose must first be converted to sugars by hydrolysis and then fermented to produce ethanol. Cellulosic feed stocks (composed of cellulose and hemicelluloses) are more difficult to convert to sugar than are carbohydrates[21]. Two common methods for converting cellulose to sugar are dilute acid hydrolysis and concentrated acid hydrolysis, both of which use sulphuric acid. Dilute acid hydrolysis occurs in two stages to take advantage of the differences between hemicellulose and cellulose.

The first stage is performed at low temperature to maximize the yield from the hemicellulose, and the second, higher temperature stage is optimized for hydrolysis of the cellulose portion of the feedstock. Concentrated acid hydrolysis uses a dilute acid pre treatment to separate the hemicellulose and cellulose (Houghton *et al*., 2006). The biomass is then dried before the addition of the concentrated sulphuric acid. Water is added to dilute the acid and then heated to release the sugars, producing a gel that can be separated from residual solids. Column chromatography is used to separate the acid from the sugars.

## Second-Generation Biofuels

Second-generation biofuels share the feature of being produced from lignocellulosic biomass, enabling the use of lower-cost, non-edible feed stocks, thereby limiting direct food vs. fuel competition. Second-generation biofuels can be further classified in terms of the process used to convert the biomass to fuel into biochemical or thermo chemical. Second-generation ethanol or butanol would be made via biochemical processing, while all other second-generation fuels discussed here would be made via thermo chemical processing. Second-generation thermo chemical biofuels may be less familiar than second-generation ethanol, because there are no first-generation analogs (Renewable Fuels Association, 1999).

On the other hand, many second-generation thermo chemical fuels are fuels that are already being made commercially from fossil fuels using processing steps that in some cases are identical to those that would be used for bio fuel production. These fuels include methanol, refined Fischer-Tropsch liquids (FTL), and Dimethyl ether (DME) (Stricklen, 2006).

Mixed alcohols can also be made from fossil fuels, but there is no commercial production today due to the immature state of some components of systems for producing these. The other thermochemical biofuel is green diesel, for which there is no obvious fossil fuel analog. Unrefined fuels, such as pyrolysis oils, are also produced thermochemically, but these require considerable refining before they can be used in engines (www.ott.doe.gov/ biofuels/history.html.).

## Second Generation Biochemical Fuels

The fuel properties of second-generation ethanol or butanol are identical to those of the first generation equivalents, but because the starting feedstock is lignocelluose, fundamentally different processing steps are involved in producing them. Second-generation biochemically-produced alcohol fuels are often referred to as “cellulosic ethanol” and “cellulosic biobutanol”[21].

The basic steps for producing these include:

- Pre-treatment
- Saccharification
- Fermentation and
- Distillation.

Pre treatment is designed to help separate cellulose, hemicellulose and lignin so that the complex carbohydrate molecules constituting the cellulose and hemicellulose can be broken down by enzyme catalyzed hydrolysis into their constituent simple sugars. Cellulose is a crystalline lattice of long chains of glucose (6-carbon) sugar molecules. Its crystalline makes it difficult to unbundle into simple sugars, but once unbundled, the sugar molecules are easily fermented to ethanol using well-known micro-organisms, and some micro-organisms for fermentation to butanol are also known[8-10]. Hemicellulose consists of polymers of 5-carbon sugars and is relatively easily broken down into its constituent sugars such as xylose and pentose. However, fermentation of 5-carbon sugars is more challenging than that of 6-carbon sugars. Some relatively recently developed micro-organisms are able to ferment 5-carbon sugars to ethanol. Lignin consists of phenols, which for practical purposes are not fermentable. However, lignin can be recovered and utilized as a fuel to provide process heat and electricity at an alcohol production facility (Jeffries, 2006).

## Bio-Refineries and Hydrogen

Bio-refineries can theoretically produce a variety of products such as biopolymers, liquid bio-fuels, biogas, electricity or hydrogen. Using proper feedstock and exploiting production synergies, bio-refineries could gain economic appeal. The pulp and paper industry as well as the food industry have processing plants already produce several products for different markets but energy carriers are not usually one of them. Hydrogen can be obtained from biomass in a number of ways, the most direct being reforming of bio-methane and bio-ethanol. Processes are well known but their efficiency and cost need to be improved.

The reduction in the widespread use of biomass for power generation may be due to increased cost of production, low conversion efficiency and feedstock availability. Most important are the lack of internalization of external costs in power generation and effective policies to improve energy security and reduce Carbon dioxide emissions. In the long term, bio-power potential will depend on technology advances and on competition for feedstock use, and with food and fibre production for arable land use. Competition may not be an issue until 2020 if industrial-scale production and international standards facilitate biomass international trade. While long-distance transportation reduces economic and environmental attractiveness of biomass, conversion into "bio-oil" (e.g., by pyrolysis) could facilitate international trade. Risks associated with widespread use of biomass relate to intensive farming, fertilizers and chemicals use and biodiversity conservation. Certifications that biomass feedstock is produced in a sustainable way are needed to improve acceptance of public forest and lands management. Nutrients should be returned to forests and land through ash from biomass combustion to alleviate nutrients loss and need for fertilizers. While over-exploitation of biomass resources in developing countries should be avoided, biomass can be important for using marginal land and bringing socio-economic benefits in these regions.

## Applications of bioenergy

### Bioenergy as Cooking Fuel

Economic development notwithstanding, traditional solid biofuel (such as firewood/chips, agricultural waste, and dried animal manure/dung cake) is still widely used for meeting cooking and space conditioning needs. Solid biofuel has traditionally been used in rural areas as cooking fuel, particularly by the poor. LPG and kerosene are currently being projected as alternatives to solid unprocessed biomass due to improved thermal efficiency of 60% in comparison to 15% of biomass-based devices. The number of households using kerosene as primary cooking fuel is decreasing steadily in both urban and rural areas in the reference period (Coelho, 2006).

### Bioenergy as Biogas

Biogas is produced when organic materials, such as cattle dung, are digested in the absence of air. It is an excellent energy source for individuals/institutions with cattle ownership. Biogas can be used in a specially designed burner for clean cooking without indoor air pollution. A biogas plant of 2 $m^3$ capacity is sufficient for providing cooking fuel to a family of five persons (standard family size in India as per Census of India, 2001). It can also power gas lamps. For example, a gas lamp with equivalent power of 60W needs 0.13 $m^3$ of gas every hour (MNRE, 2010).

## Conclusion

First-generation biofuels have some attractions, but more limitations such as

- Direct competition with food production
- The use of feedstocks optimized for food production, rather than for energy production
- Utilization of only a portion of the total biomass produced by a plant, so that land-use efficiency is low from energy supply and/or greenhouse gas mitigation perspectives
- Relatively high production costs in most cases due to the competition for feed stocks with food.

Second generation biochemical biofuels are preferred as they are biochemically produced because the starting fuel used is lingocellulose which involves a different process of production enabling the use of biofuels at lower-cost, using non-edible feed stocks.

It is important to examine inter-linkage and balance between key social, economic and ecological sustainability concerns related to small and large applications of modern Biomass Energy Technologies (BETs) in the context of rising concerns regarding sustainable development in the energy sector[20]. Ethanol has enjoyed some success as a renewable fuel, primarily as a gasoline volume extender and also as an oxygenate for high-oxygen fuels, an oxygenate in RFG in some markets, and potentially as a fuel in flexible-fuel vehicles. A large part of its success has been the Federal ethanol subsidy. With the subsidy expiry in 2008, however, it is not clear whether ethanol will continue to receive political support. Thus, the future of ethanol may depend on whether it can compete with crude oil on its own merits. Significant barriers to the success of cellulose-derived ethanol remains a challenge, if harnessed properly, appears to be a novel route to face the challenge of increased demand for biofuels.

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