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A REVIEW ON PRODUCTION OF ETHANOL FROM SUGARCANE MOLASSES & ITS USAGE AS FUEL

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ABSTRACT

In the year 2008, the Government of India announced its National Policy on biofuels, mandating a phase-wise implementation of the programme of ethanol blending with petrol in various states. This examines demand and supply aspects of the ethanol blending policy (EBP) of the Government of India. In the last two years, the demand from the industrial sector could not be fully met domestically and was met by imports. The study examines the main sectors using ethanol. The preparedness of the automobile industry is a major factor in the successful implementation of this policy.

In 2008 India imported 128.15 million metric tons of crude, constituting 75% of its total petroleum consumption for that year. By 2025 it will be importing 90% of its petroleum. In an effort to increase its energy security and independence, the Government of India in October of 2007 set a 20% ethanol blend target for gasoline fuel to be met by 2017. In India, the vast majority of ethanol is produced from sugarcane molasses, a by-product of sugar. In the future it may also be produced directly from sugarcane juice. The main objective of this study is to develop an economic framework to determine the implications of the 2017 blend mandate for India's food and energy security and allocation of land and water between food and fuel production. This is accomplished through the development of a static, spatial, multi-market economic model. The model is a partial equilibrium model which includes eight markets for agricultural commodities: wheat, rice, sorghum, corn, groundnut, rapeseed, cotton, and soybean in addition to the markets for sugar, alcohol and fuel (gasoline and biofuel).

Keywords: ethanol, sugarcane molasses, fuel.

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1. INTRODUCTION

A. What is Ethanol?

Ethanol is an alternative energy source. It is an alcohol made by fermenting corn or other similar biomass material. There are three primary ways that ethanol can be used as a transportation fuel:

1. As a blend of 10 percent ethanol with90 percent unleaded gasoline called“E-10 Unleaded”;
2. As a component of reformulated gasoline, both directly and/or as ethyl tertiary butyl ether (ETBE); or
3. As a primary fuel with 85 parts of ethanol blended with 15 parts of unleaded gasoline called “E-85.”

When mixed with unleaded gasoline, ethanol increases octane levels, decreases exhaust emissions, and extends the Supply of gasoline. Ethanol in its liquid form, called ethyl alcohol, can be used as a fuel when blended with gasoline or in its original state. It can also be used as a raw material in various industrial processes.

Ethanol is made by fermenting almost any material that contains starch or sugar. Grains such as corn and sorghum are good sources; but potatoes, sugar cane, Jerusalem artichokes, and other farm plants and plant wastes are also suitable. About 2 billion gallons of ethanol are produced annually in the United States. Each bushel of corn processed yields 2.5 to 2.7 gallons of ethanol along with several valuable co-products. The first ethanol-blended gasoline in the 1970s was 10 percent ethanol by volume (E-10), while a blend of 85 percent by volume (E-85) was introduced in the mid 1990s.

B. Clean Air Benefits:

Ethanol, when used as a gasoline component, improves combustion–helping the fuel burn more completely. Ethanol blends also reduce carbon monoxide emissions. Use of ethanol is beneficial in areas of the U.S. that are considered to exceed Environmental Protection Agency air quality standards during the winter months. Some studies have indicated that, when used in a correctly formulated fuel, ethanol can also reduce vehicle emissions which contribute to the formation of smog.

C. The Advantages of Ethanol:

More recently, the country has focused attention on other advantages of ethanol. One of these advantages is ethanol’s ability to provide octane while replacing other environmentally harmful components in gasoline. Other studies suggest that using ethanol can slow global warming. And because ethanol is produced here in the United States, it reduces imports by replacing imported gasoline and crude oil. Reducing gasoline and crude oil imports reduces American dependence on foreign oil. According to a recent poll conducted by Research Strategy Management, 75 percent of American voters believe the country needs to do something to reduce its dependence on foreign oil.

Today, ethanol is widely used and available in most areas of the United States. Ethanol is contained in over 15 percent of all gasoline sold in the United States.

The increase in consumption of fossil fuels as economies grow and the nearing depletion of such fuels has prompted a search for their alternatives worldwide. Biofuels have emerged as a substitute for fuel oil, especially for oil-importing countries and serve a multitude of purposes. The most important advantage of these fuels is that they are renewable, and are being seen as sustainable sources of energy. Some studies have also pointed out that biofuels help reduce environmental emissions,1 apart from addressing the problem of the rising import cost of fuel oil.

Among liquid fuels, there are mainly two types of biofuel: alcohols (ethanol and butanol) and diesel substitutes (such as biodiesel and hydro-treated vegetable oils). They can be used either individually as fuels or for blending in petrol or diesel. While biodiesel is mainly manufactured by transesterification of vegetable oil, ethanol is produced from starch contained in crops such as corn and sorghum or through fermentation of sugarcane, molasses, and sugar-beet. In India, ethanol production is mainly done using sugarcane as feedstock.

Transport has been identified as a major polluting sector and hence the use of biofuels is important in view of the tightening of emission norms. It is argued that blending ethanol with petrol2,3 and diesel will reduce import dependence on crude oil, saving on foreign exchange outflows to that extent. However, energy security can be addressed only if the supply of ethanol available to industry is adequate

Governments around the globe have become increasingly interested in alternative fuel sources due to growing concerns over energy security brought on by diminishing fossil fuel reserves, instability in the Middle East and the recent volatility of crude oil prices. One particularly pressing cause for concern is the widening gap between demand and supply of fossil fuel based energy resources. Energy use is expected to dramatically increase in the near future. Biofuels potentially represent a more environmentally friendly alternative to fossil fuels as they produce fewer greenhouse gas emissions when burned.

The expansion of biofuel production may also have negative social and environmental impacts. One obvious potential problem that growing greater quantities of fuel crops for biofuel feedstock may create is competition with food crops for land, water and other agricultural inputs. This could prove particularly problematic for the poor because of shortages of food and rising food prices which may result.

The environmental benefits of biofuels through reduced greenhouse gas emissions are also subject to debate. Although biofuels do release fewer emissions than their fossil fuel equivalents when burned, over their entire lifecycle biofuels may or may not result in fewer GHG emissions than their fossil fuel counterparts depending on the type of land used for growing the feedstock and the agricultural practices used in the feedstock cultivation and indirect land use changes due to increases in food prices

Biofuels have become particularly appealing to developing countries because of their potential to stimulate economic development in rural areas and alleviate poverty through the creation of employment opportunities and increased income in the agricultural sector. Biofuel production tends to be labour intensive and thus a good generator of rural employment. In addition, the production of biofuels requires investment in roads and other forms of rural and transport infrastructure which will have a “crowd in” effect by encouraging other investments. India has implemented a 5% ethanol blend mandate for gasoline fuel, scheduled to be increased to 20% by 2017. By expanding sugarcane ethanol production, the Government of India hopes to increase domestic food and energy security, accelerate rural development and reduce carbon emissions

India’s interest in improving its energy security stems from its rapidly growing dependence on foreign oil. India’s economy is growing at a rate of 7% per year, making it the second fastest growing economy in the world. The country is projected to become the third largest consumer of transportation fuel in 2020, after the USA and China (Kiuru, 2002). India’s increasing dependence on foreign energy sources will make the country increasingly vulnerable to external price shocks and supply distortions.

Another reason for India to take an interest in a domestic biofuels industry is its potential to accelerate rural development. As in most developing countries, the majority of India's labor force works in the agricultural sector, therefore in India there is particularly high potential for biofuels to raise incomes, provide employment, and contribute to rural development. This combined with India's aforementioned concerns over energy security has led the Government of India recently to develop a keen interest in encouraging the expansion of a domestic biofuels industry. The primary feedstock for bio-ethanol in India is sugarcane molasses. Sugarcane requires prime agricultural land, fertilizer and large quantities of irrigation water. Expansion of sugarcane production for biofuels in India will therefore most likely increase competition for agricultural inputs.

The process of producing ethanol through fermentation has been used by cultures around the world since prehistoric times. Saccharomyces cerevisiae yeast is added to a sweet solution such as a fruit juice or as in the case of the Indian alcohol industry, sugarcane molasses. The yeast metabolizes the sugars in the solution into ethanol and carbon dioxide. However, because the ethanol is toxic and the yeast can survive no more than a 10% ethanol concentration, in order to purify the ethanol any further, a distillation method must be used. This produces ethanol having 95% purity

Molasses is a co-product of sugarcane production and is the main source of ethanol in India. The yield of molasses from crushed sugarcane ranges from 4 to 4.5% (Indian Sugar Mills Association 2008). The Indian Government dictates the proportion of molasses that may be used for the production of alcohol versus alternative end products. The current policy allocates 70% of molasses to alcohol production which leaves 30% for animal feed or other uses such as fuel ethanol (Raju et al 2009). This policy, were it to remain in place in the future would not leave much feedstock available for fuel ethanol production.

2. EXECUTIVE SUMMARY

India is one of the fastest growing economies of the world, with its gross domestic product (GDP) growing at an average annual rate of over seven per cent since 2004. Energy inputs are a critical component of national economic activity. However, since it is believed that the conventional sources of energy will be exhausted in few decades; biofuels are being increasingly seen as potential alternatives to the liquid fossil fuels. In this context, ethanol is being seen as a promising renewable fuel for transportation purposes for the near future.

In the year 2008, the Government of India announced its National Policy on biofuels, mandating a phase-wise implementation of the programme of ethanol blending with petrol in various states. This study examines demand and supply aspects of the ethanol blending policy (EBP) of the Government of India.

In India, ethanol production is mainly done using sugarcane as feedstock. For successful implementation of the EBP in the country, a steady supply of sugarcane (or sugarcane juice) as feedstock is required. However, sugarcane production in a bumper crop year just about meets the requirement of all the sectors. In other years, there is a shortfall due to which the EBP has not been successfully implemented till now. In the past few years, there was a large unmet demand for ethanol from the industrial sector that was met by imports.

The existing vehicular fleet in the country is compatible with the 5 per cent ethanol-blended petrol. Sufficient lead time would have to be given to the automobile industry to make appropriate engine and other modifications to make vehicles compatible with higher levels of blended fuel.

3. NEW VEHICLE TECHNOLOGY

The 1990s saw the introduction and operation of variable fuel vehicles. These vehicles are capable of operating on unleaded fuel with ethanol mixtures up to 85 percent without having to make any engine adjustments. These vehicles were introduced in 1992 and have been used extensively in federal and state fleets and in some city governments. They became commercially available shortly thereafter.

E-85 vehicles have been designed for versatility. The key component in a variable fuel vehicle is a sensor that determines the percentage of ethanol in the fuel. With the help of a computer, the vehicle automatically adjusts for best performance and emissions. Chrysler began offering E-85 minivans in the 1998 model year and Ford continues to offer the Taurus and added Windstar and Ranger to the E-85 flexible fuel vehicles in the 1999 model year. Ford, GMC, Chevrolet and Daimler-Chrysler are now offering E-85 variable fuel vehicles.

A. Why Ethanol Now?

Ethanol use and production has increased considerably during the 1980s and 1990s. Growth in use of “E-10 Unleaded” gasoline has taken place because the fuel performs well in automotive engines and is competitively priced with “conventional” gasoline. Other reasons for increased production and use of ethanol, especially in the Midwest include:

1) Ethanol reduces the country’s dependence on imported oil, lowering the trade deficit and ensuring a dependable source of fuel should foreign supplies be interrupted.
2) Farmers see an increased demand for grain which helps to stabilize prices.
3) The quality of the environment improves. Carbon monoxide emissions are reduced, and lead and other carcinogens (cancer causing agents) are removed from gasoline.
4) Car owners benefit from increased octane in gasoline, which reduces engine “knock” or “pinging.” Ethanol-blended fuels also absorb moisture and clean the fuel system.

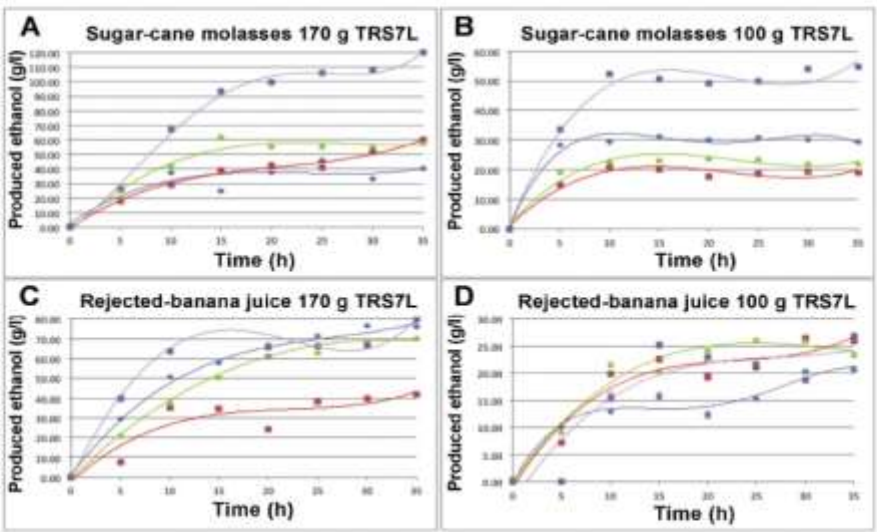
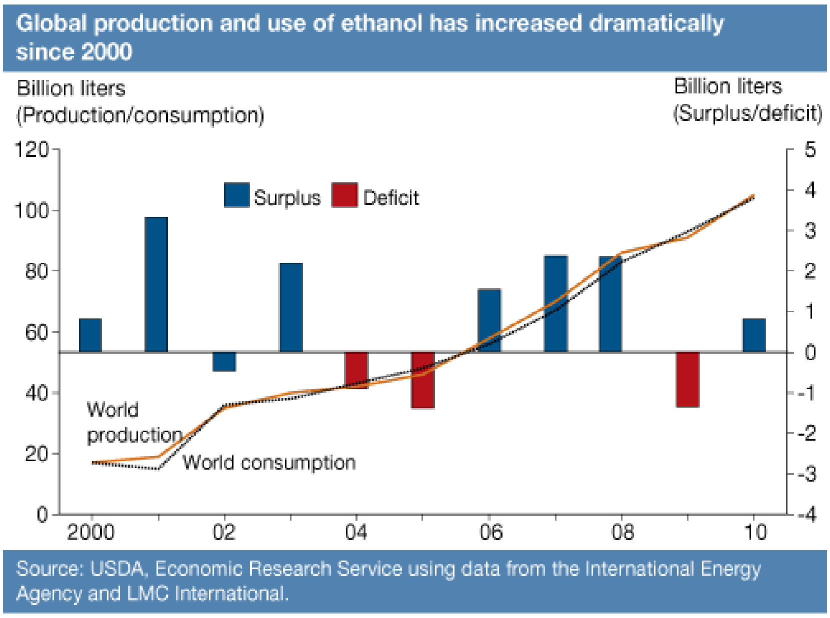


Figure 3. Kinetics of ethanol production by *S. cerevisiae* strains: **CBS8066** (♦), **recombinant GG570-CIBI** (•), **recombinant GG570-CIBII** (▲) and **Ethanol Red®** (X) under anaerobic conditions and in sugar-cane molasses with *170* **(A)** or *100 g/l TRS* **(B)** or rejected-banana juice with *170* **(C)** or *100 g/l TRS* **(D)**

B. Ethanol around the World:

Other countries are both producing and using ethanol in large quantities or are providing incentives to expand ethanol production and use. Brazil and Sweden are using large quantities of ethanol as a fuel. Some Canadian provinces promote ethanol use as a fuel by offering subsidies of up to 45 cents per gallon of ethanol.

India is initiating the use of ethanol as an automotive fuel. A move has been made by distilleries in India to use surplus alcohol as a blending agent or an oxygenate in gasoline. Based on experiments by the Indian Institute of Petroleum, a 10 percent ethanol blend with gasoline and a 15 percent ethanol blend with diesel are being considered for use in vehicles in at least one state. In France, ethanol is produced from grapes that are of insufficient quality for wine production. Prompted by the increase in oil prices in the 1970s. Brazil consumes nearly 4 billion gallons of ethanol annually. In addition to consumption, Brazil also exports ethanol to other countries.

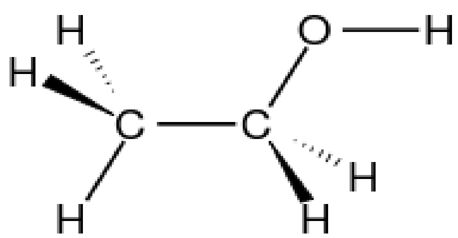


Sweden has used ethanol in chemical production for many years. As a result, Sweden's crude oil consumption has been cut in half since 1980. During the same time period, the use of gasoline and diesel for transportation has also increased.

Emissions have been reduced by placing catalytic converters in vehicle exhaust systems which decrease carbon monoxide, hydrocarbon, and nitrogen oxide emissions. To address global warming concerns, the amount of carbon dioxide produced while burning fossil fuels must be reduced. Ethanol-blended gasoline and ethanol-blended diesel are being considered as viable alternatives to further lower emission levels.

4. CHEMISTRY

Ethanol is a colorless, volatile, flammable liquid that is the intoxicating agent in liquors and is also used as a fuel or solvent. Ethanol is also called *ethyl alcohol* or *grain alcohol*. Ethanol is the most important member of a large group of organic compounds that are called alcohols. Alcohol is an organic compound that has one or more hydroxyl (OH) groups attached to a carbon atom. Alcohol is shown as: C-O-H or C-OH.



What is attached to the carbon at the three remaining bonds or locations determines the particular kind of alcohol. Ethanol has hydrogen present at two sites while the remaining site holds another carbon atom. This carbon atom, in turn, holds three more hydrogen atoms. In its pure form, ethanol is a colourless clear liquid with a mild characteristic odor which boils at 78º C (172º F) and freezes at -112º C (-170º F). Ethanol has no basic or acidic properties. When burned, ethanol produces a pale blue flame with no residue and considerable energy, making it an ideal fuel. Ethanol mixes readily with water and with most organic solvents. It is also useful as a solvent and as an ingredient when making many other substances including perfumes, paints, lacquers, and explosives.

How is Ethanol Made?

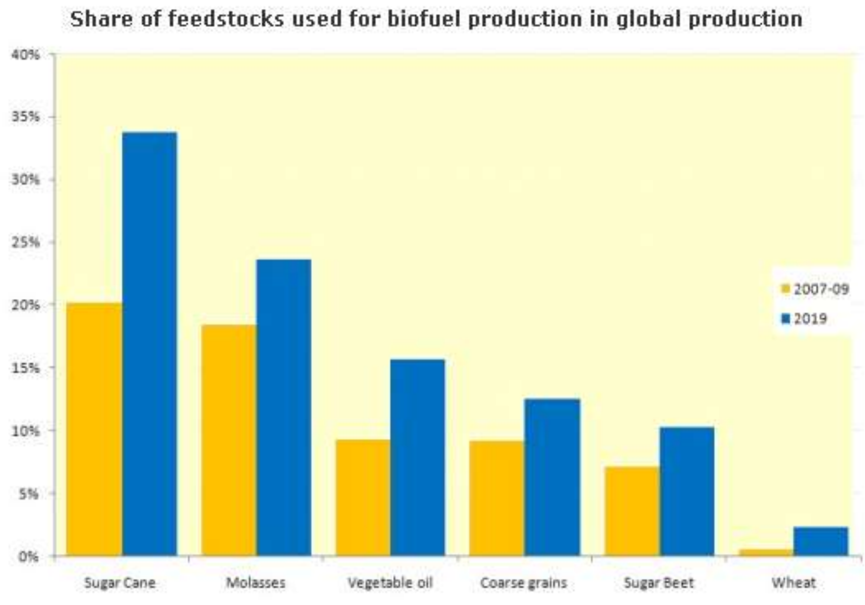
Ethanol is a product of fermentation. Fermentation is a sequence of reactions which release energy from organic molecules in the absence of oxygen. In this application of fermentation, energy is obtained when sugar is changed to ethanol and carbon dioxide.

Changing corn to ethanol by fermentation takes many steps. Starch in corn must be broken down into simple sugars before fermentation can occur. In earlier times, this was done by chewing the corn. This allowed the salivary enzymes to naturally break down the starch. Today, this is achieved by cooking the corn and adding the enzymes alpha amylase and gluco amylase. These enzymes function as catalysts to speed up the chemical changes.

Once a simple sugar is obtained, yeast is added. Yeast is a single-celled fungus that feeds on the sugar and causes the fermentation. As the fungus feeds on the sugar, it produces alcohol (ethanol) and carbon dioxide. In fermentation, the ethanol retains much of the energy that was originally in the sugar, which explains why ethanol is an excellent fuel.

5. COMMERCIAL PRODUCTION

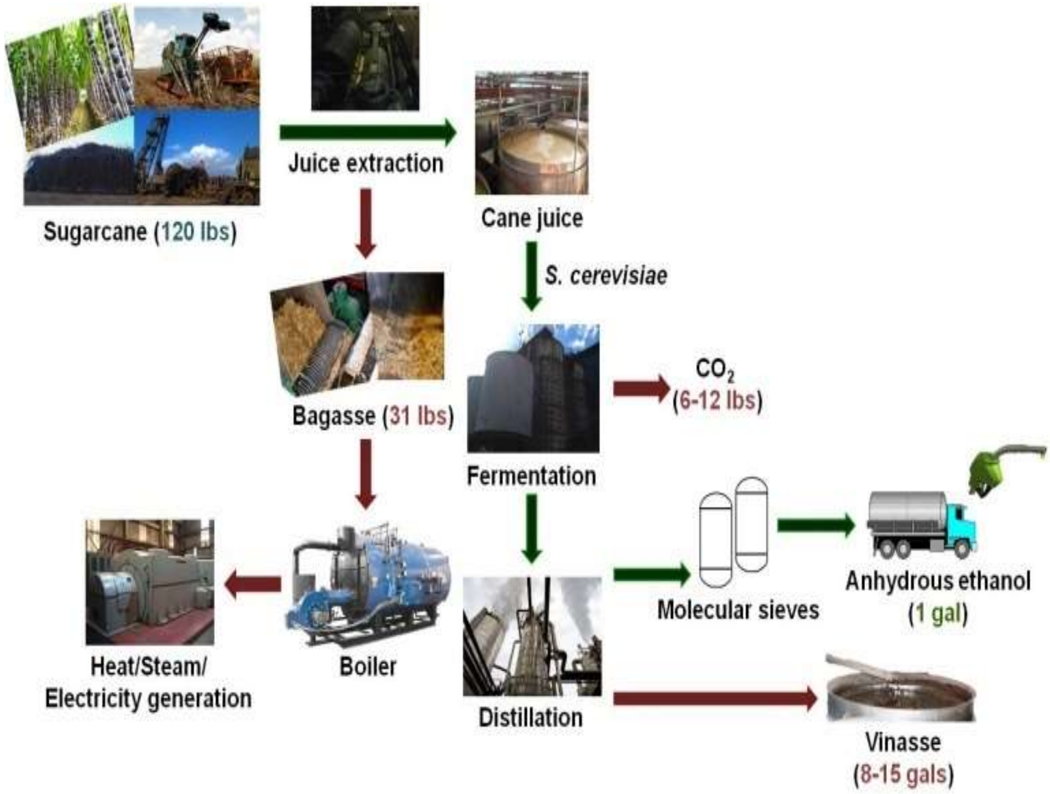
Most of the ethanol production in the United States is made in 60 production facilities in 20 different states. Most of these plants are located in the Midwest due to the ready availability of corn. Changing the starch in kernels of corn to sugar and changing sugar to ethanol is a complex process requiring a mix of technologies that include microbiology, chemistry and engineering. Ethanol is produced from corn by using one of two standard processes: wet milling or dry milling. Dry milling plants cost less to build and produce higher yields of ethanol (2.7 gallons per bushel of corn), but the value of the co-products is less.

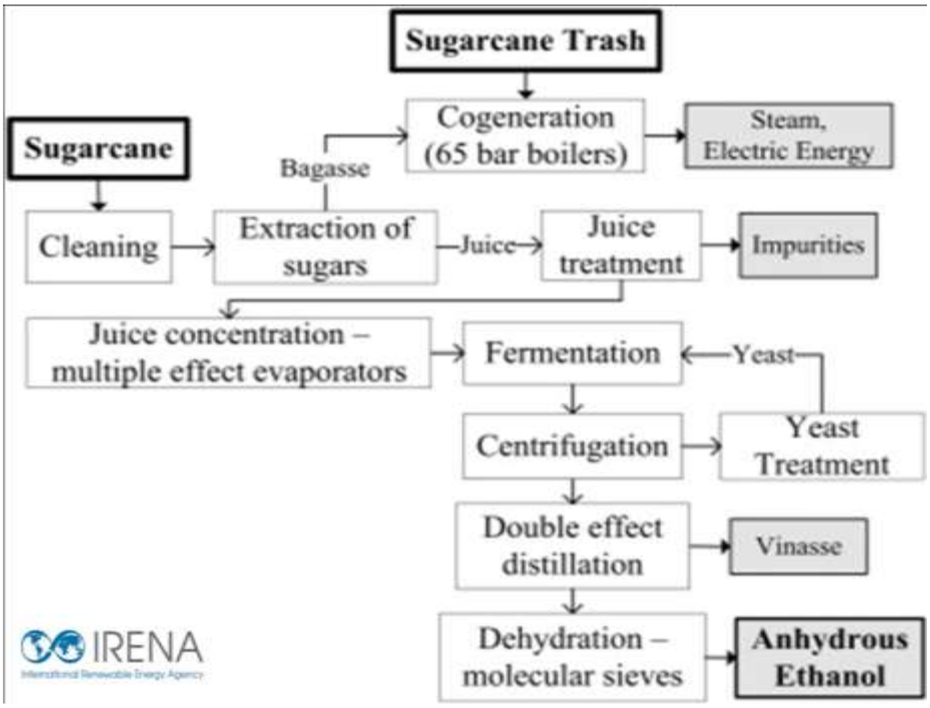


A. DRY MILLING

Most of the ethanol plants in the country utilize a dry milling process. The major steps of dry milling are outlined below:

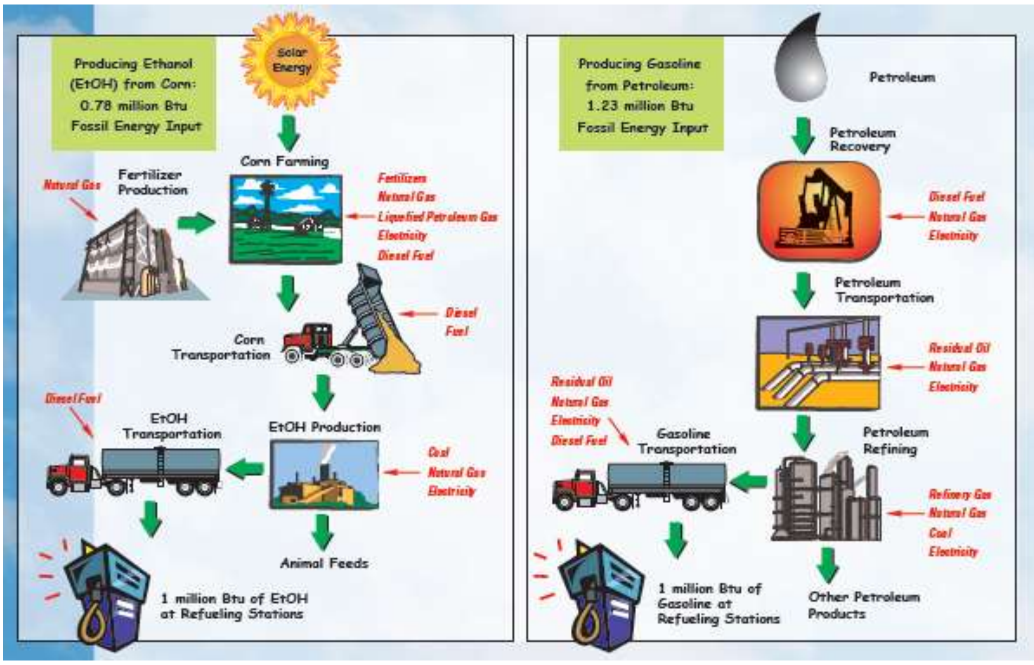
1. **Milling:** After the corn (or other grain or biomass) is cleaned, it passes first through hammer mills which grind it into a fine powder.
2. **Liquefaction:** The meal is then mixed with water and an enzyme (alpha amylase), and passes through cookers where the starch is liquefied. A pH of 7 is maintained by adding sulfuric acid or sodium hydroxide. Heat is applied to enable liquefaction. Cookers with a high temperature stage (120º-150º C) and a lower temperature holding period (95º C) are used. The high temperatures reduce bacteria levels in the mash.
3. **Saccharification:** The mash from the cookers is cooled and the enzyme gluco amylase is added to convert starch molecules to fermentable sugars (dextrose).
4. **Fermentation:** Yeast is added to the mash to ferment the sugars to ethanol and carbon dioxide. Using a continuous process, the fermenting mash flows through several fermenters until the mash is fully fermented and leaves the tank. In a batch fermentation process, the mash stays in one fermenter for about 48 hours.
5. **Distillation:** The fermented mash, now called "beer," contains about 10 percent alcohol, as well as all the non-fermentable solids from the corn and the yeast cells. The mash is then pumped to the continuous flow, multi-column distillation system where the alcohol is removed from the solids and water. The alcohol leaves the top of the final column at about 96 percent strength, and the residue mash, called *stillage*, is transferred from the base of the column to the co-product processing area.
6. **Dehydration:** The alcohol then passes through a dehydration system where the remaining water is removed. Most plants use a molecular sieve to capture the last bit of water in the ethanol. The alcohol at this stage is called *anhydrous* (pure, without water) ethanol and is approximately 200 proof.
7. **Denaturing:** Ethanol that is used for fuel is then denatured with a small amount (2-5%) of some product, like gasoline, to make it unfit for human consumption.





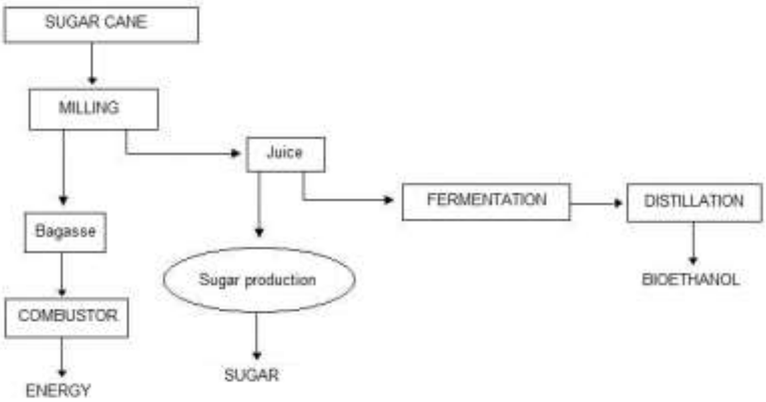
B. WET MILLING

The wet-milling operation is more elaborate because the grain must be separated into its components. After milling, the corn is heated in a solution of water and sulfur dioxide for 24 to 48 hours to loosen the germ and the hull fiber. The germ is then removed from the kernel, and corn oil is extracted from the germ. The remaining germ meal is added to the hulls and fiber to form corn gluten feed. A high-protein portion of the kernel called gluten is separated and becomes corn gluten meal which is used for animal feed. In wet milling, only the starch is fermented, unlike dry milling, when the entire mash is fermented.



What is Fuel Ethanol?

Ethanol is a high octane, water-free alcohol produced from the fermentation of sugar or converted starch. It is used as a blending ingredient in gasoline or as a raw material to produce high-octane fuel-ether additives. Ethanol is made from grains (mainly corn) or other renewable agricultural or forestry products such as wood, brewery waste, potatoes, cheese whey, paper waste, beets, or vegetable waste.



6. ENGINE PERFORMANCE & ETHANOL

Auto manufacturers today are recommending ethanol-blended gasoline for the vehicles they sell. A recent survey revealed that nine out of ten auto dealers use ethanol-blended gasoline in their personal vehicles. Over half of the dealerships surveyed indicated their customers reported benefits that included: reduced knocking and pinging, improved gas mileage, better acceleration, and improved starting qualities.

Independent automotive technicians also trust their family cars to ethanol blends. A 1997 Iowa survey indicated that nine out of ten technicians used ethanol in their personal vehicles and reported the same benefits as the auto dealers. E-10 Unleaded (10% ethanol / 90% gasoline) is approved under the warranties of all domestic and foreign automobile manufacturers marketing vehicles in the United States. In fact, the nation's top three automakers, Daimler-Chrysler, Ford and General Motors, recommend the use of oxygenated fuels such as ethanol blends because of their clean air benefits and performance qualities.

Ethanol is a good cleaning agent. In newer vehicles it helps keep the engine clean. In older vehicles it can sometimes loosen contaminants and residues that have already been deposited in a vehicle's fuel delivery system. Occasionally, these loosened materials collect in the fuel filter, and can then be removed simply by changing the fuel filter. All alcohols have the ability to absorb water. Condensation of water in the fuel system is absorbed and does not have the opportunity to collect and freeze. Since ethanol blends contain at least 10 percent ethanol, they are able to absorb water and eliminate the need for adding a gas-line antifreeze in winter.

Ethanol is a fuel for old and new engine technology. Automotive engines older than 1969 with non-hardened valve seats may need a lead substitute added to gasoline or ethanol blends to prevent premature valve seat wear. Valve burning is decreased when ethanol blends are used because ethanol burns cooler than ordinary unleaded gasoline. Many high performance racing engines use pure alcohol for that reason.

Modern computerized vehicles of today, when operating correctly, will perform better than non-computer equipped vehicles. Improved performance is due to the vehicle's computerized fuel system being able to make adjustments with changes in operating conditions or fuel type. Some of the chemicals used to manufacture gasoline, such as olefins, have been identified as a cause of deposits on port fuel injectors. Today's gasolines contain detergent additives that are designed to prevent fuel injector and valve deposits.

Car owners should review their vehicle owner's manual. This will help to answer many questions. The owner/driver should note the octane requirement or Antiknock Index (AKI) number of gasoline required for proper engine performance for the vehicle. Then note the octane number on the sticker on the gas pump to make sure it is not less than the required number. Using a higher octane number will not realize better economy unless engine knock or ping already exists.

The performance of ethanol-blended gasoline has been proven by years of use. The Nebraska State Highway Patrol has been using ethanol-blended gasoline more than 20 years. In several states, state vehicles have been successfully using ethanol-blended gasoline since 1979. Three-time IHRA world champion funny car driver Mark Thomas also used ethanol to fuel his winning Dodge Avenger.

FUEL QUALITY

The quality of fuel used in any motor vehicle engine is very important to its long life and proper operation. If the fuel is not right for the air temperature or if fuel changes to a vapour incorrectly, driveability will suffer. Gasoline is a complex mixture of approximately 300 various ingredients, mainly hydrocarbons, refined from crude petroleum oil for use as fuel in engines. Refiners must meet gasoline standards set by the American Society for Testing and Materials (ASTM), the Environmental Protection Agency (EPA), state regulatory agencies and their own company standards.

7. ANTIKNOCK INDEX (AKI) AND OCTANE RATINGS

Gasolines are most commonly rated based on their Antiknock Index (AKI), a measure of octane quality. The AKI is a measure of a fuel's ability to resist engine knock (ping). The AKI of a motor fuel is the average of the research octane number and the motor octane number: (R+M)/2. This is also the number displayed on the octane decal posted on a gasoline pump. In general, a low research octane could cause a low to medium speed knock and run-on (or dieseling) after the engine is shut off. A low motor octane could cause engine knock when power is needed during acceleration, such as passing or climbing hills.

A typical average octane number of 87 would contain a research octane of 92 and a motor octane of 82. However, it could also be the average of 94 and 80, depending on the availability of blending products on hand at the refinery. These different blends can affect engines differently, depending on the octane requirement of that particular engine, and explains why engines can perform differently with a change of fuel.

Factors affecting the octane number requirement include:

- Compression ratio
- Barometric pressure/altitude
- Ignition timing
- Temperature
- Air/fuel ratio
- Humidity
- Combustion temperature (intake manifold heat, inlet air temperature, coolant temperature)
- Exhaust gas re-circulation rate
- Combustion chamber deposits
- Combustion chamber design Using a higher octane or AKI fuel will not increase gas mileage unless the engine is knocking or pinging with the lower octane fuel.

8. DEMAND FOR AND SUPPLY OF ETHANOL IN INDIA:

There are three main uses of ethanol in India. Of the total available ethanol, the maximum – about 45 per cent – is used to produce potable liquor, about 40 per cent is used in the alcohol-based chemical industry (as a solvent in synthesis of other organic chemicals) and the rest is used for blending with petrol and other purposes.

The demand for ethanol has been continually increasing on account of the growth of user industries and use of ethanol as a fuel in the country. However, the production and availability of ethanol has largely lagged behind. India is the fourth largest producer of ethanol in the world after Brazil, the United States of America (USA) and China, producing approximately 2000 million litres of ethanol, mainly by fermentation of sugarcane molasses. Ethanol is made by fermentation of sugars: enzymes from yeast change simple sugars into ethanol and carbon dioxide. Potable ethanol and more than half of industrial ethanol is made by this process

However, the amount of ethanol currently produced in India is not sufficient to meet domestic demand. In the year 2008-09, there was a huge unmet demand from the industrial sector, which was met by imports.

A. DEMAND FOR ETHANOL

Data on ethanol production and consumption in India is published by many sources. Among these are the Indian Sugar Mills Association (ISMA), the U.S. Department of Agriculture (USDA), and the Indian Chemical Council (ICC). The estimates from these various sources vary considerably. One reason is that the year in question varies, e.g. the sugar year used by ISMA is from October to September, and the alcohol year used by ICC is from December to November.

Estimates provided by USDA are for calendar year and those provided by the Planning Commission are for financial year April to March. Monthly data is not available to make comparisons across different sources.

Table 1 shows ethanol production and consumption figures from various sources. From this table we note that while the ICC data shows the widest deficit of ethanol, the least deficit is shown by data from ISMA. The data reported by the USDA show variability that is similar to the ISMA data: both report a surplus in 2006, 2007, and 2008, while showing a deficit in 2004 and 2005. Data estimates by the ICC present a slightly different picture.

According to these, there has been a deficit of ethanol not only in 2003–04 but in all subsequent years (not shown by ISMA or USDA). In the final analysis however, we note that there is a huge deficit in the domestic supply of ethanol reported by each of the sources, though the amount of this deficit varies. It is noteworthy that ethanol production is beset with a cyclical pattern shown by sugarcane production, with three–four years of bumper harvests followed by relatively poor crops over a similar period.

Table 1 Ethanol production and consumption in India (million litres)

Ethanol Production	**2013**	**2014**	**2015**	**2016**	**2017**
ISMA (in sugar year)	1240	1925	2950	2715	1560
ICC (in alcohol year)	980	1590	2100	2200	1300
USDA FAS	1199	1300	1,898	2,398	2,150
Ethanol Consumption					
ISMA (in sugar year)	1410	1550	1700	1840	2010
ICC (in alcohol year)	1470	1740	2120	2280	1650
USDA FAS	1430	1479	1639	1750	1940
Surplus Ethanol					
ISMA (in sugar year)	(–170)	(375)	(1250)	(875)	(–450)
ICC (in alcohol year)	(–490)	(–150)	(–20)	(–80)	(–350)
USDA FAS	–231	–179	259	648	210
Imports					
ICC (in alcohol year)	490	150	20	80	350
USDA FAS	–	–	29	15	70

In the year 2003, the Report of the Committee on Development of Biofuels was published by the Planning Commission of India. It gave projections of demand and supply of ethanol for India for the end of each five-year plan. This report shows the break-up of production and consumption of ethanol in terms of molasses and cane. Data from different sources shows that as of 2010, the actual production of ethanol in India has not kept pace with the demand.

B. ETHANOL IN INDIA'S AUTOMOBILE SECTOR

The Government of India"s policy mandating 5 per cent ethanol blending in petrol is currently being implemented in the country. An indicative target of minimum 20 per cent ethanol-blended petrol across the country has been set for the year 2017. The preparedness of the automobile industry is a major factor in the successful implementation of this policy, given the fact that petrol-run vehicles account for the majority of vehicles registered in India.

The Planning Commission (2003) gives an account of the advantages of ethanol blending in conventional petrol vis-à-vis other substitutes such as methanol. Ethanol"s vapour pressure is lower than that of petrol, resulting in lower evaporative emissions while its flammability is also much lower than that of petrol, reducing the risk of vehicles catching fire. In addition, there is no gum formation associated with ethanol, and anti-oxidants and detergent additives are not required.

Other advantages of ethanol are that it improves the octane number, has a higher volumetric efficiency leading to increased power and has advantages of wider flammability limits and higher flame velocity (Planning Commission, 2003). Although the calorific value of ethanol is lower than that of petrol, it is still preferred because of its higher efficiency due to its higher oxygen content. This is also the reason for its use as a 100 per cent fuel in Brazil.

Test results of conventional vehicles for ethanol compatibility reveal that the existing vehicular fleet in India is mostly compatible with 5 per cent ethanol-blended petrol with almost no serious environmental implications. A blending of less than 10 per cent has a few disadvantages, which are not serious, and there is no need to modify the engine. Blends above 15 per cent ethanol, however, require engine modifications.

Internationally it has been shown that low ethanol-petrol blends (5–10 per cent ethanol) can fuel petrol vehicles with little if any engine modification during production (IEA, 2007). This has also been proved in Brazil and the US during the past two decades. Today, auto manufacturers in Brazil produce vehicles that are specially modified to run on a higher percentage of ethanol.

The main mechanical differences between ethanol and petrol vehicles lie in engine calibration and the fuel management system. The success in using ethanol as a fuel in Brazil, the US and the EU offers a large experience that can be usefully tapped by countries such as India to develop their own infrastructure for EBP.

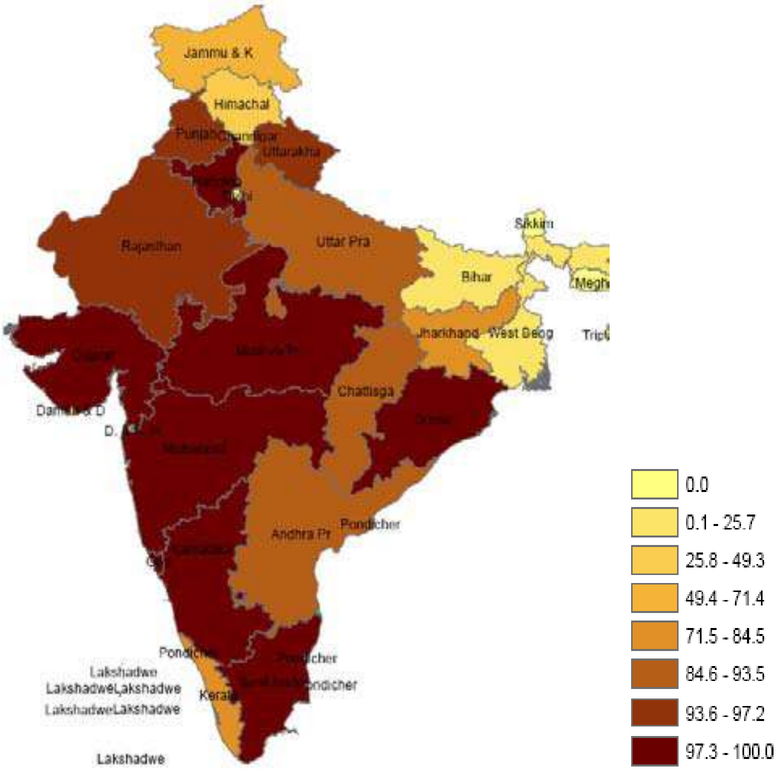
A vehicular fleet with Flex Fuel Vehicles (FFV) will be essential to run a successful long-term ethanol programme as India plans to mandate 20 per cent of ethanol blending in petrol by 2017. FFV technology as adopted in Brazil is now sufficiently well-developed to allow the gradual introduction of biofuels in any country.

In India, apart from the scarcity of ethanol at an affordable price, multiple taxes on denatured ethanol that complicate inter-state movement, unclear licensing and procurement rules, non-standardised blending methodology; and non-compatibility of existing handling, storage, dispensing and retail distribution systems with ten percent blended petrol are other areas of concern (SIAM, 2008).

There is a need to establish separate dispensing outlets with labelling at petrol-pumps and in-line (injection) blending instead of splash blending(using control-systems to control water absorption in fuel).

The automobile industry needs sufficient lead time to make appropriate engine and other modifications so that vehicles are compatible with higher levels of blended fuel. Ethanol has lower energy content than petrol, and thus ethanol-blended petrol has a lower calorific value than standard petrol. Consumers would therefore need larger fuel tanks, and other design modifications would have to be made to vehicles if a higher level of blended fuel is used.

Percentage of Sugarcane Area Irrigated



Sugarcane Irrigated Yield (kg/ha)

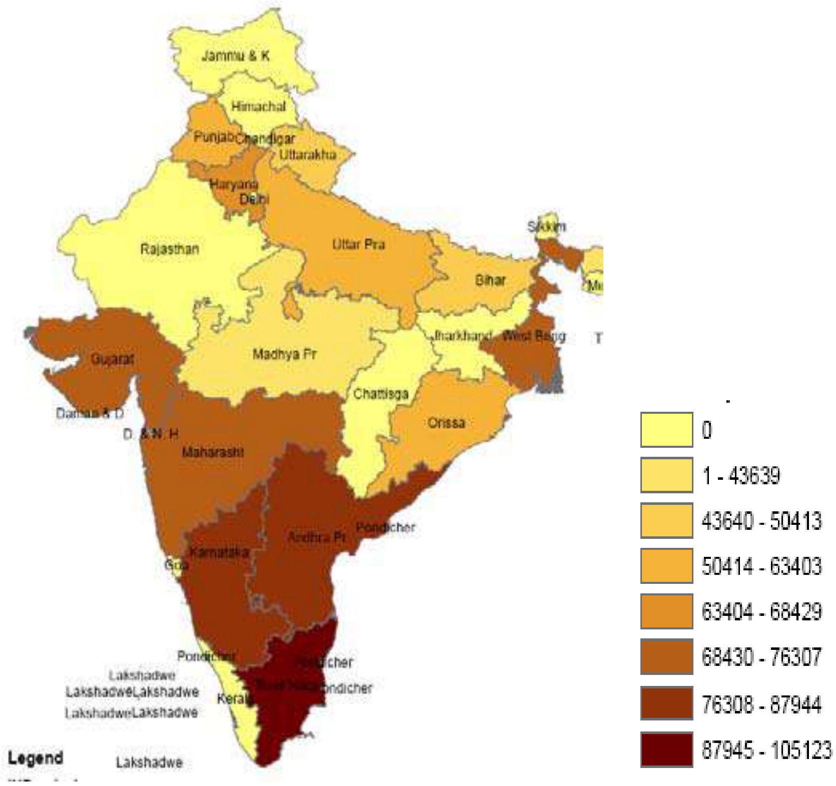


Table 2 Sensitivity to Sugarcane Ethanol Conversion Cost (Percentage Change Relative to Base Scenario)

Sugarcane to Ethanol Conversion Cost		
High Sugarcane Ethanol Cost		
	No Mandate	**20% Mandate**
Land Use		
Rice	0.00	0.33
Wheat	0.00	1.19
Sugarcane	0.00	-4.68
Production		
Rice	0.00	0.15
Wheat	0.00	1.09
Sugarcane	0.00	-4.36
Sugar	0.00	9.23
Alcohol	0.00	-100.00
Prices		
Rice	0.00	-0.13
Wheat	0.00	-1.50
Sugar	0.00	-9.37
Alcohol	0.00	9.60
Ethanol		37.79

9. POLICY RECOMMENDATIONS AND CONCLUSION

The study examines the domestic demand and supply situation of ethanol in context of „Ethanol Blending Programme" in India. The ethanol blending programme was launched in India in 2002. The blending of bio-ethanol at 5 per cent with petrol was made mandatory from October 2008 and was to be taken up by the oil marketing companies in 20 states and four union territories.

The Indian approach to biofuels is based on non-food feedstock to deliberately avoid a possible conflict between food and fuel. However, the implementation of this policy has not had much success. This was mainly due to the shortage of ethanol. For successful implementation of EBP in India, a steady supply of sugarcane (or sugarcane juice) as feedstock at affordable price *vis-à-vis* petrol is required.

The estimated total sugarcane requirement in India by 2011–12 is more than the production of sugarcane in bumper years (approximately 355 and 340 million tonnes during 2006–07 and 2007–08 respectively). Achieving an increase in area under sugarcane cultivation is difficult because it is a highly water-intensive crop and largely irrigated crop in India. But improvements in the productivity and yield of sugarcane and in the recovery of sugar may bear fruit.

In May 2009, the Planning Commission of India advised the government to consider providing incentives to companies to acquire sugarcane plantations abroad, to bring ethanol into the country. Other options include collaboration with Brazil and other prospective international suppliers of ethanol in areas of R&D and cross border investment. These measures along with other steps to augment the domestic availability of ethanol, like the integration of the production and milling of sugarcane to the ethanol production stage can alleviate some bottlenecks.

A DBT–CII (2010) study on estimation of net energy and carbon balance of bio-ethanol across its value chain concludes a net positive energy balance resulting in overall reduction of carbon emissions; life-cycle studies in the field are still ongoing. The lower calorific value of EBP has implications for material, design and performance compatibilities of vehicular fleet. As the discussion on the tests of automobiles revealed, the regulated emissions of carbon dioxide, nitrogen oxide and hydrocarbons increased using ten percent blending with mileage accumulation on all test vehicle categories. Thus, while the blending up to five percent does not have any serious implications, the subsequent step up to ten and twenty percent will have to be done with caution.

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