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Bio-ethanol (2nd Generation Ethanol): A Solution to Ever Polluting Gasoline to Climate in India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Environmentally sustainable energy sources are called for due to contemporaneous development in industries along with the rapid pace of urbanization. Ethanol produced from biomass can be deliberated as a clean and safest liquid fuel and an alternative to fossil fuels as they have provided unique environmental, strategic economic benefits. For the past decade, it has been noticed that there is an increasing trend found in bio ethanol production which has created a stimulus to go for advancement in bio ethanol production technologies. Several feed stocks have been used for the bio ethanol production but the second generation bio ethanol has concentrated on the lignocellulosic biomass. Plenteous lignocellulosic biomass in the world can be tapped for ethanol production, but it will require significant advances in the ethanol production process from lignocellulosic because of some technical and economic hurdles found in commercial scale. This review will encompass the current status of bio ethanol production in terms of their economic and environmental viability along with some research gaps as well as policy implications for the same.

Keywords: Biofuel; bioethanol; lignocellulosic biomass; time series; price levels.

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1. INTRODUCTION

Energy from biomass (agricultural and forest products, organic wastes, and residues) had made a dominant position before the arrival of fossil fuels as a prominent source of energy in the later part of the twentieth century. Today, even a small shock in the petroleum sector, i.e., a cut in the production sector or an increase in prices makes a direct impact on the agricultural sector [1]. The emerging concern with increasing oil prices along with global warming and its consequences are the immediate justification for the decrease in dependence upon fossil fuels. The feedstock for next-generation biofuel will be basically of cellulose-rich organic materials, harvested for their gross biomass [2]. Cellulosic biomass like woody plants, grass species, and crop residues being abundant in number compared to food crops, can be easily harvested with minimal interference to the food economy, and gives less stress on land, air, and water resources. But it has to overcome certain technical and economic hurdles [3]. After numerous research and development, a system has been made to perform economically feasible bioconversion from biomass to bioethanol using the combination of chemical, biochemical and thermal techniques [4]. The utilization of first-generation biofuels brought out from food resources such as starchy substrates and high-value sugars being controversial, the use of non-food substances such as lignocelluloses, i.e., second-generation biofuels is looked for. Hence, the conversion of cellulosic biomass to bioethanol is considered as one of the best viable alternative fuel to solve the problems associated with first-generation fuels. Recently, technologies for converting algae into ethanol have also been developed. But the process is more complex relative to the processing of sugars and grains.

Apart from being a renewable substitute for fossil fuels, numerous social, economic and environmental advantages are offered by biofuels. It leads to decrement in vehicular pollution and greenhouse gas emission due to the lesser amount of emission of sulfur dioxide, particulate matter and carbon monoxide from them [5]. The sectoral development could result in increased cultivation of the feedstock crops like Pongamia (*Pongamia pinnata*), jatropha (*Jatropha curcas*), etc. which could give rise to higher income and employment chances for socially and economically backward communities cultivating the particular crops [6,7,8]. Another advantage can be added that the greening of wastelands and regeneration of degraded forest lands can be done through the cultivation of biofuel crops [9]. On the other side, with many developed countries pursuing aggressive policies for encouraging the production and use of biofuels, new dimensions on the adverse impact of the expansion of biofuels have surfaced.

The Indian economy has been growing at a rate of approximately 7.73 percent since 2010 [10]. India had ranked 4th in consumption and import of crude oil and petroleum products after the United States, China, and Japan in 2015. There was a gap found between demand and supply of Indian oil which continues to be widening, as in 2015 the demand reached approximately 4.1 million barrels per day compared to production of around 1 million barrels per day of total domestic liquids [10]. The recent World Energy Outlook (WEO) report of the International Energy Agency (IEA) has reported that the demand of India's primary energy will increase from 750 Mtoe to 1258-1647 Mtoe (the range is defined by WEO 450 Scenario and Current Policies Scenarios) between 2011 and 2035 [11], i.e., greater than twice over 25 years. The oil demand in India will reach more than 8 million barrels per day in 2035 [11], whereas the current domestic production of crude oil has been more or less stagnant over the years, meeting only 18 percent of the national requirement [12]. The balance between them occurs through imports of nearly 172 million tons of crude petroleum products that cost the country close to US$140 billion in 2011-12 [12]. Volatile oil prices and the uncertainty about sustained oil supplies have led India to search for alternatives, particularly for substituting petroleum products, to promote energy security.

Recently in the international market, the food prices have risen drastically which has been believed to be due to the diversion of food crops towards the production of energy and specifically seen for maize-based ethanol production in the US [13,14,15]. In the case of paddy, however, other trade policy-related factors were at work [16]. It is expected that very shortly unprecedented levels of food riots will be seen in the world which would be only due to price hike in major food grains. The ripples of price rise in these staples got reflected in the domestic markets of almost all the countries including India. As a result of concerns over possible impacts on food prices, China with the prediction of negative consequences has changed its domestic biofuels policy and restricts the use of food grains as feedstock and abruptly slowed its growth in production of ethanol [17]. Rosegrant [13] has compared the increase in prices during the period 2000-2007 with that of historical growth rates and came to preside that, around 30 percent of increment in the weighted average of grain prices was mainly due to their increased demand for biofuels production.

Being a developing country, India also started its biofuel programme, with a view to explore a cleaner source of energy and to offset the growing burden of crude oil imports, at least partially where the programme will be solely based on non-food feedstocks and are grown on degraded or wastelands not suited to agriculture, thus avoiding a possible conflict of food versus fuel security. However, being the first of its kind, and non-existence of an enabling environment for production, processing, marketing and distribution of biofuels, the programme has witnessed slow progress as yet. Consequently, the Government has so far not been able to meet its mandated blending targets of ethanol with petrol. Similarly, the blending of diesel with biodiesel in the transport sector has not yet commenced owing to several impeding factors that pull down the development of a mature biodiesel supply chain in the country. In this context, several questions arise regarding the future of biofuel expansion in India. The important ones among them are: What is the present status of India's biofuel programme? How far is the existing choice of feedstocks and technology suitable in meeting India's biofuel production requirements in the future? What are the major constraints and impediments that hold back the progress of the biofuel programme in the country? What are the main pre-requisites for the development of viable and self-sustainable biofuel industry in the country? What economic and social implications would result from the large-scale expansion of biofuels and how is it going to impact the future food production systems?

2. CURRENT STATUS OF BIOETHANOL IN INDIA

Globally India ranks second in sugarcane production and also famed as a large producer of bioethanol from sugarcane molasses [18]. Bioethanol is mainly produced from sugarcane molasses following fermentation process and estimation has shown that 85-100 kg of sugar (8.5–10 percent) and 35-45 kg (3.5-4.5 percent) of molasses could be incurred from 1 ton of sugarcane [19,20]. According to Indian standards, bioethanol can be recovered up to 22-25 percent from sugarcane molasses [21]. The practical scenario has depicted that major portions of sugarcane (70 – 80 percent) has been diverted to sugar production and then rest 20 -30 percent for sweeteners (Jaggery and Khandsari) and seeds [22]. The molasses during sugar production is made available for the production of bioethanol. The cyclical nature of the crop, as well as sugar production, creates periodic market gluts/ deficits impacting farm income and farm prices of sugarcane farmers. $1/4^{th}$ of the alcohol produced is used for industrial purposes while 30 to 35 percent is used for beverages and the remaining 3 to 4 percent for other uses [23,24,25].

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 percent ethanol blended petrol. Sufficient lead time would have to be given to the automobile industry to make the appropriate engine and other modifications to make vehicles compatible with higher levels of blended fuel.

3. SUBSTRATE-SPECIFIC PRODUCTION OF BIOETHANOL

The potential feedstocks for second generation ethanol production considered in this study are lignocellulosic feedstocks.

3.1 Lignocellulosic Feedstock

The major components of lignocellulosic feedstocks are cellulose and hemicellulose, which can be converted to sugars through a series of thermochemical and biological processes and eventually fermented to bioethanol. In general, lignocellulosic feed-stocks are divided into three categories: (1) agricultural residues (e.g., crop residues and sugarcane bagasse), (2) forest residues, and (3) herbaceous and woody energy crops. The theoretical, as well as practical yield of ethanol produced from all kind of feedstock, has been compiled in Table 1.

Table 1. List of feedstock and feedstock wise bioethanol yield

S.N	Feedstock	Ethanol chemical yields from Literature Gal./ton of feedstock	Practical ethanol chemical yield Gal./ton of feedstock	References
1	Corn Stover	350 lr/ton	330lr/ton	Kadam et al. [30]
		302 lr/ton	215 lr/ton	Sassner et al. [34]
2	Sugarcane	110.5 lr/ton (Conventional distillation)	102.5 lr/ton (Conventional distillation)	Dias et al. [40]
		115.7 lr/ton (Double effect distillation)	105.7 lr/ton (Double effect distillation)	
3	Rice straw	226.8- 254.01 lr/ton	172.6-316.8 lr/ton	Kadam et al. [41]
4	Wheat straw	217.7-264.6 lr/ton	186.9-338.3 lr/ton	Wallace et al. [42]
5	Sorghum straw	244.1-244.9 lr/ton	150.06-271.3 lr/ton	Wallace et al. [42]
6	Softwood(Spruce)	426 lr/ton	292 lr/ton	Sassner et al. [34]
7	Hardwood (Salix)	345 lr/ton	239 lr/ton	Sassner et al. [34]
8	Switch grass	350-485 lr/ton	253-415 lr/ton	Bansal et al. [37]
9	Miscanthus	350-475 lr/ton	253-378 lr/ton	Bansal et al. [37]

3.1.1 Agricultural residues

Agricultural residues are advantageous for biofuel production as compared to grain crops and energy crops because there is no need for any additional land and residue-based biofuel will cause minimal impact on food prices. Furthermore, it will be possible to improve fuel's carbon balance along with avoiding greenhouse gas emission with direct and indirect land use changes [26]. Crop residue removal has been seen beneficial for some crops by improving soil temperature, seed germination and pest control [27]. But it has also been seen that excess removal will harm soil health, environment and crop production also[28]. Many studies have stated that bioethanol can be produced from different agricultural residues. Chandra Prasad [29] has used sugarcane molasses to make bioethanol production whereas Kadam [30] has used Corn Stover and Nutawan and Parameswaran [31] have used rice straw as potential feedstock. Wheat straw has been used a possible feedstock for bioethanol [32] and Goshadrou et al. [33] has taken sweet sorghum molasses for bioethanol production.

3.1.2 Forest residues

Forest residues have also experimented for bioethanol production including fuelwood, primary and secondary wood processing mill residues. Sassner [34] have used Softwood (Spruce) and Hardwood (Salix) for bioethanol production. Galbe [35] has reviewed bioethanol production from softwood, with focus on hemicelluloses and cellulose hydrolysis. However, they are restricted by several factors like transportation costs, costs of logging/ collection activities [36].

3.1.3 Energy crop

Perennial forage crop species are a promising source of feedstock for second-generation biofuels. Bansal et al. [37] has made a comparative analysis between switchgrass and miscanthus concerning bioethanol production. Switchgrass is frequently mentioned because of its relatively low water and nutrition input requirement and costs, positive environmental impact, and adaptability to low-quality land [38]. Miscanthus is a grass native to Asia and a compelling herbaceous biomass feedstock for Europe [39], in part because of its cold tolerance and low levels of nitrogen needed.

There is a comparative study between the theoretical and practical yield of ethanol from different feedstock in Table 1 which has shown that the actual yield is lower compared to the theoretical yield due to conversion, recovery and extraction efficiencies. Numerous research findings have indicated that the conversion efficiency (percentage of sugar that is chemically converted to ethanol) ranges from 92 to 92.5 percent [43,44] and recovery efficiency (percentage of ethanol that can be recovered from the chemical mixture) at 99 percent due to the two-stage distillation process. The first stage contributes 95.6 percent distillation followed by the second stage using desiccants, molecular sieves and denaturants for remaining water removal [45]. The composition of crop residues (Starch, lignin, and others) provides a combined effect on the efficiencies. The extraction, conversion, and recovery efficiencies majorly cause the ethanol chemical yields to be lower than the theoretical.

4. PRODUCTION COST ESTIMATION OF LIGNOCELLULOSIC FEEDSTOCKS

The practical estimated values of cost of production, delivery, and storage are variegated depending upon different available sources hence experiencing large scale production is lacking. Despite very recent interest in second-generation biofuels, the vast literature area has been placed which are summarised in Table 2.

4.1 Agricultural Residues

In Table 2 it is found that the costs of crop residues ranged between $19 to $84 per tonne. Such an extensive range has reflected that there must be differences in including the items in the calculation (e.g., Labour payment, alternative costs) yields, storage requirements, distances to conversion facilities, and the level at which each of these items is compensated. Taking into an instance, Gallagher et al. [46] has estimated the cost including only transport, increased fertilizer and harvesting cost which were lower compared to recent studies in the table. They have not included important ones like Feedstock acquisition, storage, and alternative costs such as their feed value. An incentive of $11 per tonne to farmers and in addition to that higher transportation and bailing cost has been assumed by Tokgoz et al. [47].

Perlack and Turhollow [36] included the costs of collecting, hauling, and handling corn stover along with conversion facility, as well as an $11 per tonne given as compensation to growers for potential compaction of soil, lessening surface organic matter, and some amount of profit requested by them. Here they have emphasized that the size of biofuel plant and density of available residues can lead to notified differences in estimates through their impact on costs of transportation. This observation is also substantiated by Petrolia [48], who had not included farmers' payment in his estimation but conceded that some emolument should be needed for growers for making the stover available with them.

The opportunity/ alternative cost and another associated cost of residues for bio ethanol production vary among different studies because they depend mostly on the local conditions like residue removal impact on yields and remedy costs (e.g., stemming from additional fertilizer or tilling), potential values of the residues, etc. The costs of residues of the forestry industry as well as woody energy crops are estimated and reported in the literature are presented in Table 2.

Walsh [62] estimated the aggregated US supply curve by taking the primary mill residues and reported that the price range from $42 to $47 per dry tonne was favorable for doubling the quantities of residues to enter the market and can bid away from their current use, but price increment above $47 would cause smaller impacts on availability of residues showing a lower supply elasticity. Similarly, another analysis was done by Biomass Research and Development Initiative [63] which portrayed that the price range ($44–$51 per tonne) could bring significant supplies of feedstocks of forest land.

Feedstock wise production cost of ethanol has shown divergent figures in Table 2 which was due to wide changes in yield and land rent charges spatially reflecting the profitability of the options available to the growers. Better soils always prove to higher agricultural returns and thus higher per hectare opportunity costs for feedstock production. On the contrary, higher yields tend to lower the opportunity cost of land by diluting these over more tonnes of feedstock.

4.2 Herbaceous Energy Crops

In Tennessee the long term leases of land rented @ $148 has yielded 15 tonnes/ha [53] (Epplin et al. 2007) For production in Nebraska and South Dakota, Perrin et al. [57] used land rents ranging from $62 to $222 per hectare, contingent on the field location. For his base case, [56] Duffy (2008) assumed land costs in Iowa of $198 per hectare and yields of 11 tonnes/hectare. Also for the case of Iowa, Babcock et al. [57] obtained relatively high costs of production, using a different approach. These authors argue that for switchgrass to bid area away from corn and soybeans in the Corn Belt, the herbaceous crop should provide similar expected returns over variable costs of production, roughly $618 per hectare. These differences across studies combined with different production and harvesting practices make for different cost calculations in the literature.

5. TRENDS IN THE PRODUCTION OF BIOETHANOL WORLDWIDE

Bioethanol production is seen to contribute about 4 percent of the 1300 billion liters of gasoline consumed globally in 2007 which further goes on increasing [64] (REN21 2007). Global production of bio-ethanol increased from 13123.1 million gallons in 2007 to over 27050 million gallons in 2017 and the increasing trend from 2007 to 2017 with a compound annual growth rate of 8.1 percent which is depicted in Fig. 1 showing 2007 to 2010 it goes on increasing then started falling up to 2012 then again 2012 onwards it continued increasing and the forecasted value through projective technique shows that it will go on increasing further. The United States, Brazil, and several EU member states have the largest programs promoting bio-fuels in the world. National bio-fuel policies tend to vary according to available feedstock for fuel production and national agriculture policies. With all of the new government programs in America, Asia, and Europe in place, total global fuel bio-ethanol demand could grow to exceed 38273 million gallons by 2020. The United States produced 16.1 billion gallons of bioethanol in 2018, up from 4.84 billion gallons in 2006 [65] (Statista 2019).

The United States is the world's largest producer of bio-ethanol fuel, accounting for nearly 58 percent of global bio-ethanol production followed by Brazil, EU, China and others (Fig. 2).

Brazil is the world's largest exporter of bio-ethanol and second-largest producer after the United States contributing 26 percent [66] (Balat 2009). All of Brazil's bio-ethanol is produced from sugar cane, most are used domestically substituting 40 percent of Brazilian petrol consumption and approximately 20% is exported to the United States, EU and other markets [66] (Balat 2009). On March 9, 2007,

Table 2. Estimated costs of selected feedstocks delivered to a bio-refinery

Feedstock	Estimated cost[a]		States/country	References
	$/tonne	$/L ethanol		
Agricultural residues (corn stover and crops straws)				
	19-20	0.063–0.067	Kansas, Iowa	Gallagher et al. [46]
	48-57	0.158–0.190	US	Perlack and Turhollow [36]
	57-69[b]	0.190–0.230	Minnesota	Petrolia [48]
Corn Stover	84	0.279	US	Tokgoz et al. [47]
	55	0.184	US	Frederick et al. [49]
Winter wheat, continuous	22–31	0.067–0.093	Kansas	Gallagher et al. [46]
Winter wheat, fallow	42	0.14	Kansas	Gallagher et al. [46]
Spring wheat, continuous	27	0.089	Minnesota	Gallagher et al. [46]
Sorghum	23–26	0.071–0.077	Kansas	Gallagher et al. [46]
Barley	24	0.08	Minnesota	Gallagher et al. [46]
Oats	26	0.085	Minnesota	Gallagher et al. [46]
Rice	28	0.093	Arkansas	Gallagher et al. [46]
Forest products residues and some woody energy crops				
Hardwood primary mill residue	37	0.125	US	National Renewable Energy Laboratory (NREL) [50]
Softwood primary mill residue	38	0.127	US	National Renewable Energy Laboratory (NREL) [50]
Hardwood secondary mill residue	34	0.112	US	National Renewable Energy Laboratory (NREL) [50]
Softwood secondary mill residue	34	0.112	US	National Renewable Energy Laboratory (NREL) [50]
Primary forest fuel (residues)	27	0.09	Sweden	Junginger et al.[c] [51]
Yellow poplar	48	0.16	US	Frederick et al. [49]
Loblolly pine	71–82	0.238–0.272	US	Frederick et al. [49]
Poplar	110–132	0.366–0.439	Italy	Manzone et al.[d] [52]
Herbaceous energy crops				
Switchgrass	55–74	0.184–0.245	Tennessee	Epplin et al. [53]
Switchgrass	44–71	0.147–0.237	US	Graham et al. [54]
Grassy biomass	29–65	0.097–0.217	US	Mapemba et al. [55]
Switchgrass	125	0.418	Iowa	Duffy [56]
Switchgrass	92–124	0.308–0.413	Iowa	Babcock et al. [57]
Switchgrass	56–60	0.187-0.200	US	Vadas et al. [58]
Switchgrass	56–67	0.186–0.224	Iowa	Hallam et al. [59]

Feedstock	Estimated cost[a]		States/country	References
	$/tonne	$/L ethanol		
Switchgrass	46–88[e]	0.154–0.294[e]	N. Dakota/Nebraska	Perrin et al. [60]
Alfalfa	77–90	0.257–0.300	US	Vadas et al. [58]
Alfalfa	78–83	0.260–0.278	Iowa	Hallam et al. [59]
Reed canarygrass	65–98	0.217–0.327	Iowa	Hallam et al. [59]
Switchgrass	43	0.144	Oklahoma	Aravindhakshan et al. [61]
Miscanthus	51	0.169	Oklahoma	Aravindhakshan et al. [61]

[a]inflation adjusted to 2008. Yields of 300 L of ethanol per tonne of feedstock were used.
[b]These numbers are for a plant producing 50 million gallons a year. Costs between $55 and $93 per ton were obtained by varying the plant size and the harvesting method.
[c]Originally reported in 2002 euros/GJ, converted using 21.1 MJ/L of ethanol (LHV) a yield of 300 L/tonne of forest residues, an exchange rate of 1.08 euros/dollar, and updated to 2008 dollars using the GDP deflator (multiplied by 1.175).
[d] Under conditions in Italy; originally in euros/tonne, converted with an exchange rate of 0.68 euros/dollar and 300 L of ethanol per tonne of biomass.
[e]Does not include transportation costs to the biorefinery

Table 3. Ethanol production in the world (2007-17) and projection up to 2026

Year	Ethanol production (Million Gallons)	Trend values	Decadal CAGR
2007	13123.1	16670	
2008	17643.8	17807	
2009	20303	18944	
2010	23310.9	20081	
2011	22404.1	21218	0.081591
2012	21812	22355	
2013	23429	23492	
2014	24583	24629	
2015	25683	25766	
2016	26583	26903	
2017	27050	28040	
2018	29177	29177	
2019	30314	30314	
2020	31451	31451	
2021	32588	32588	1.818462
2022	33725	33725	
2023	34862	34862	
2024	35999	35999	
2025	37136	37136	
2026	38273	38273	

Source: Renewable Fuels Association. http://www.ethanolrfa. org/resources/industry/ statistics /#1454098996479-8715d404-e546 and author's calculation

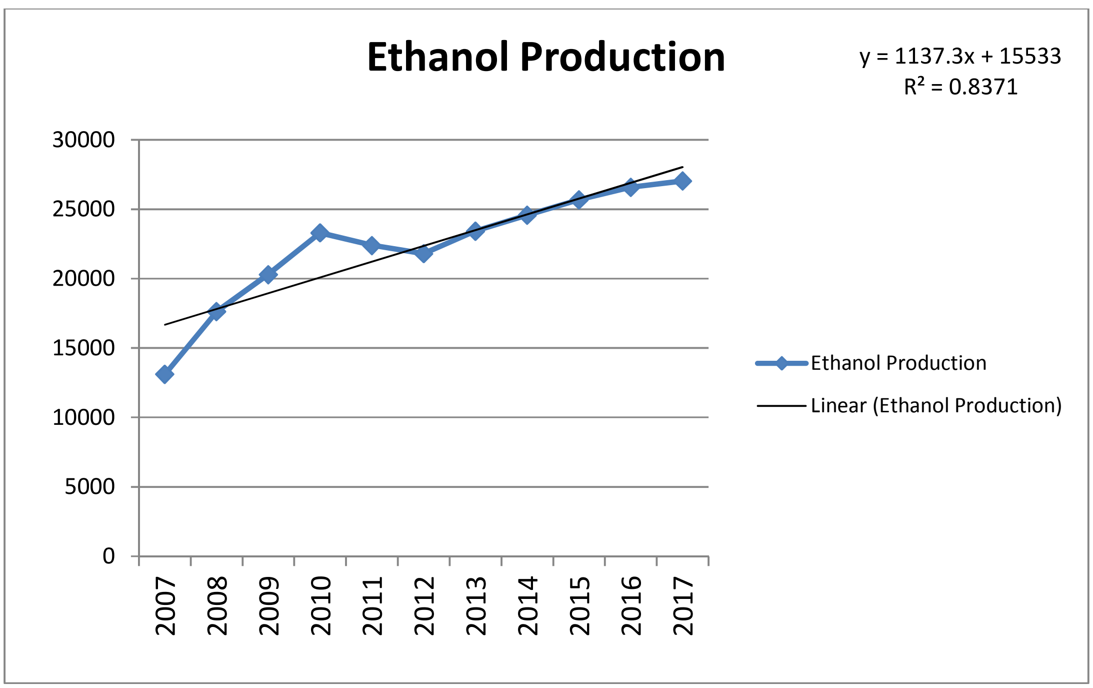

Fig. 1. World ethanol production (in a million gallons)

the United States and Brazil signed a Memorandum of Understanding (MOU) to advance cooperation on bio-fuels. The two countries agreed to: (1) advance research and development bilaterally, (2) help build domestic bio-fuels industries in third countries, and (3) work multilaterally to advance the global development of bio-fuels [66].

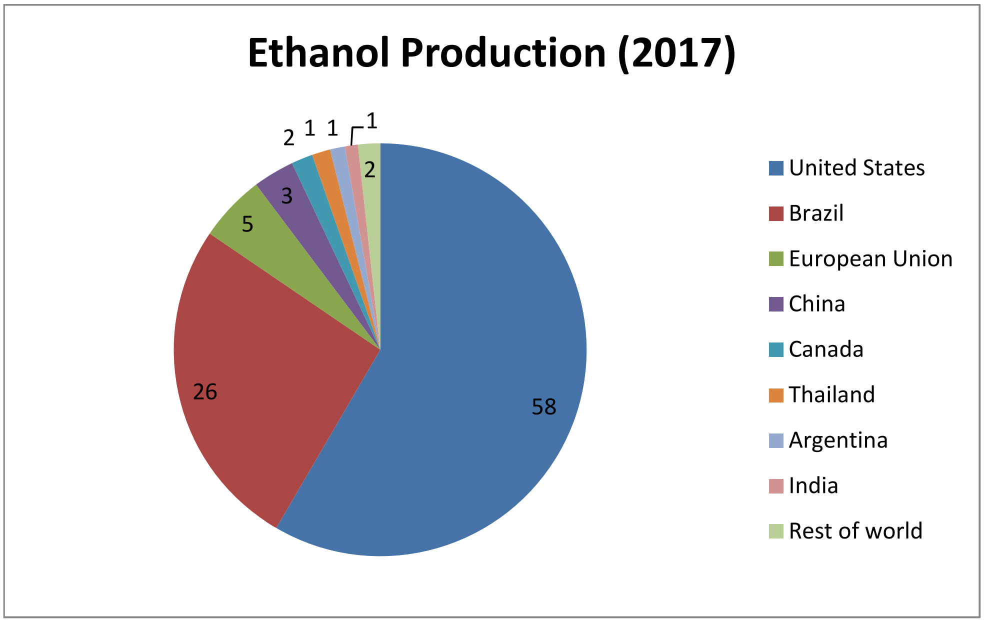

Fig. 2. The contribution of countries in world ethanol production

6. DEMAND AND SUPPLY OF BIO ETHANOL IN INDIA

The Indian economy has been growing at a rate of approximately 7.73 percent since 2010 [10]. In the year 2008, the Government of India announced its National Policy on bio fuels, mandating a phase-wise implementation of the programme of ethanol blending with petrol in various states. There are three main uses of ethanol in India. Of the total available ethanol, the maximum – about 45 percent – is used to produce potable liquor, about 40 percent is used in the alcohol-based chemical industry (as a solvent in the synthesis of other organic chemicals) and the rest is used for blending with petrol and other purposes. India is the fourth largest producer of bioethanol in the world after Brazil, the United States of America (USA) and China, producing approximately 2000 million liters of bioethanol, mainly by fermentation of sugarcane molasses [1]. However, the current bioethanol production amount in India is not sufficient for meeting the domestic demand. The huge unmet demand from the industrial sector occurred in 2008-09 which was met by main imports. In 2003, Planning Commission of India published the report of the Committee on Development of Biofuels and gave projections of demand and supply of bioethanol in India for the end of each five-year plan presented in Table 4. It has reported the break-up of production and consumption of bioethanol in terms of cane and molasses.

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 (shown in Table 4). 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.

7. RESEARCH AND IMPLICATION GAPS IN BIOETHANOL PRODUCTION

The individual biocatalytic along with the integration of biology and engineering into efficient processes portray a gap which should be addressed for achieving economic ethanol production from a cellulosic feedstock. Another research gap has been found in longevity and robustness of catalysts as well as cleans up of syngas. There is a need to improvise the research to fill this gap for improving the feedstock quality and reducing the down-stream costs for equipment and processing. In the case of green pyrolysis, research gaps exist in the development of stabilizers for the oils, so they are not too viscous during transport. Research is

Table 4. Projected Demand and Supply of Ethanol in India (million liters)

Year	Ethanol production			Ethanol utilization			Ethanol blending requirement for transport sector		Petrol demand
	Molasses	Cane	Total	Industry	Potable	Balance			
2001–02	1775	0	1775	600	648	527	5%	448.03	
							10%	896.05	8,960.52
							20%	1,792.10	
2006-07	2300	1485	3785	711	765	2309	5%	638.14	
							10%	1,276.27	12,762.72
							20%	2,552.54	
2011-12	2300	1485	3785	844	887	2054	5%	814.3	
							10%	1,628.61	16,286.09
							20%	3,257.22	
2017-18	2300	1485	3785	1003	1028	1754	5%	1,039.27	
							10%	2,078.54	20,785.36
							20%	4,157.07	

Source: Planning Commission [67]

Note: Figures for petrol demand in a million liters are calculated on an assumption of ethanol density of 0.789 g/ml. Planning Commission (2003) also gives ethanol demand estimates, assuming an ethanol density of 0.85 g/ml needed to target the modification of the catalytic conversion as a result of which the stability could be exhibited over time, which is a requirement for long-distance transport. There is a necessity for acceleration of development in desirable engine technology. Appropriate policies should have been formed to provide a structural basis so that the development of hybrid fuels can be targeted precisely.

8. CONCLUSION

Transportation sectors have huge scope for promotion of biofuels as a result of which numerous research programs have started focussing on the development of concepts like green energy, sustainable development, eco-friendly process, and renewable sources, etc in transportation sectors. Bioethanol is the most used biofuel in the world for transportation sectors which will continue to develop as a transport fuel as well as a gasoline additive. But in spite of laboratory success stories of bioethanol, the commercial plant scale production is still being a challenging matter whose solution could bring out so many benefits not only to fuel/ power industry but also for environmental rehabilitation and balance issues. Worldwide very few companies are engaged in commercial production of bioethanol e.g. Iogen Corporation, Canada (http://www.iogen.ca) using wheat straw and corn stover. But in India, despite an ample amount of biomass, still no commercial bioethanol production from lignocelluloses has made possible. There is a urgent need of government support specially in exemption from sales tax and excise tax, rectification of tax anomalies, proper pricing and encouraging pilot projects on bioethanol. There should e implementation of another new bioethanol policy which will help enhance economic development with conscious utilization of biomass feedstock with sustainable agricultural practices thereby bringing up new age farmers into the limelight and horizon of activities and threshold of business to become renewed with options to deal better in life.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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