Chapter 9
Sugarcane as a Potential Biofuel Crop

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Abstract Sugarcane (*Saccharum* spp.) belonging to family Poaceae is a tropical perennial grass used widely for sugar production. Research scientists have discovered sugarcane as an alternative biofuel source to conventional petroleum fuels that lead to global warming. The sugars extracted from sugarcane can be easily fermented to produce ethanol. In addition, the bagasse (biomass remaining after the juice is extracted from the stalks) can be further used by sugar mills to generate steam and electricity. The current total global production of renewable fuels is 50 billion liters a year, and sugarcane alone accounts for about 40%, thus becoming a major contributor for biofuel production. The tremendous success of sugarcane industry to produce ethanol as biofuel in Brazil has also enhanced the interest in other parts of the world. With conventional technologies, sugarcane can yield several products from fiber to chemicals. But with the help of genetic recombination, sugarcane would roll to produce the novel biofuels more efficiently. Research scientists have identified the key enzymes that can hasten the process of ethanol production more powerfully. There is tremendous potential of sugarcane as a biofactory which can uplift both socioeconomic status of a country and sustainability of natural resources. Now, it's time to augment weightage to produce biofuels in developing

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countries like India which would initiate rural development, create more job opportunities, and also save foreign exchange to great extent.

Keywords Biofuel • Ethanol • Genetic recombination • Socioeconomic • Sugarcane

9.1 Introduction

Globally with rapid increase in population along with increased demand of the fossil fuels, a time will come which will reveal the truth of the extinction of these renewable sources. The world population is estimated to increase from 6.7 billion to 8 billion by 2030 (USCB 2016). On the other hand, global oil production is expected to decline from 25 billion barrels to 5 billion barrels by 2050 (Campbell and Laherree 1998). But with a new discovery of use of biofuel, now the demand of this biofuel has increased to many folds. Sugarcane is one of the main source for biofuel that would totally replace the fossil fuel in coming years and would not only contribute to maintenance of ecological balance but also would strengthen the industry and contribute to energy source diversification worldwide (Ericlam et al. 2009). Use of biofuel has positive impacts as it eliminates lead compounds from petrol as well as reduction of poisonous emission of harmful gases (Goldemberg et al. 2008). There is also the reduction of CO_2 emissions as sugarcane ethanol requires only a small amount of fossil fuels for its production, belonging to a renewable source of fuel energy. Out of total global production of renewable fuels of 50 billion liters a year, about 40% of it comes from sugarcane that is mostly produced by Brazil. Brazil tops the annual production with 73,93,000 metric tons while India ranks 2nd with 341,200 metric tons and third comes China with annual production of 125,500 metric tons. Bioethanol production from sugarcane and starch-rich feedstocks such as corn and potato is considered as the first-generation process and it has already been developed. Sugarcane (*Saccharum* spp.) is now considered as the most productive first-generation energy crop. The success of the Brazilian sugarcane industry in ethanol production has increased interest in producing sugarcane for ethanol throughout the world. The sugars extracted from sugarcane can be easily fermented to produce ethanol. In addition to this, the bagasse (biomass remaining after the juice is extracted from the stalks) is used by sugar mills to generate steam and electricity (Salassi and Breaux 2006; Mahmood-ul-Hassan et al. 2015). Brazil, which is considered as leading producer of sugarcane (Orellana and Neto 2006), has revealed that in last 20 years, the amount of sugarcane harvested and processed has almost tripled to meet the demand for sugarcane ethanol and bioelectricity within the country. As compared to other agricultural activities, sugarcane occupies only petite quantity of land, but yet, this small portion has been able to swap almost 42% of its gasoline needs with sugarcane biofuel (ethanol). In 2015/16, Brazilian ethanol production reached 30.23 billion liters (8 gallons) (Barros 2015). Brazil has been considered as a commendable model in developing and commercializing use of biofuels in its proposition to minimize enslavement on foreign oil alone with decreasing hydrocarbon air pollution and maintaining ecological balance. There is a positive correlation between increase in atmospheric greenhouse gases such as carbon dioxide with that of petroleum use and contributes global warming has created a vital need to develop and optimize “green fuels” that will have carbon neutral or even carbon negative capabilities (Graham-Rowe 2008) and sugarcane-based ethanol is the answer. Thus we can say that there is tremendous prospective of sugarcane biofactory which can boost both socioeconomic conditions of a country and sustainability of natural resources. Now it’s the phase to produce biofuels in the developing countries like India which would strengthen rural progress, create greater job facilities, and also save foreign trade to great point.

9.2 Biology of Sugarcane

Sugarcane belonging to the genus *Saccharum* L., of the tribe Andropogoneae in the grass family (Poaceae) (Hodkinson et al. 2002) is a tropical perennial grass. Although sugarcane performs best in tropical and subtropical environments with temperatures between 70 and 90 °F, it is highly sensitive to cold, and yields are reduced in areas that experience frequent frost and below freezing temperatures. Commercial sugarcane varieties are complex hybrids of *Saccharum officinarum* and other *Saccharum* spp. like *S. spontaneum, S. robustum, S. officinarum, S. barberi, S. sinense*, *and S. edule*. This hybridization results in a wide range of physical characteristics, pests and disease tolerance, fiber and sucrose content, and cold tolerance. The height of the mature hybrid is about 16 ft. Likewise; stalk diameters can range from pencil-thin to up to 2 in. The inflorescence, or tassel, of sugarcane is a red- to white-colored, open-branched panicle. Sugarcane is clonally propagated by means of “seed-cane” which is a section of a mature cane stalk with buds or “eyes” located at the nodes. Sugarcane is harvested after 9–14 months of growth in Florida, but in other countries it is harvested 10–12 months after growth. Once an established sugarcane crop has been harvested, it ratoons annually from underground buds on basal portions of old stalks (Sandhu et al. 2016) and typically four rations can be used (Bull 2002). Sugarcane is having stout jointed fibrous stalks that are rich in the sugar sucrose accumulating in the stalk internodes. Sucrose is extracted and purified and fermented to produce ethanol which can be used as biofuel.

9.3 Sugarcane Biofuel Production

9.3.1 First-Generation Biofuel

The first-generation biofuel plants utilize either sugars or starch and sugar-based biofuel are predominately produced in Brazil from sugarcanes. Globally, 21 million m^3 ethanol is produced from sugarcane while 60 million m^3 ethanol is produced from corn and grains (REN21 2012). The foremost step is the liquidification of the sugar extracted from the sugarcane. This is followed by the hydrolysis or saccharification that releases the sugars (glucose) monomers into the solution. During the subsequent fermentation with yeast (*Saccharomyces cerevisiae*) the sugar monomers are converted into ethanol and carbon dioxide. An ethanol concentration of 10% (w/v) is obtained at the end of the fermentation. The fermented liquid is then distilled to separate and purify the ethanol, which is then dehydrated to concentrations above 99.7% applicable for fuel (NSAI 2014). In the bottom of the distillation column, the sillage consisting of about 10% total solids (which includes residual substrate, yeast, and by-products). Some of the solid particles are removed from liquid via centrifugation by a decanter and the remaining thin silage is sent to an evaporator. The centrifugation cake and the resulting syrup from the evaporation are normally mixed to produce distillers dried grains and soluble (DDGS) which is used as protein source for animal feed (Taherzadeh et al. 2013). The first-generation bioethanol production is shown in the flowchart in Fig. 9.1.

9.3.2 Second-Generation Biofuel

Second-generation ethanol utilizes different types of lignocellulosic materials as substrate. Here, the energy balance for production from cellulosic materials is predicted to be superior to the present methods from sugarcane (Larson 2006). Currently, only negligible amounts of second-generation biofuel are produced around the world and are not commercially feasible. In Norway, one company named Borregaard is considered to be the largest producer of second-generation biofuel production with annual production of 20,000 m^3 (Rodsrud et al. 2012). The production of bioethanol from lignocelluloses is followed by few important steps, i.e., milling, thermophysical pretreatment hydrolysis, fermentation, distillation, and product separation/processing. It involves pretreatment and hydrolysis of the lignocellulosic material where steam explosion is followed by an alkaline delignification step. In the steam explosion, 70% of the hemicellulose is hydrolyzed into pentoses, with small cellulose losses and no lignin solubilization (Ojeda et al. 2011). The pretreated solids are separated from the obtained pentoses liquor using a filter. Pentoses are either fermented into ethanol or biodigested (producing biogas for the cogeneration system). In some cases, pretreatment is followed by an alkaline delignification step, where most of the lignin is removed from the pretreated material decreasing its inhibitory effects on enzymes in the enzymatic hydrolysis step (Rocha et al. 2012). The solid fraction obtained after filtration of the material is sent to enzymatic hydrolysis. The hydrolyzed liquor produced in the enzymatic hydrolysis, rich in glucose, is separated from the unreacted solids, i.e., residual cell lignin, which are used as fuels in the cogeneration system. In the integrated process, the hydrolyzed liquor is mixed with sugarcane juice; thus, concentration, fermentation, distillation, and dehydration operations are shared between both processes (Fig. 9.2).

Yeasts are specially used for the conversion of sugars into ethanol (mostly *Saccharomyces* spp.) to convert glucose into ethanol. C-5 sugars like xylose are

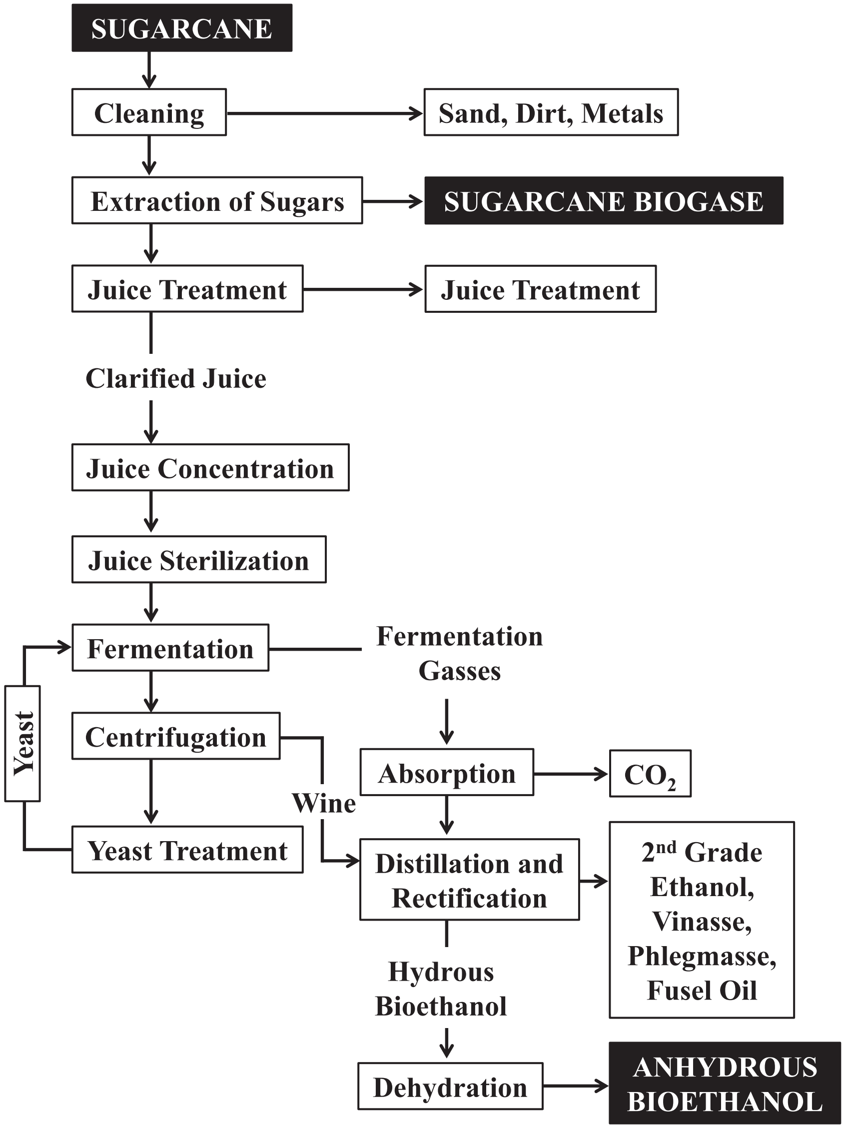

Fig. 9.1 Flowchart for the bioethanol production process from sugarcane (Source: Dias et al. 2011)

converted into ethanol at low rates by very few yeast (*Pichia* spp.) strains. Research has been carried out to undergo either to adapt yeasts for the use of both C-5 and C-6 sugars or to modify *Saccharomyces* genetically to obtain yeast that produces ethanol simultaneously from C-5 and C-6 sugars. Lignocellulosic biomass is the most promising feedstock for the production of fuel bioethanol. Large-scale production of bioethanol from lignocellulose containing materials has still not been implemented commercially in many places.

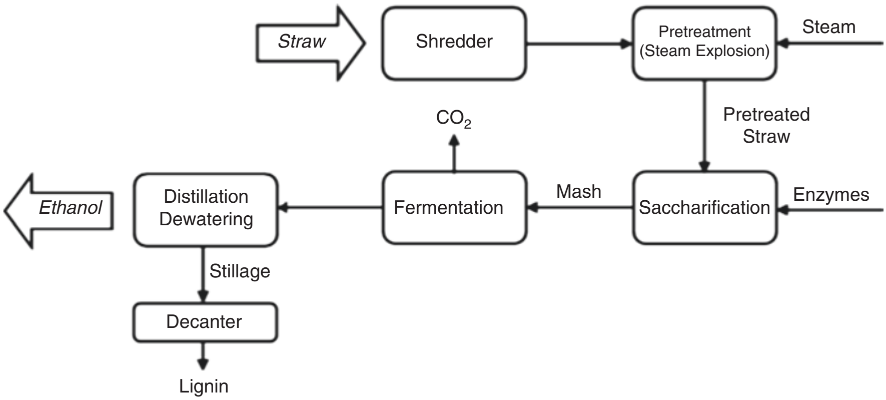

Fig. 9.2 Flow chart showing bioethanol production from lignocelluloses (Kahr et al. 2012)

9.4 Technological Improvement in Sugarcane Biofuel

Although ethanol is being successfully produced from the sugarcane, the produce is not up to the mark. There is a lot of scope for increasing production of novel biofuel (ethanol) and more efficiently in many ways. There are certain biological problems in the pathways of sucrose synthesis, translocation pathways, cell wall composition, and lignin synthesis and that needed to be more focused and carefully understood with the help of biotechnology approaches so that we can improve regulation of these and other pathways (Ericlam et al. 2009).

A big challenge is how to reduce cost of pretreatment and enzyme and how to enlarge the technologies for maximum efficiency of conversion of sugarcane biomass into biofuels. So, it is possible through genetic approaches including genetic modification, molecular biology, and plant breeding efforts to improve sugarcane cultivars with high cellulose, biomass yields, less lignin, fiber content, and maximum conversion of the biomass to biofuels in addition to improve pretreatment process and enzyme hydrolysis process (Hoang et al. 2015). However, despite these limitations, significant progress has been made towards genetically modified microorganisms that will digest the cellulose organic waste and xylose utilizing yeast strains have been developed for ethanol production (Paula 2016).

9.4.1 Importance of Genetic Engineering for Improvement of Efficacy of Biofuel

For efficient production of biofuels from plant materials, it requires proper processes that would initiate the biochemical makeup of the starting materials. Microbes are commonly used in industrial processing of crop materials to produce biofuels. The biological processes of these microbes which involve breakdown of cellulose and other molecules to sugar, fermentation of sugar to yield ethanol or butanol, etc. are involved in the stepwise process of converting plant materials to biofuels. Most of the plants, with the exception of sugarcane or sugar beet, do not store considerable amount of sugar. Starch is produced in many plants as a storage form of carbon and energy. Maize and cassava produce large amounts of starch in seeds (maize) or roots (cassava). Starch is composed of long chains of sugar molecules, which can be hydrolyzed to simple sugars using microbial enzymes. Sugar produced in this way can then be fermented to ethanol. Here lie the opportunities of genetically engineered organisms producing starch hydrolyzing enzymes. Research is also being directed at identifying biochemical approaches to metabolize lignin and hemicelluloses present in plants so that usable products might be produced from these molecules as well. A much broader range of sugars can be fermented by organisms such as *Saccharomyces*, *E. coli*, *Xymomonas*, and *Pichia*, all of which have shown promising results for use in fermentation. These organisms produce enzymes that ferment a broader array of five and six carbon sugars. Since the microorganisms used for fermentation cannot survive at ethanol levels greater than 10–15%, distillation must be used to remove the remaining water and achieve high concentrations of ethanol. The use of genetic engineering to increase the tolerance to ethanol of the organisms used in fermentation is an active field of research. The possibility to "engineer a single organism to secrete all the necessary enzymes and utilize all the available sugars in a process referred to as integrated bioprocessing" represents a goal that many recognize as achievable (Somerville 2007).

Secondly, there are other relevant problems like sucrose synthesis and translocation pathways, cell wall composition and pathways for lignin synthesis that are needed to be more thoroughly understood. Thus the traditional plant physiology studies combined with molecular techniques are to be developed for a better understanding of plant development and gene expression before taking any biotechnological interventions to improve regulation of these and other pathways.

Many scientists have carried out the different interacting processes involved in accumulation of sucrose in sugar-storing stems of sugarcane. They have identified the key role of enzymes in this process through genetic engineering. Several genetic modification was done in sugarcane for boosting of the sucrose yield; for example, Groenewald and Botha (2008) identified a particular enzyme that raised the amount of sucrose in young stems of the genetically modified sugarcane plants and discussed metabolic engineering of sugars and its derivatives in plants (Patrick et al. 2013).

The prospect for genetic modification (GM) has large impact on devoted energy crops like sugarcane which started its pace from 2015 and continues till 2025 in the whole world. There is need for lot of technical challenges in using cellulose and lignin for biofuels production which have been already discussed above that can be solved with genetic modification. The most important impact of biotechnology on biofuels in the next 5 years will be on microorganisms involved in the processing of biomass to biofuels. Development and improvement of enzymes used for digesting cellulose, hemicellulose, and lignin into sugars and other simpler components are essential. Improvements in the efficiency and yield of fermentation will also continue till the time speculated.

9.5 Benefits of Ethanol as Biofuel

Ethanol is a comparatively low-cost alternative fuel. Sugarcane ethanol is an alcohol-based fuel produced by the fermentation of sugarcane juice and molasses. It is clean, affordable, and low carbon biofuel; sugarcane ethanol has emerged as a leading renewable fuel for the transportation sector. Ethanol is used in mainly two ways, namely, blended with gasoline and as pure ethanol. The ethanol is better than petroleum because it reduces air pollution and harmful emissions by adding oxygen to gasoline. Ethanol-fueled vehicles produce lower carbon monoxide and carbon dioxide emissions, and lower levels of hydrocarbon and oxides of nitrogen emissions. It always burns with a smokeless blue flame that is invisible in normal light (Sukesh et al. 2010). It is high octane fuel that helps prevent engine knocking and generates more power in higher compression engines. Moreover ethanol reduces global dependence on oil.

Below are some few valid reasons why to use biofuel instead of gasoline. They are:

9.5.1 Balance in Energy Due to Ethanol Production

Ethanol production from sugarcane has become an attractive replacement for gasoline in context that it is basically a renewable source of fuel which supplies electricity in surplus (Goldemberg et al. 2014). This is responsible for the low carbon emissions in the country Brazil (most of the carbon dioxide emission of the country), 75% of all national emissions, is due to Amazonia Forest deforestation (MCTI 2004). But for second-generation processes, the energy balance for production from cellulosic materials is estimated to be much better than the present methods from sugarcane (Larson 2006).

9.5.2 Environmental Aspects

As the amount of alcohol in gasoline increased, lead additives were reduced and they were completely eliminated by 1991. Brazil was then one of the first countries in the world to eliminate lead entirely from gasoline. The aromatic hydrocarbons (such as benzene), which are mainly harmful, were also eliminated and the sulfur content was reduced to many fold. In pure ethanol cars, sulfur emissions were eliminated. The simple addition of alcohol instead of lead in commercial gasoline has dropped the total carbon monoxide, hydrocarbons, and sulfur transport-related emissions by significant numbers. Due to the ethanol blend, lead ambient concentrations in Saa Paulo Metropolitan Region were reported to be dropped from 1.4 mg/m^3 in 1978 to less than 0.10 mg/m^3 in 1991, according to CETESB (the Environmental Company of Sao Paulo State), far below the air quality standard of

1.5 mg/m^3 (Coelho and Goldemberg 2004). Also, ethanol hydrocarbon exhaust emissions are less toxic than those of gasoline, since they present as lower atmospheric reactivity.

9.5.3 Social Aspects

Regarding socioeconomics aspects of the agribusiness, the most vital point is on the subject of job and income creation for a very wide range of workface capacity building programs, with the flexibility to support local characteristics using different technologies on the farm. Biomass and biofuels trade contribute to rural development, allowing additional income and job creation for developing countries, contributing to the sustainability of natural resources, collaborating with GHGes emission reduction in a cost-effective way, and thus diversifying the world's fuel needs.

9.6 Government Interventions

The global production of biofuels has almost tripled since 2005 in Brazil. This rapid increase in production in industrialized countries has been due to the fact that it reduces both their dependency on imported fossil fuel products and carbon emissions. For many developing countries like India, this trend presents new trade opportunities, as it increases the rural employment opportunities and also decreases the dependency of oil import from foreign. However, this poses a number of governance challenges. There have been reports of emerging and developing economies in certain developing countries (Brazil, Mexico, Indonesia, Malaysia, Zambia, and Ghana). All these happened due to the active role of government in developing a viable domestic biofuel industry and then exploring the effectiveness of national governance systems in managing the potential externalities of biofuel sector expansion.

A case study has been reported here for Brazil and Indonesia to depict how government has played a major role in expansion of biofuel production in the countries.

9.6.1 Government Role in Market Development in Brazil

One of the oldest and most competitive biofuel sectors compared to other parts of the worlds is Brazil having sugarcane-derived ethanol production since 1970s. Almost one-third of total global production has been accounted from Brazil, thus making it the second largest biofuel producer in the world. Government initiation for the need to biofuel started with the country's exposure to high oil prices during the 1973 oil crisis. With a well-established sugarcane sector, which at that time was under pressure from low world sugar prices, diversification into ethanol production also created an opportune market outlet for sugarcane. Brazilian government imposed the phased implementation of mandatory blending requirements, which now stand at 20–25%, and offered discount for ethanol fuels at the fuel pump. This created a guaranteed domestic market in the country. In addition, ethanol producers were eligible for several other incentives, including concessionary credit lines, price and offtake guarantees, and tax breaks. Moreover, research and development by public institutions was critical to sector innovation, especially with regard to agronomic and biotechnological improvements. Although the cost of production in the early stage was more but technological advances and gains from economies of scale brought down the cost of production to large extent. With pure ethanol typically selling at between 60 and 70% of the price of gasoline, producer subsidies and pricing interventions are no longer necessary in the country (Goldemberg et al. 2004a, b).

9.6.2 Government Role in Market Development in Indonesia and Malaysia

After Brazil, other countries started to give commitment on domestic biofuel sector after examining the profits of it. Domestic consumption of biodiesel was seen as offering two key benefits: it would support the creation of another, more profitable, market for palm oil products, and it could contribute to alleviating the burgeoning federal cost of fuel subsidies. The rise in oil prices between 2005 and 2008, in particular, put biofuels firmly on the political agenda in many countries. Both Malaysia and Indonesia, for instance, adopted biofuel policies and laws during this period. Like Brazil, both countries are well positioned to exploit a well-established feedstock sector. Both countries heavily subsidize the end-price of transportation fuels; they have sought to ease this burden through the blending of biofuels, particularly biodiesel (Chin 2011; Caroko et al. 2011). The effect of high oil prices was especially detrimental to Indonesia, which, in contrast to Malaysia, is now a net oil importer. When oil prices peaked in 2008, fuel subsidies in Indonesia constituted almost one-third of total government spending (Dillon et al. 2008). In response to these pressures, both countries announced ambitious blending targets and established dedicated government agencies to oversee development of the biofuel sector. In response to this apparent government commitment and renewed global interest in biofuels, many sugarcane and palm oil sector actors in both countries made considerable investments in their biodiesel production capacities. Total production capacity in 2010 was estimated at 2.6 billion L for Malaysia and almost 4 billion L for Indonesia (Adnan 2010; Van Gelder and German 2011). Despite this early enthusiasm amongst both private and public sectors, current production remains well under installed capacities, with Malaysia producing only 222 million L and Indonesia 104 million L of biodiesel in 2009 (Hoh 2010; Baskoro 2010). In Indonesia, the government has since introduced consumer subsidies over and above the existing fuel subsidy, and is providing various producer incentives to encourage domestic biodiesel production and prevent price inflation at the pump.

9.6.3 Government Role in Market Development in India

India is one of the rapid growing economies in the world. The development agencies focus primarily on economic growth, equity, and well-being of human. Energy is a critical input for socioeconomic development. The energy plan of each and every country aims at efficiency and security and also to provide environment-friendly approaches and optimal use of primary resources for energy generation. Although fossil fuels plays a dominant role in the energy scenario in our country in the next few decades but this conventional fossil fuel resources are limited, nonrenewable, and polluting and, therefore, need to be used wisely. On the other hand, renewable energy resources are indigenous, nonpolluting, and virtually inexhaustible. India is endowed with abundant renewable energy resources. Sugarcane is a good source of renewable biofuel which is nonpolluting in nature. The petro-based oil meets about 95% of the requirement for transportation fuels, and the demand has been steadily rising. The domestic crude oil is able to meet only about 23% of the demand, while the rest is meeting from imported crude for which India has to spent large bulk of money. Thus from the security point of view, alternative fuels like sugarcane biofuel need to be developed in order to curb pollution. Biofuels are environment-friendly fuels and their utilization would address global concerns about suppression of carbon emissions. In the context of the International perspectives and National imperatives, it is the endeavor of this Policy to facilitate and bring about optimal development and utilization of indigenous biomass feedstocks for production of biofuels. Thus our government policy has tried to accelerate the development and promotion of the cultivation, production, and use of biofuels to meet the increasing demand and substitute for petrol and diesel for transport and other applications which will not only throw in to energy security but also climate change mitigation, apart from creating new employment opportunities and leading to environmentally sustainable development. The scope of the Policy encompasses bioethanol, biodiesel, and other biofuels, as listed below:

(a) ***Bioethanol:*** Ethanol produced from biomass such as sugar containing materials, like sugar cane, sugar beet, sweet sorghum, etc.; starch containing materials such as corn, cassava, algae, etc.; and cellulosic materials such as bagasse, wood waste, agricultural and forestry residues.
(b) ***Biodiesel:*** A methyl or ethyl ester of fatty acids produced from vegetable oils, both edible and nonedible, or animal fat of diesel quality.

In India, bioethanol is produced mainly from molasses, a by-product of the sugar industry. Cultivators, farmers, landless laborers, etc. would be encouraged to undertake plantations that provide the feedstock for biodiesel and bioethanol. Corporates would be enabled to undertake plantations through contract farming by involving farmers, cooperatives, Self Help Groups, etc. in consultation with Panchayats, where necessary. Such cultivation or plantation would be supported through a Minimum Support Price for the nonedible oil seeds used to produce biodiesel. Ethanol is mainly being produced in the country at present from molasses, which is a by-product of the sugar industry. 5% blending of ethanol with gasoline has already been taken up by the Oil Marketing Companies (OMCs) in 20 States and 4 Union Territories. 10% mandatory blending of ethanol with gasoline has become effective from October 2008 in the states of India. In order to boost up the availability of ethanol and reduce over supply of sugar, the sugar industry has been permitted to produce ethanol directly from sugarcane juice. Financial incentives, including subsidies and grants were being formulated by different government bodies. National Biofuel Fund has been considered for providing financial incentives for producing sugarcane biofuel. International scientific and technical cooperation in the area of biofuel production, conversion, and utilization will be established in accordance with national priorities and socioeconomic development strategies and goals. Both bilateral and multi-lateral cooperation programs for sharing of technologies and funding projects would be urbanized, and participation in international partnerships, whenever necessary, will also be taken into account (MNERGOI 2016).

9.7 Summary and Conclusion

Use of biofuel leads to breeze the gap between food, fodder, and fuel security. Biofuels have become agreeable to most of the developing countries because of their potentiality to stimulate economic development in rural areas and lessen poverty by creating employment opportunities and increased income level in the agricultural sector. Biofuel production is labor intensive and thus a good initiator 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 "host in" effect by encouraging other investments in this section (Hausman 2007, 2012). Many developing countries have therefore begun to explore biofuel policies of their own feasible ways. China, for example, has announced a biofuel fusing target of 15% for all kinds of transportation by fuels by 2020 (Dong 2007). India too 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 (GOI 2016). 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).

In 2008 India imported 128.15 million metric tons of crude oil valued at $75.7 billion, constituting 75% of its total petroleum consumption for that year. By 2025, it will be importing 90% of its petroleum (Parimal et al. 2010). 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. In 2003, they launched the first phase of their biofuels program in which 5% blending of ethanol in gasoline was mandated in certain areas of nine major sugarcane growing states and four union territories. In 2009 the Indian sugar industry estimated that 680 million liters of ethanol would be needed to meet just a 5% blend but only 585 million liters of ethanol were produced that year (Bureau 2009). In December of 2009 the Government of India set an official target of at least 20% blending of ethanol with gasoline by 2017 (IANS 2009).

Some important advances have been made by researchers for plant genetic engineering for biofuel production, but still there is dire need to develop technologies for elite sugarcane varieties having high sucrose content, less lignin, and easy to conversion process for biofuel production. There are some specific challenges related to the cost of microbial cellulose enzyme because their production is still expensive. To solve these problems, research is being focused on the targeting of these enzymes to multiple subcellular locations in order to increase levels of enzyme production and produce enzymes with higher biological activities. Genetic engineering play an important role in deconstruct plant cell wall polysaccharides, to suppress lignin biosynthesis enzymes, increase the level of sugars and plant biomass that have decreasing the overall biofuel production cost.

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