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Biofuel Roadmap for India

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PROMOTING LOW CARBON TRANSPORT IN INDIA

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Abbreviations

AEZ	Agro-Ecological zone
BAU	Business As Usual
BDBP	Biodiesel Blending Programme
BIS	Bureau of Indian Standards
BL	Billion Litres
BTL	Biomass-to-liquid
CCEA	Cabinet Committee on Economic Affairs
EBP	Ethanol Blending Program
EBPP	Ethanol Blended Petrol Programme
EIA	Energy Information Administration (EIA)
ESCOs	Energy Service Companies
FAME	Fatty Acid Methyl Ester
GAEZ	Global Agro-Ecological Zones
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GoI	Government of India
HVO	Hydrotreated Vegetable Oil
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
ISMA	Indian Sugar Mills Association
ISSASS	International Society for Southeast Asian Agricultural Sciences
LC	Lignocellulosic
LCT	Low Carbon Transport

MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
Mha	Million hectares
MNRE	Ministry of New and Renewable Energy
MoA	Ministry of Agriculture
MoPNG	Ministry of Petroleum and Natural Gas
MPP	Minimum Purchase Price
MSP	Minimum Support Price
Mt	Million tonne
NAPCC	National Action Plan for Climate Change
NBF	National Biofuel Fund
NBM	National Biodiesel Mission
NPB	National Policy on Biofuels
NCAP	National Centre for Agricultural Economics and Policy Research
PPAC	Petroleum Planning and Analysis Cell
OMC	Oil Marketing Company
R&D	Research and Development
TBOs	Tree-Borne Oilseeds
UNEP	United Nations Environment Programme
UT	Union Territories

Photo credit: Scott Bauer

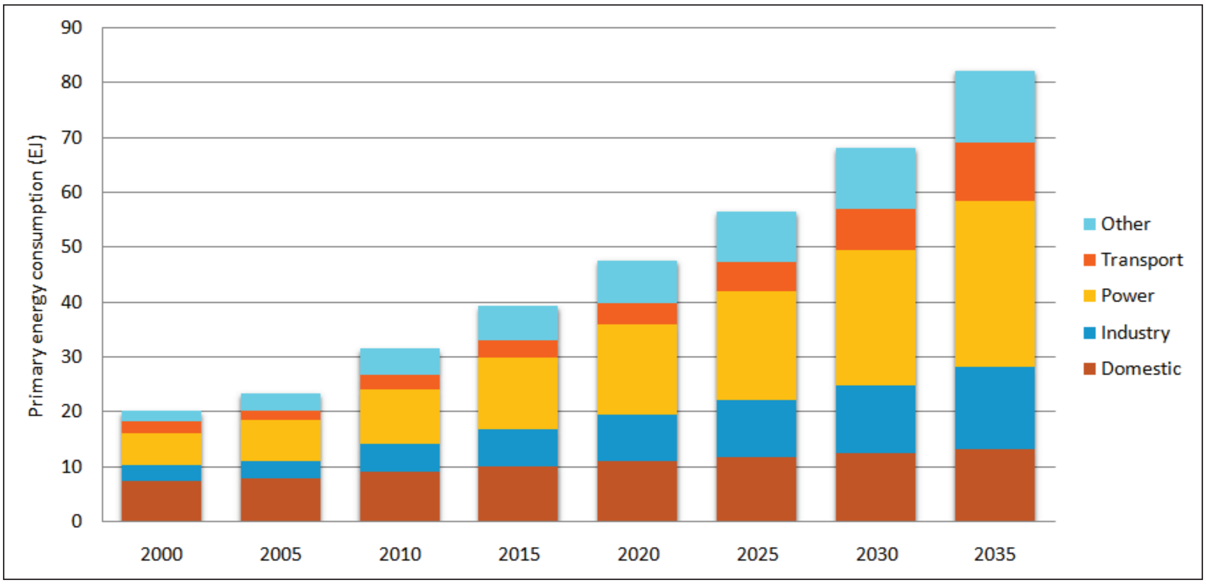
1. Introduction

1.1 Context

India is currently the world's fourth largest emitter of greenhouse gases (GHG), and its transport sector accounts for 13 percent of the country's energy-related CO_2 emissions (MoEF, 2010). However, India's growing transport sector can become more sustainable and climate compatible by aligning development and climate change agendas. As stated in India's National Action Plan for Climate Change (NAPCC), transport emissions can be reduced by adopting a sustainability approach, which includes measures such as increased public transport use, higher penetration of biofuels, and enhanced vehicle efficiency. This study is an output of the **Promoting Low-Carbon Transport in India** (LCT) project, a major UNEP initiative that examines the transport sector's critical role in reducing GHG emissions.

The Indian economy has been growing at a rate of approximately seven percent since 2000 (EIA, 2013). A result of this high economic growth rate is a parallel surge in energy demand. Studies project that under the current policy scenarios, in the next two decades India's primary energy demand will double, from 750 Mtoe in 2011 to 1469 Mtoe in 2030 (IEA, 2014). After coal, oil is the country's largest energy source, accounting for about 30.5 percent of primary energy consumption (BP, 2013). The transport sector's share of the country's total primary energy consumption will increase from 8.1 percent in 2010 to 11.3 percent in 2030 (Figure 1). In 2013, India was the world's fourth-largest consumer and net importer of crude oil and petroleum products after the United States, China, and Japan. India's petroleum product demand reached nearly 3.7 million barrels per day, far above the country's roughly 1 million barrels per day of total liquid production (EIA, 2014). Unless alternative fuels based on indigenously-produced renewable feedstock are developed to substitute or supplement petro-based fuels, India's energy security will remain vulnerable.

Figure 1: Primary energy consumption by sector

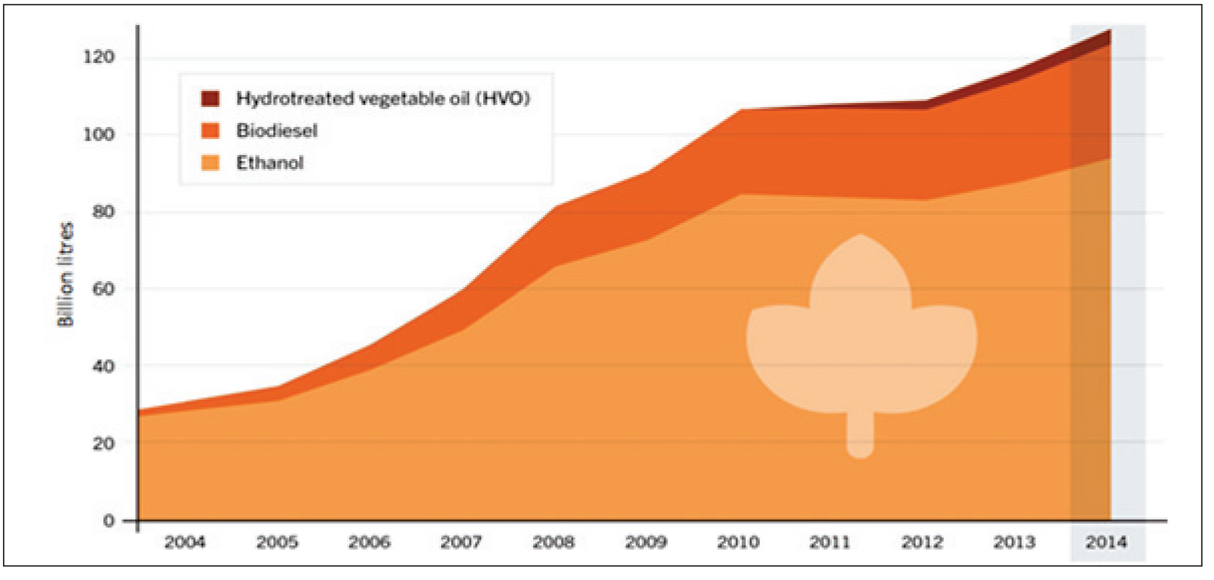


Biofuels are emerging as the most promising alternative options to conventional fuels, as they can be produced locally, and can substitute diesel or gasoline to meet the transportation sector's energy requirements. Biofuels could have positive implications for national energy security, local air quality and GHG mitigation, employment generation and rural development. This report looks at the status and potential of biofuels in India, identifies key challenges in achieving the country's biofuel targets, and analyses their role in India's long-term transport scenarios.

1.2 Current status of biofuels

In 2014, global biofuel production was 127.7 billion litres, 74 percent of which was fuel ethanol. Biodiesel, which accounted for 23 percent, was largely derived from fatty acid methyl ester (FAME), as well as hydrotreated vegetable oil (HVO)[1] in limited but increasing quantities (Figure 2). The top countries for biofuel production were the United States, Brazil, Germany, China, and Argentina. Global production of fuel ethanol grew from 17 billion litres in 2000 to 94 billion litres in 2014, an average annual growth of approximately 13 percent. Over the same time period, global production of biodiesel grew from 0.8 billion litres to 29.7 billion litres, an average annual growth of approximately 30 percent (REN21, 2015).

Figure 2: Ethanol, biodiesel, and HVO global production trends, 2004–14

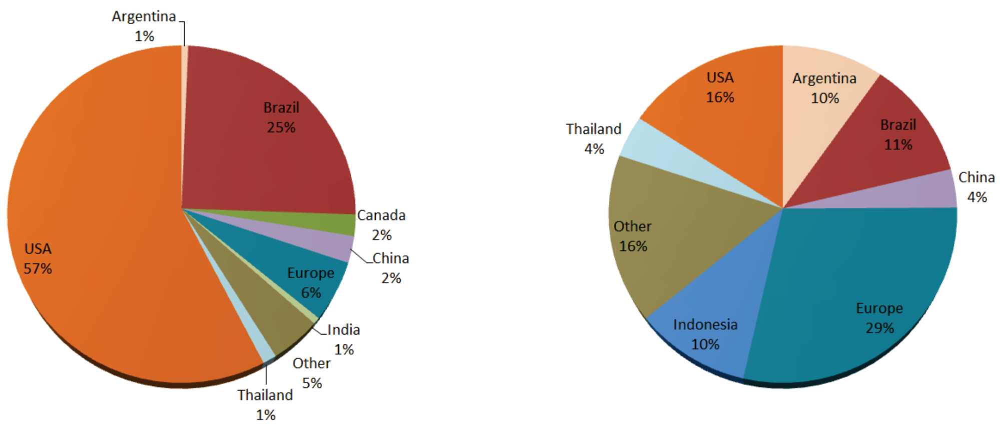


Source: REN21 (2015)

Nevertheless, biofuels accounted for just 3.5 percent of global road transport fuels (energy content basis) in 2014 (REN21, 2015). Figure 3 shows the production of ethanol and biodiesel by country and region in 2014. India's biofuel production currently accounts for nearly 1 percent of global production. The two leading ethanol producers, the USA and Brazil, account for almost 82 percent of all ethanol production. Biodiesel production is more evenly distributed across different regions, with the top 10 countries accounting for less than 80 percent of total production.

1 Hydrotreated Vegetable Oil (HVO), also called Hydroprocessed Esters and Fatty Acids (HEFA) is a renewable diesel fuel that can be produced from a wide array of vegetable oils and fats. The term HVO is used collectively for these biogenic hydrocarbon-based renewable biofuels.

Figure 3: Biofuel production by country in 2014



a) Ethanol **b) Biodiesel**

Source: REN21 (2015)

Biofuels are supported by governments in many different ways, including blending mandates or targets, subsidies, tax exemptions and credits, reduced import duties, support for research and development and direct involvement in biofuel production, as well as other incentives to encourage local biofuel production and use. Biofuel blend mandates—which require that specific amounts of biodiesel, ethanol, and/or advanced biofuels be mixed with petroleum-based transportation fuels—are now in place in 33 countries, with 31 national mandates and 26 state or provincial mandates (REN21, 2015).

1.3 India's biofuel policy

Over a decade ago, India took the initiative on biofuels with the aim of reducing the country's dependence on oil imports and improving energy security. In 2001, the country began a five percent ethanol blending pilot program, and in 2003, formulated a National Biodiesel Mission (NBM) with a goal of 20 percent biodiesel blends by 2011–2012. In 2003, the Government of India (GoI) also mandated a gasoline blend with five percent ethanol in nine states and four union territories (UTs). In November 2006, the mandate was expanded to include almost the entire country, except for a few north-eastern states and Jammu & Kashmir. Like many other countries around the world, India has endured setbacks in its biofuel program due to supply shortages, sharp fluctuations in oil prices, and global concerns about food security.

In December 2009, in order to strengthen and formalize the country's commitment to promoting a sustainable biofuels industry, India adopted the National Policy on Biofuels (NPB). The policy encourages the use of renewable fuels and proposes a 20 percent biofuel (ethanol and biodiesel) mandate by the end of 2017 (MNRE, 2009). However, the NPB does not allow private biofuel manufacturers to market directly. The responsibility for biofuel storage, distribution and marketing is vested in Oil Marketing Companies (OMCs). Biodiesel manufactures must send their biodiesel to OMC-approved collection centres where quality standards are verified. Price and minimum quality requirements are also laid out in the NPB.

Ethanol production in India has risen from 1.5 billion litres in 2002 to 2.7 billion litres in 2013 (OECD/FAO, 2014). However, as per the Report of Expert Committee on *Auto Fuel Vision and Policy 2025* ethanol blends are only available in 13 states and the average blend is two percent (GoI, 2014). The major reason

for non-realization of the Ethanol Blending Program (EBP) are the shortage in supply of ethanol as per the OMCs and low prices of ethanol decided by the government as per Indian Sugar Mills Association (ISMA). In order to improve the availability of ethanol and eliminate uncertainty regarding both pricing and supply, in December 2014 the Indian government fixed price ranges for ethanol. Depending on the distance of the distillery from the OMC depot, ethanol prices range from Rs. 48.5 per litre to Rs. 49.5 per litre (Damodaran, 2014). Further, ethanol produced from non-food feedstocks, such as cellulosic and lignocellulosic materials (including those derived from petrochemicals) were allowed, provided they meet the specifications of the Bureau of Indian Standards (BIS). To increase energy security, GoI is considering a ten percent ethanol blend, which could reducing petroleum imports by up to US$ 3 billion a year (GoI, 2014).

Large-scale blending of biodiesel with conventional diesel has not yet begun in India. Approximately 20 biodiesel plants produce 140 to 300 million litres of biodiesel annually. Most Indian-produced biodiesel is used locally by the informal sector for irrigation and electricity generation, or by automobile and transportation companies for experimental projects (USDA, 2015). The NBM primarily focused on the expansion of Jatropha cultivation in two phases - *demonstration phase* and *expansion phase*, aiming to make the program self-sustainable by producing enough biodiesel to meet the 20 percent blending target. However, Jatropha-based biodiesel production projects have not been as promising as expected due to insufficient yield and revenue, despite state governments offering farmers a minimum purchase price (Gunatilake et al., 2011; Kant and Wu, 2011; Axelsson et al., 2012). The government is offering subsidy programs and tax concessions as part of its effort to boost feedstock production for biofuels.

In June 2015, GoI made key cabinet decisions on biofuels, including granting marketing rights to private biodiesel manufacturers, provided they meet the quality standards of the Ministry of Petroleum and Natural Gas (MoPNG). An exemption was proposed for B100 biodiesel (pure, unblended biodiesel) in order to explore its use as a standalone fuel. The exemption gives private manufacturing marketing rights for B100 biodiesel and authorises retailers to sell it directly to consumers. The new policy will also determine the price of biodiesel. With the intention of further promoting biofuels, the government is exploring the use of a five percent biodiesel blend by bulk users such as railways and defence establishments (GoI, 2015).

1.4 Scope of the report

In India, alcohol and ethanol are commonly derived from molasses, a by-product of sugar production. However, current estimates indicate that molasses alone will not be able to provide enough ethanol to meet India's blending mandates. There has been much criticism of the use and sustainability of first-generation biofuels derived from food crops, including the "food vs. fuel" debate, as well as questions about net GHG balance, net energy balance and water utilization. These discussions have led to growing interest in second-generation biofuels (Bringezu et al., 2009; Ackom et al, 2010; Somerville et al., 2010; Fairley, 2011). More than half of India's land is used for agriculture, producing massive amounts of crop residues that could be used for second-generation biofuel production. Depending on the feedstock choice and the cultivation technique, second-generation biofuel production can potentially lower GHG emissions, and since it is made from agricultural waste residues, does not use land dedicated for food crops. Sustainably produced, second-generation biofuels can potentially promote rural development and improve economic conditions in developing regions.

This report provides a roadmap for biofuels in India and identifies the challenges that need to be overcome to achieve the country's biofuels targets. Section 1 presents an overview of biofuels and highlights the

salient features of India's national biofuels policy. Section 2 details India's current blending targets and future biofuel demand. The technical potential and costs of second-generation biofuels are presented in Section 3, and biofuel's economic potential is explored in Section 4. Finally, India's biofuel roadmap is presented in Section 5.

Photo credit: Gerfriedc

2. Current Targets for Blending and Future Demand for Biofuel

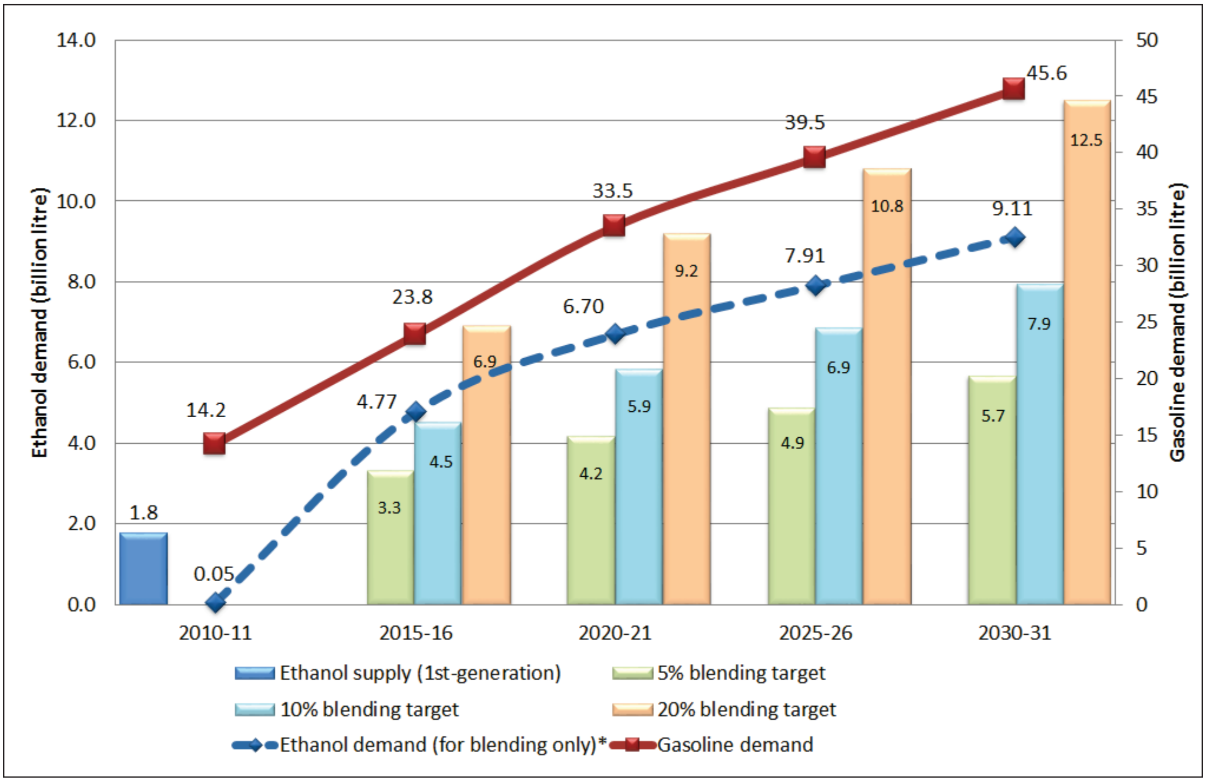
2.1 Ethanol demand and production in India

India is the world's second largest sugarcane producer and a major manufacturer of molasses-derived ethanol. According to the Ministry of Agriculture (MoA), the four states of Uttar Pradesh, Maharashtra, Karnataka and Tamil Nadu contributed more than 80 percent of the country's total sugarcane production in 2010-11 (MoA, 2012). Ethanol in India is primarily produced by the fermentation of molasses. It is estimated that 85-100 kg of sugar (8.5–10%) and 35-45 kg (3.5-4.5%) of molasses can be obtained from 1 tonne of sugarcane whereas the recovery of ethanol from molasses is 22-25%, as per Indian standards (Ravindranath et al., 2005). Theoretically, if the entire sugarcane crop (342.4 Mt in 2010–11) is used for sugar production, estimated molasses production is 15.4 Mt, and the associated estimated ethanol yield is 3.6 billion litres (Purohit and Fischer, 2014). In reality, 70 to 80 percent of sugarcane produced in India is used for sugar production, and the remaining 20 to 30 percent is used for alternative sweeteners (jiggery and khandsari) and seeds (Raju et al., 2009). Moreover, 32.5 percent of the available molasses is used in alcoholic beverages, 25 percent by industry, and 3.5 percent for other applications. The surplus available alcohol is diverted for blending with transportation fuel.

In India, rising per capita income, urbanisation, and infrastructure development has led to increased vehicle density, and consequently, increased demand for gasoline. During the five-year period from 2007 to 2012, demand for gasoline rose by 10.1 percent (PPAC, 2013). Similarly, the rate of growth in demand for ethanol increased by three percent for industrial and other uses and 3.3 percent for potable use (Shinoj et al., 2011). As the GoI is setting an ambitious target of 20 percent ethanol and gasoline blends by 2017, it is important to anticipate ethanol demand so that necessary measures can be taken to ensure sufficient supply.

How much ethanol will be required for blending depends both on blending targets and gasoline demand. According to a study by Dhar and Shukla (2015), which conducted an extensive analysis of energy demand in the transport sector for the period 2010 to 2050, under the business-as-usual (BAU) scenario projected gasoline demand will increase from 14.2 billion litres in 2010 to 45.6 billion litres in 2030. As shown in Figure 4, total ethanol consumption in 2010 was 1.8 billion litres of molasses-derived ethanol, out of which only 50 million litres was used for blending (USDA, 2015). If India is to achieve the 20 percent blending targets set out in the NPB, the country will need to produce 6.7 billion litres of ethanol by 2020 and 9.1 billion litres by 2030. For 2017 alone, the year in which the 20 percent blending regime would start, over 7 billion litres of ethanol would be required to reach the target. Figure 4 also shows the overall ethanol demand (including potable, industry, and other applications) with different blending targets.

Figure 4: Ethanol demand with blending targets (%) in India



**with 20% blending target*

Projections for area and production of sugarcane up to 2030–31 are derived from sugarcane production data from 1950–51 to 2011–12. The net ethanol availability is estimated at 3.2 and 3.6 billion litres in 2020-21 and 2030-31 respectively. In order to achieve the 20 percent blending target without compromising industrial, potable and other needs, India must either increase its ethanol production by nearly three times the present level, or must opt for massive imports of ethanol. Increasing ethanol production to such levels would be extremely challenging, since the country's sugarcane yield has been stagnating at approximately 65-70 tonne/ha (MoA, 2012) for the past several years. It also would not be feasible to increase the area for cultivating sugarcane, as this would mean diverting land from other staple food crops. As sugarcane consumes approximately 20,000-30,000 m^3 of water per hectare per crop (Raju et al., 2012), the overexploitation of groundwater for energy production would not be a sustainable option. While only molasses is used in India to produce ethanol, its direct production from sugarcane juice would compete with sugar production for the food market.

2.2 Biodiesel demand and accessibility in India

In order to meet its goal of 20 percent biodiesel in high speed diesel (HSD) by 2012, the NBM set a target of dedicating 11.2 to 13.4 Mha of land to Jatropha cultivation by the end of its 11th Five-Year Plan. The central and several state governments provided fiscal incentives to farmers for planting Jatropha and other non-edible oilseeds. Several public institutions also supported the NBM's plan in various ways, including state biofuel boards, state agricultural universities and cooperative sectors. However,

the government's ambitious plan was not realized due to a lack of enough Jatropha seeds to produce the targeted amount of biodiesel. Further, the cost of biodiesel production turned out to be 20 to 50 percent more expensive than the set purchase price[2]. Consequently, there were no biodiesel sales. Approximately, 20 Indian biodiesel plants annually produce 140 to 300 million litres of biodiesel (USDA, 2010; Raju et al., 2012), which is mostly utilised by the informal sector locally for irrigation, electricity etc., and by automotive companies for experimental projects.

According to a study by Dhar and Shukla (2015), under a BAU scenario, demand for diesel for transport is expected to grow from 46.9 billion litres in 2010 to 155.7 billion litres in 2030. Figure 5 shows biodiesel demand for the three different blending targets in the near future. Biodiesel demand for 20 percent blending targets is expected to grow 19.8 and 31.1 billion litres in 2020-21 and 2030-31, respectively.

Figure 5: Biodiesel demand with blending targets (%) in India

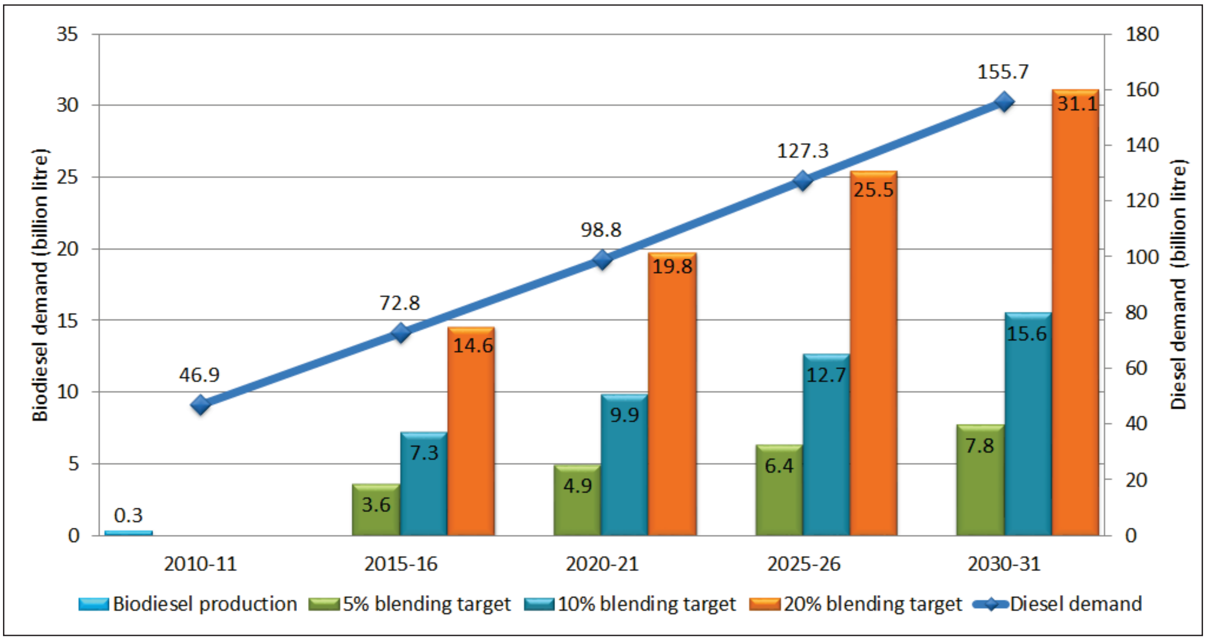


Table 1 shows the estimated demand for biodiesel and the associated land requirements for Jatropha plantation according to various blending requirements. The seed yield is assumed to be 2.5 t/ha and the biodiesel recovery rate is considered to be 30 percent (Purohit and Fischer, 2014). Assuming that the yield and oil content of Jatropha would remain at the same level and that no new superior feedstocks would be introduced, some 25 Mha and 40 Mha of Jatropha cultivation would be necessary to meet the 20 percent blending target by 2020-21 and 2030-31, respectively.

2 In October 2005, the MoPNG announced a biodiesel purchase policy under which OMCs would purchase biodiesel from 20 procurement centres across the country to blend with high speed diesel by January 2006. The purchase price was set at US$ 0.49 per litre.

Table 1. Biodiesel demand and associated land requirement for Jatropha plantation

Year	Diesel demand (BL)	For 5% blending		For 10% blending		For 20% blending	
		Biodiesel demand (BL)	Jatropha area (Mha)	Biodiesel demand (BL)	Jatropha area (Mha)	Biodiesel demand (BL)	Jatropha area (Mha)
2010-11	46.9	2.3	3.0	4.7	6.0	9.4	11.9
2015-16	72.8	3.6	4.6	7.3	9.3	14.6	18.6
2020-21	98.8	4.9	6.3	9.9	12.6	19.8	25.2
2025-26	127.3	6.4	8.1	12.7	16.2	25.5	32.4
2030-31	155.7	7.8	9.9	15.6	19.8	31.1	39.7

The Indian Planning Commission has estimated that with appropriate availability of planting stocks, it would be possible to cultivate 13.4 Mha of Jatropha by the year 2012 (GoI, 2003). However, Jatropha plantations have been slow to take off. Lack of good quality plant stock, disputes over wasteland ownership, and other issues have hindered Jatropha cultivation. So far, So far, only 0.5 Mha land has been planted with Jatropha, and the government has not initiated the purchase of biodiesel through the designated purchase centres, even though an MPP of $0.49 per litre was announced a few years ago. In January 2015, the Union Cabinet amended the NPB to make it easier for customers to purchase biodiesel directly from private manufacturers, authorized dealers, and authorized OMC joint ventures. The price of biodiesel is presently market determined.

2.3 Feasibility of achieving targets using the first-generation pathway

Although India, through its multi-pronged policy approach, has taken positive steps towards developing and promoting biofuels, the possibility of achieving the NPB's 20 percent blend target seems remote. Due to constraints such as the state of existing infrastructure and institutional set-up, production is currently limited to first-generation biofuels, namely molasses-derived ethanol and tree-borne oilseed (TBO) biodiesel. Feedstock and first-generation biofuel production depends on well-established technologies, and the final product has been widely commercialized. However, concerns about food security and land use have raised questions about the viability of first-generation biofuels. The direct benefits of biofuels are linked to indirect impacts that may adversely affect GHG emissions, ecosystems, and food and water security (Koh and Ghazoul, 2008). While both first- and second-generation biofuel producers may compete with other industries for feedstock (Ackom et al., 2010b), currently competition is more pronounced with first-generation biofuels. There is great concern about feedstock competition between the biofuel and food industries, and how using of food crops for fuel production would impact food security, the food industry and society in general. The increasing questions about the sustainability of many first-generation biofuels has called attention to the potential of second-generation (or "advanced") biofuels.

2.4 Second-generation pathway

Second-generation biofuels can be produced through two different processes: biochemical or thermochemical. The biochemical process is based on enzymatic hydrolysis of the lignocellulosic material, using a variety of enzymes that break the cellulosic material into sugars. In the second step of the biochemical process, the sugars are fermented into alcohol, which is then distilled into ethanol. The

thermochemical process uses high temperatures to transform feedstock into a synthesis gas. This gas is then transformed into different types of liquid or gaseous fuels, called “synthetic fuels” (such as BTL-diesel and bio-SNG). The future scenarios analyse two technology pathways for analysis i) cellulosic ethanol into ethanol and ii) BTL-diesel using the Fischer-Tropsch process (Wright and Brown, 2007), as there is information on these two technology pathways on their costs since there are demonstration projects for both these technologies (Wright and Brown, 2007; IEA, 2013a).

Photo credit: FAO Aquaculture Photo Library

3. Technical Potential and Cost of Second Generation Biofuels

Second-generation biofuels are derived from agricultural residues and by-products, organic wastes, and materials from energy plantations, using a variety of woody, grassy, and waste materials as a feedstock. These new fuels offer considerable potential for promoting rural development and improving economic conditions in emerging and developing regions. Countries such as the United States, Brazil, and Canada have initiated major biofuel programs to produce cost-efficient ethanol and other fuels from agricultural and forest lignocellulosic biomass (REN21, 2015).

In India, concerns about the economics and sustainability of molasses-based ethanol have led to a search for alternative ethanol feedstocks. Sweet sorghum, for example, has advantages that make it a potential source of raw material for commercial ethanol production (Basavaraj et al., 2013). The potential for second-generation biofuels depends on the several factors: the crop residues generated annually, current usage levels, and the surplus available for energy use. In this section, we will assess the energy potential of biomass resources in the form of residues and wastes in India. To assess the availability of crop residues for energy generation, it is imperative to understand how agricultural land use, prevailing crop patterns, crop residue use, and costs.

3.1 Agricultural residue availability in India

Some 43 percent of India's 328 million hectares is planted with crops. The net cropped area has been stable since 1970 at approximately 140 Mha. However, the gross cropped area, which measures multiple crops grown per year, increased from 132 Mha in 1950–51 to approximately 195 Mha in 2008–09. There are two main growing seasons in India, namely *Kharif* (monsoon season in the southwest) and *Rabi* (monsoon season in the north-east). The gross cropped area includes land that produces multiple crops in the same year (usually two crops), mainly on irrigated land. The net irrigated area has increased substantially in the last few decades, from 21 Mha in 1950–51 to 63 Mha in 2008–09. Rice and wheat are the dominant crops, together accounting for 41 percent of the cropped area, while pulses, oil seeds, and other commercial crops account for 13.8 percent, 15.9 percent and 10.2 percent, respectively. Table 2 presents the area and production of different crops (MoA, 2012). For the years 2020–21 and 2030–31, the projected area and productivity are based on data from 1950–51 to 2011–12 (Purohit and Fischer, 2014).

Table 2. Area and production of different crops in India

Crop	Economic produce	Area (Mha)			Crop production (Mt)		
		2010/11	2020/21	2030/31	2010/11	2020/21	2030/31
Rice	Foodgrains	42.9	48.1	50.3	96.0	109.9	123.2
Wheat	Foodgrains	29.1	33.7	36.6	87.0	108.2	121.1
Jowar (Sweet Sorghum)	Foodgrains	7.4	5.2	3.4	7.0	6.0	5.7
Bajra	Foodgrains	9.6	9.3	8.8	10.4	11.4	12.3
Maize	Foodgrains	8.6	8.4	9.0	21.7	24.8	28.3
Other cereals	Foodgrains	2.9	2.1	1.5	4.6	3.9	3.8
Gram	Foodgrains	9.2	8.9	8.7	8.2	8.4	8.6
Tur (Arhar)	Foodgrains	4.4	4.4	4.7	2.9	3.1	3.3
Lentil (Masur)	Foodgrains	1.6	1.7	1.9	0.9	1.2	1.4
Other pulses	Foodgrains	11.2	12.8	13.2	6.2	6.3	6.8
Groundnut	Oilseeds	5.9	6.0	6.1	8.3	8.9	9.6
Rapeseed & Mustard	Oilseeds	6.9	7.2	7.9	8.2	9.6	11.0
Other oilseeds	Oilseeds	14.5	16.7	18.6	16.0	19.3	22.4
Cotton	Fibre	11.2	11.9	12.6	5.6	6.1	6.4
Jute and Mesta	Fibre	0.9	1.0	1.0	1.9	2.3	2.5
Sugarcane	Sugar	4.9	5.1	5.6	342.4	406.4	459.3
Total		**171.0**	**182.4**	**190.1**	**627.3**	**735.9**	**825.8**

Source: (MoA, 2012; Purohit and Fischer, 2014)

Figure 6 shows the total residue production in India from the cultivation of different grains, oilseeds, fibres and sugarcane. The specific ratios of residue to grain production of different crops are taken from Kumar et al. (2002); Ravindranath et al. (2005) and Purohit and Michaelowa (2007). For the year 2010–11, the area and total crop production was 171 Mha and 627 Mt, respectively. The gross residue availability is estimated at 680 Mt for 2010-11 and 877 Mt for 2030–31 respectively (Purohit and Fischer, 2014).

Figure 6: Gross residue availability from crop production in India[3]

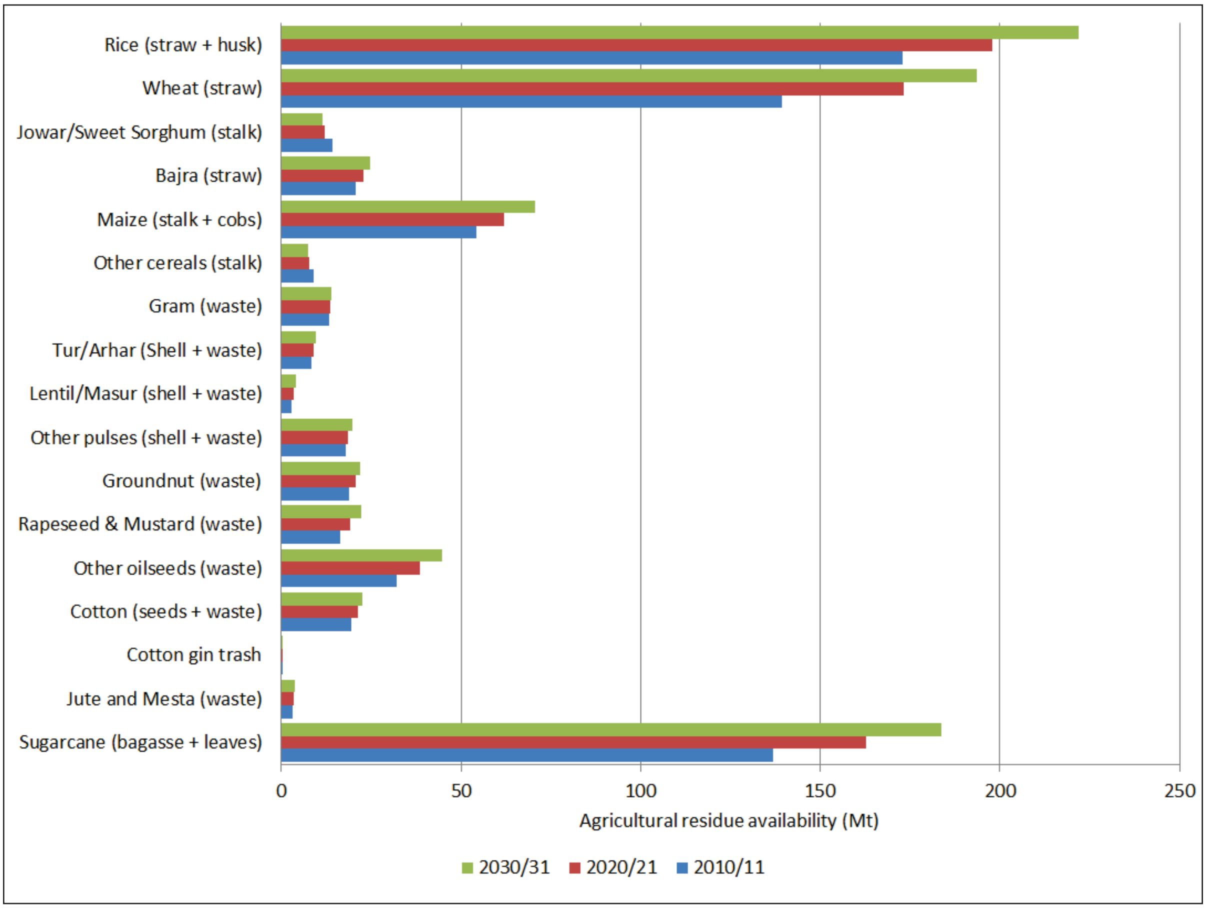
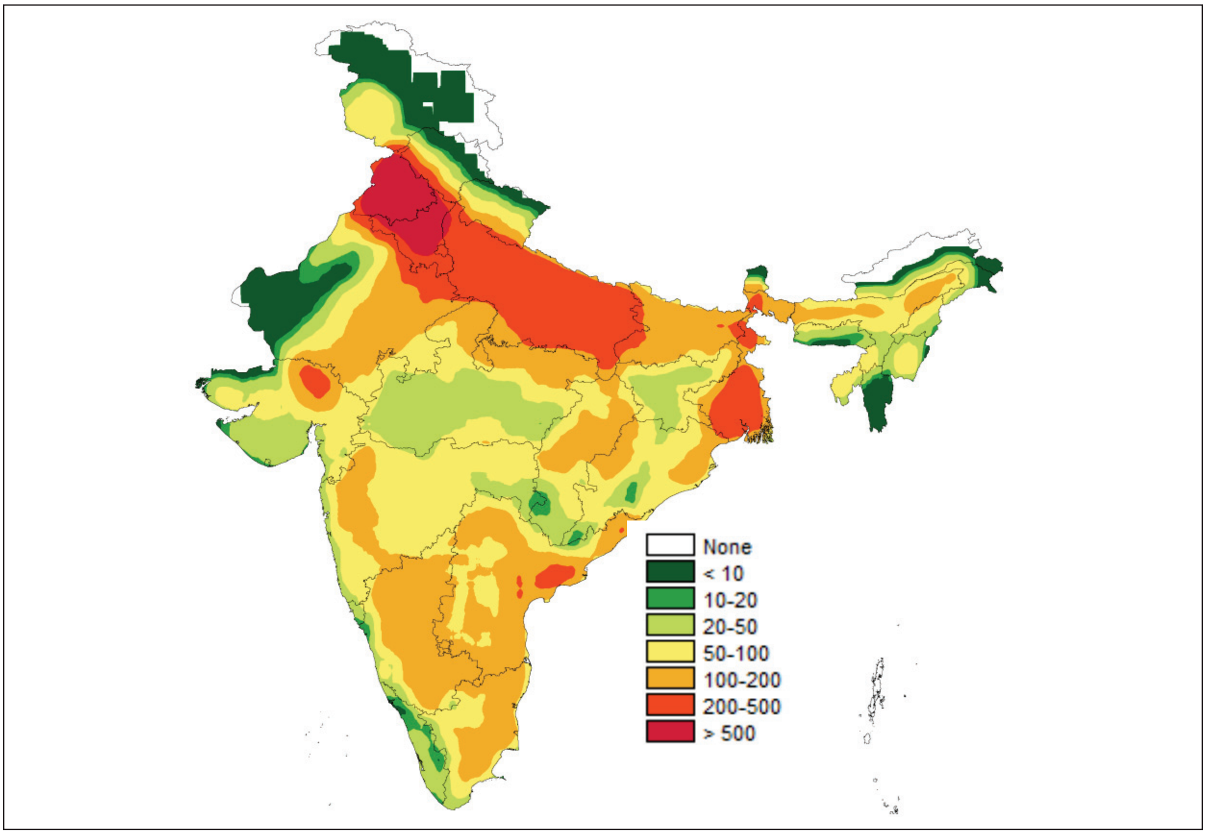


Figure 7 presents the density of annual cereal crop residue production in 2010–11 within a radius of 50 km around the shown location. The highest average densities of more than 500 tonnes per km^2 were calculated for Punjab and Haryana, where intensive wheat-rice systems are practiced on mostly irrigated land. The pixels shown in dark red, with an average density exceeding 500 ton per km^2, indicate that the estimated total crop residue production in a radius of 50 km was more than 3.9 Mt in 2010–11 (Purohit and Fischer, 2014). The crop residue production tables for different crops by state are available in Purohit and Fisher (2014).

3 Moisture content (air day): 30% for bagasse and 10% for all other agricultural residues

Figure 7: Density of annual cereal crop residue production in 2010– 11 (tonnes/km^2)



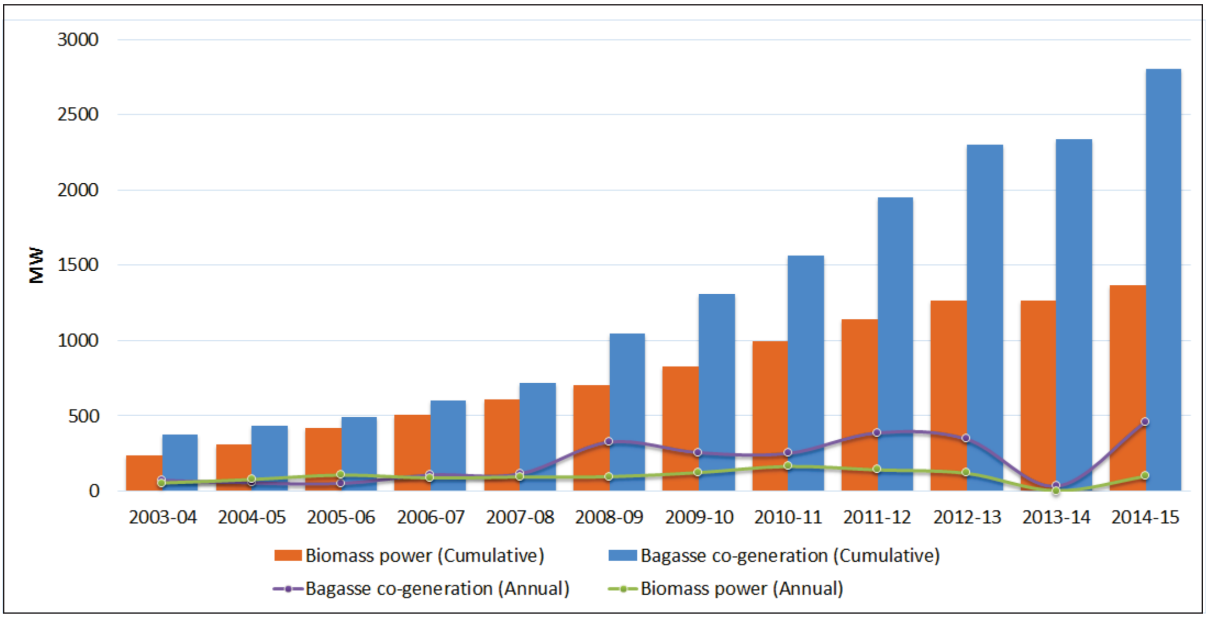
Source: Adapted from Purohit and Fischer (2014)

The use of crop residues varies from region to region and depends on their calorific values, lignin content, density, palatability by livestock, and nutritive value. Most cereal and pulse residues have fodder value. However, the woody nature of some crop residues makes them appropriate only for fuel uses. In India, most crop residues are used either as cattle fodder, cooking fuel, or thatch material for housing (Purohit et al., 2006; Purohit, 2009). India has a large cattle population of 512 million (Ravindranath et al., 2005). Although India has over 10 Mha of grazing land, grass productivity is low due to climate and land degradation. Consequently, cattle fodder consists almost entirely of crop residues from cereals and pulses. The estimated total amount of residues used as fodder was 301 Mt in 1996–97 (CMIE, 1997), and in 2010–11, an estimated 360 Mt was used, accounting for approximately 53 percent of total residue, as shown in Figure 6. In rural areas, cereal crop residues are primarily used as fodder, and the only residues that are likely to be available for energy production are rice husk/straw, maize stalks and cobs, and ligneous residues.

An alternative application of non-fodder and non-fertiliser agricultural residues is biomass power and bagasse cogeneration. The Indian Ministry of New and Renewable Energy (MNRE) implemented its Biomass Power/Cogeneration programme with the objective of promoting technologies for generating grid power with the country's biomass resources. Policies at the state and national level promote biomass cogeneration. A package of fiscal concessions, such as accelerated depreciation, concessional custom duty, excise duty exemption, income tax exemption on projects for power generation for 10 years, and electricity duty exemption, are available to biomass power/cogeneration projects. As of 2014, 1365 MW

of biomass power and 2800 MW of bagasse cogeneration projects (grid interactive) had been installed in India (MNRE, 2015). As of June 2015, an additional 602 MW biomass (non-bagasse) cogeneration and 170 MW biomass gasification off-grid projects had also been installed (MNRE, 2015). Thus, when estimating the net biofuel potential of agricultural residues in India, it is important to factor in the significant use of agricultural residues for power generation.

Figure 8: Installed capacity of biomass power and bagasse cogeneration projects in India



Source: MNRE Annual Reports

For the base year 2010–11, the installed capacity of grid-connected bagasse cogeneration projects was 1562 MW. Using a specific bagasse consumption of 1.6 kg/kWh and a capacity factor of 53 percent (MNRE, 2012), the bagasse used in the cogeneration projects was estimated at 11.6 Mt, which is 20 percent of the bagasse availability for energy applications. Similarly, the cumulative installed capacity of grid and off-grid biomass power/cogeneration projects was 1400 MW (998 MW grid-connected biomass power and 274 MW off-grid biomass cogeneration (non-bagasse), and 128 MW biomass gasification projects) during 2010–11 (MNRE, 2011). Using the specific biomass consumption of 1.21 kg/kWh and capacity factor of 80 percent (MNRE, 2012), the biomass used in the power/cogeneration projects was estimated at 11.8 Mt, which is approximately 10 percent of (non-bagasse) agricultural residues available for energy applications. This share of residues used for power/cogeneration is kept constant in estimates of net biofuel production from agricultural residues for the near future.

For the year 2010–11, the agricultural residues available for energy applications was estimated at 150 Mt, of which 130 Mt could be used to produce approximately 28 billion litres of ethanol annually (Table 3), assuming ethanol yields of 214 lge/ton dry matter (t_{DM}) for cellulosic-ethanol and 217 lge/t_{DM} for biomass-to-liquid (BTL) diesel (IEA, 2010). For the estimates presented in Table 3, it is assumed that 20 percent of agricultural residue is lost in collection, transportation and storage, etc. (Purohit, 2009; Singh, 2015). Ethanol yields per t_{DM} will improve up to 250 litres per t_{DM} in 2020–21, 275 litres per t_{DM} in 2025–26 and to 300 litres per t_{DM} in 2030–31. Other studies also showed the bio-conversion to cellulosic ethanol and BTL to be in a range that varies from 110–330 lge/t_{DM} for biochemical enzymatic

hydrolysis ethanol and 75–200 lge/t_{DM} for Fischer-Tropsch BTL, respectively (Sims et. al., 2010; Ackom et. al, 2013). The net obtainable ethanol production is estimated at 37 and 50 billion litres in 2020–21 and 2031–31, respectively, which would be sufficient to meet the 20 percent blending target by 2030–31. In our estimate, this potential biofuel production represents approximately one-fourth of the gross residue availability (Figure 6) if all crop residues (e.g., straw, husks, stalks, cobs, shells, bagasse, etc.) were to be converted into biofuels. Due to the predominant feed use, this potential production accounts for only 5.1 percent of the theoretical maximum from foodgrains, straw, stalks, and husks. The net ethanol production would increase by 23 percent (from 50 to 62 billion litres) in 2030–31 if an additional 10 percent of crop residues obtained from foodgrains (such as paddy straw, wheat straw, jowar stalks, bajra straw) could be diverted to the biofuel production route. Moreover, according to the Biomass Atlas of India (BRAI, 2015), it is estimated that an additional 104 Mt of biomass is available in India in forest and wastelands, an amount that is not considered in this analysis.

Table 3. Biofuel potential from net availability of agricultural residues

Crop residue	Agricultural residue used for fodder, fuel and other purposes* (%)			Net agri-residue availability for biofuels** (Mt)			Net ethanol availability (billion litres)		
	Fodder	Fuel	Other	2010/11	2020/21	2030/31	2010/11	2020/21	2030/31
Rice straw and husk	80.8	11.1	8.0	13.8	15.8	17.8	3.0	4.0	5.3
Wheat straw	86.4	0.0	13.6	0.0	0.0	0.0	0.0	0.0	0.0
Jowar stalk	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bajra straw	89.8	0.0	10.2	0.0	0.0	0.0	0.0	0.0	0.0
Maize stalk and cobs	81.0	19.0	0.0	7.4	8.5	9.7	1.6	2.1	2.9
Other cereals stalk	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gram waste	0.0	100.0	0.0	9.5	9.7	10.0	2.0	2.4	3.0
Tur shell and waste	3.5	48.5	48.0	2.9	3.1	3.3	0.6	0.8	1.0
Lentil shell and waste	3.5	48.5	48.0	1.0	1.3	1.4	0.2	0.3	0.4
Other pulses - shell and waste	3.5	48.5	48.0	6.3	6.4	6.9	1.3	1.6	2.1
Groundnut waste	0.0	13.2	86.8	1.8	1.9	2.1	0.4	0.5	0.6
Rape & Mustard waste	0.0	100.0	0.0	11.8	13.9	15.9	2.5	3.5	4.8
Other oilseeds waste	0.0	100.0	0.0	23.1	27.8	32.2	4.9	7.0	9.7

Cotton seeds and waste	0.0	100.0	0.0	14.1	15.3	16.2	3.0	3.8	4.9
Cotton gin trash	0.0	100.0	0.0	0.3	0.3	0.4	0.1	0.1	0.1
Jute and Mesta waste	0.0	100.0	0.0	2.2	2.6	2.8	0.5	0.7	0.9
Sugarcane bagasse and leaves	11.8	41.0	47.2	35.9	42.6	48.2	7.7	10.7	14.5
Total				**130.2**	**149.3**	**166.8**	**27.9**	**37.3**	**50.1**

* Source: Ravindranath et al. (2005)

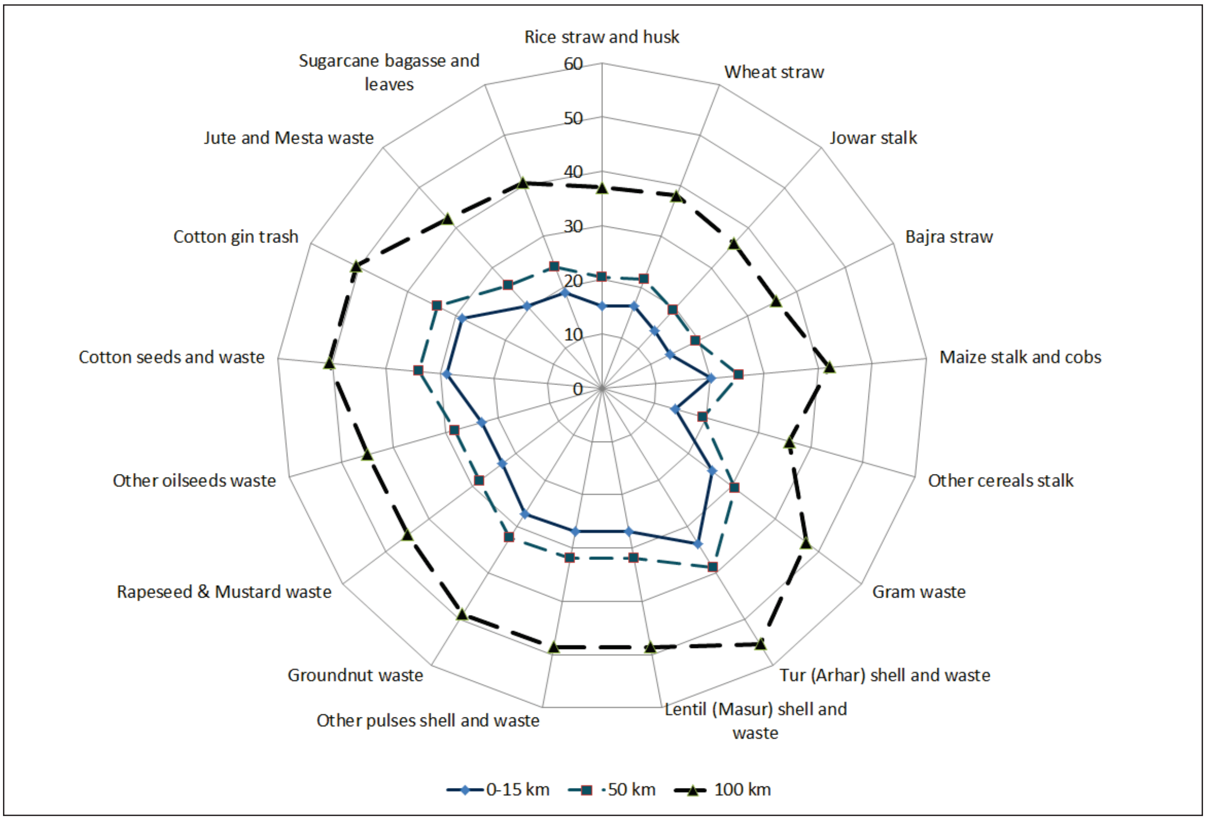
** Apart from fodder and other applications the net agricultural residue availability for biofuels also takes into account the residue used for biomass power/cogeneration projects.

3.2 Market price and cost of agricultural residues

It is difficult to assess the costs of agricultural and forestry residues due to the absence of established markets for these materials. The cost of supplying agricultural residue supply to biofuel production facilities strongly depends on regionally specific conditions, such as the availability of the residues, transport infrastructure, whether there is a bio-refinery with access to roads, rail or ports. In India, molasses is commonly used for alcohol and ethanol production. During the previous decade, molasses prices fluctuated substantially, ranging from US$18 to US$92 per tonne. The market price of agricultural residues also varies considerably in India. According to available literature, the market price of rice husks varied from US$18 to US$74 per tonne in 2010, whereas the price of rice straw was US$11 to US$13 per tonne (Sharma, 2010). Another study reported the price of bagasse at US$12 to US$14 per tonne, whereas the price of rice husks was at US$22 to US$30 per tonne (IRENA, 2012). As mentioned above, straw from foodgrains is primarily used for cattle feed in India. Moreover, foodgrain straw is also used for construction material, straw board, paper and hardboard units, as well as packing materials for glassware. As per CSE (2010) estimates, US$92 to US$111 per tonne is the standard rate for wheat or bajra straw anywhere in Rajasthan at harvest time. In Gujarat, it varies from US$74 to US$92 per tonne, while in Maharashtra it varies from US$83 to US$102 per tonne.

Tripathi et al. (1998) observed that when taking in to account a critical analysis of various factors associated with agricultural residues (including production, transport, and handling at the processing plant) the cost may be substantial. Figure 9 presents the cost of various agricultural residues at distances of 15 km, 50 km, 100 km from farms (Purohit and Fischer, 2014). The cost of residues varies from a minimum of US$14 per tonne for bajra straw to a maximum of US$34 per tonne for arhar stalks. Transportation costs contribute significantly to the total price of the residues.

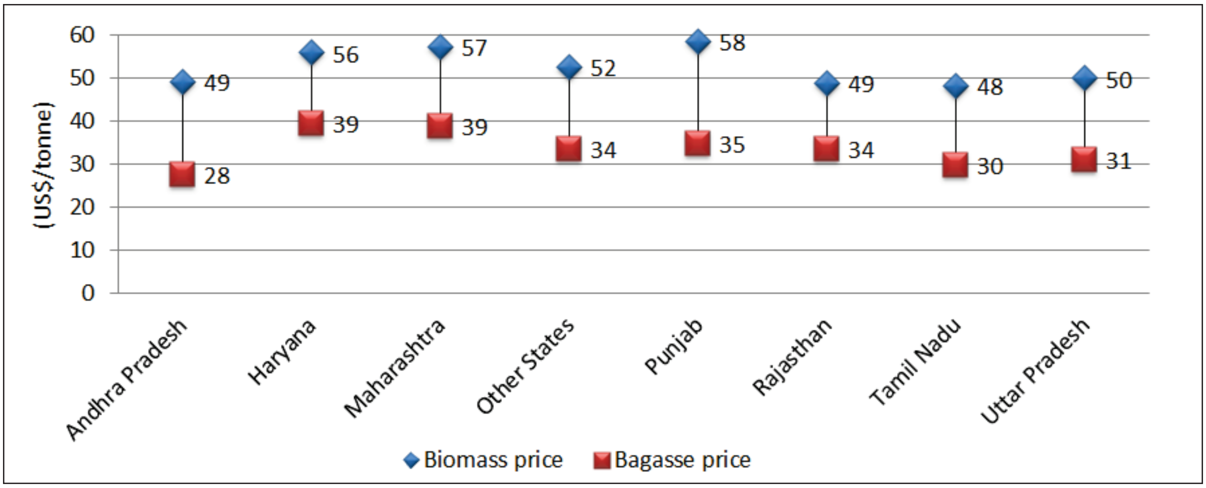
Figure 9: Cost of agricultural residues (US$/tonne) from farmgate



Source: Purohit and Fischer (2004)

At a transportation distance of 100 km, the cost of agricultural residues varied from US$36 per tonne for bajra straw to US$55/tonne for arhar stalks. These prices are quite close to the biomass/bagasse price estimates provided by CERC show in Figure 10 (CERC, 2015).

Figure 10: Biomass feedstock price by state in India as per CERC

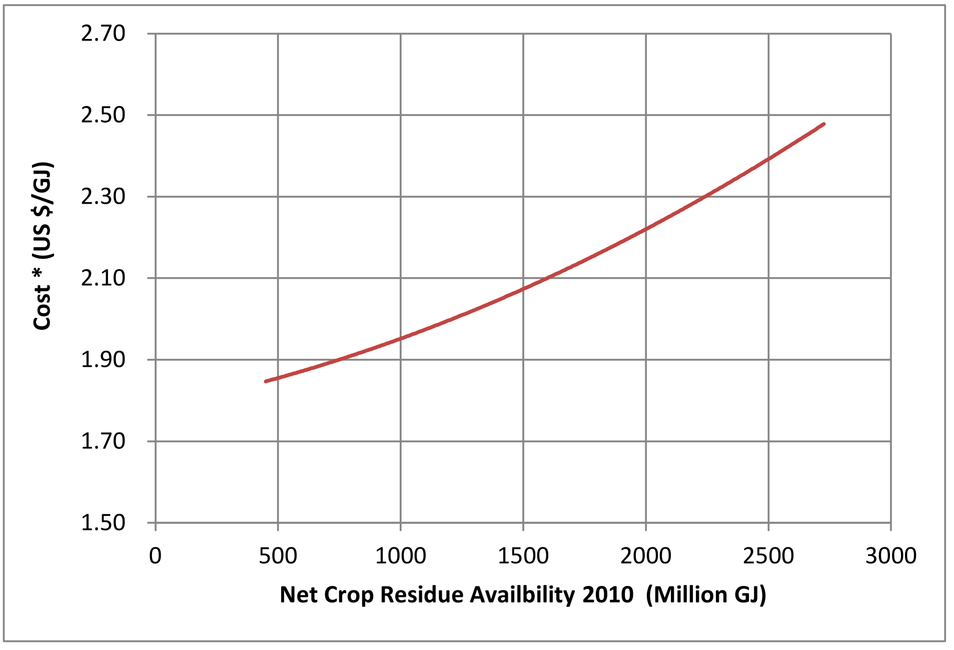


Source: CERC (2015)

3.3. Cost curve for biomass

Since bio-refineries can use different kinds of biomass to produce ethanol or biodiesel, instead of studying individual types of biomass an aggregate supply curve was developed (Figure 11). This supply curve reflects factory gate price for a bio-refinery. Since transportation is a major component of biomass costs (Purohit and Fischer, 2014) the refinery size must be taken into account when balancing the benefits from economies of scale with the cost of transporting biomass. The calculations are made for a bio-refinery with a capacity of 150 million US gallons per year (567 million litres). For a refinery of this size, based on a second-generation cellulosic ethanol production process, the agricultural residues required at refinery gate would be approximately 1.3 Mt[4] annually.

Figure 11: Aggregate biomass supply curve for the top ten states



In order to produce 1.3 Mt of agricultural residue, there must be a sufficiently dense source or catchment area. Some states with a high cropping intensity, like Maharashtra and Uttar Pradesh, can meet this demand within a radius of 60 km from a bio-refinery. However, for the states that produce the top 10 crops (Figure 7) the biomass feedstock would need to be transported an average distance of 72 km.

4 Ethanol has a density of 789 kg/m^3 and therefore refinery output is 450 tonnes. If we consider an efficiency of 35% then biomass required as an input would be 1.3 Mt

Photo credit: FAO Aquaculture Photo Library

4. Economic Potential of Biofuels

The economic potentials for ethanol and biodiesel were analysed using the ANSWER MARKAL model. ANSWER MARKAL is a bottom-up energy system model (Loulou et. al., 2004) that is used extensively for analysing Indian energy systems. The model framework and underlying assumptions are described in Dhar and Shukla (2015). As the model tries to optimise the overall energy system costs, the results show the least costly solution. The biomass supply curve was used as an input for the second-generation biomass conversion technologies based on the bio-chemical and thermo-chemical routes. Biomass was shown to be available for both the bio-refineries that produce second-generation biofuels as well as those that generate power.

The scenario for the future assumes a favourable enabling environment where biofuel producers have an easy access to markets and can make use of existing infrastructure for gasoline and diesel distribution, and so there is no additional distribution cost. The scenario also assumes a rapid reduction in bio-refineries costs as lessons learned are applied to new refineries. First-generation ethanol made from sugarcane molasses is shown to be sufficient to meet the demand for potable and industrial needs, with a small surplus left for blending (Table 4). However, this surplus will not be nearly enough to meet the five percent blending target (Figure 4). This surplus ethanol supply would need to be supplemented with ethanol produced from second-generation biomass in order to meet the blending target. Further, the surplus availability of ethanol is expected to decrease with time due to increasing demand for potable, industrial and other sectors (Table 4).

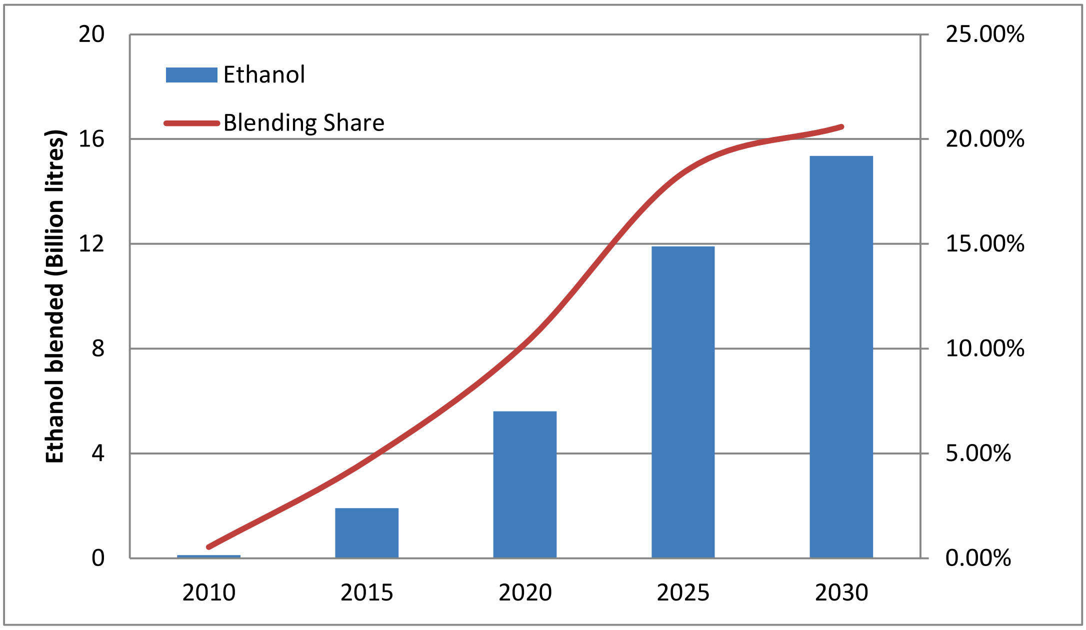
Table 4. Ethanol availability for blending from first-generation biofuels

Year	Ethanol production from molasses (BL)	Ethanol use (BL)			Net ethanol availability for blending (BL)
		Potable	Industry	Other	
2010	2.72	0.88	0.68	0.10	1.06
2015	3.01	1.04	0.79	0.11	1.08
2020	3.22	1.22	0.91	0.13	0.96
2025	3.43	1.44	1.06	0.15	0.79
2030	3.64	1.69	1.23	0.17	0.56

4.1 Ethanol potential

In the medium-term (by 2030), it would be possible to achieve the 20 percent blending target using both first- and second-generation biofuels. However, in the short-term (by 2020), achieving the 20 percent blending target would be difficult. The amount of ethanol required for a 20 percent blend in 2030 would be around 12.5 billion litres, almost equivalent to the current demand for gasoline. The bulk of this demand would be met through second-generation biofuels derived from agricultural residues.

Figure 12: Demand for ethanol for blending and share in blending



4.2 Biodiesel potential

So far, the Indian biodiesel program has relied on Jatropha. Since the Jatropha program has multiple objectives (using degraded lands, creating rural employment, and improving energy security) it has been analysed separately in Section 2. The economic analysis using the ANSWER MARKAL model focuses on producing second-generation biodiesel with crop wastes. The model(ibid) allocates crop wastes for both power generation and biofuel production. Within biofuels, biodiesel is competing with ethanol for crop wastes. The analysis shows that biodiesel not the ideal product for biomass conversion, and second-generation biodiesel production would reach a little more than 5 billion litres by 2030 (or three percent of diesel demand). In absolute terms, second-generation biodiesel production would be less than ethanol.

Figure 13: Biodiesel from second-generation pathways for blending and share in blending

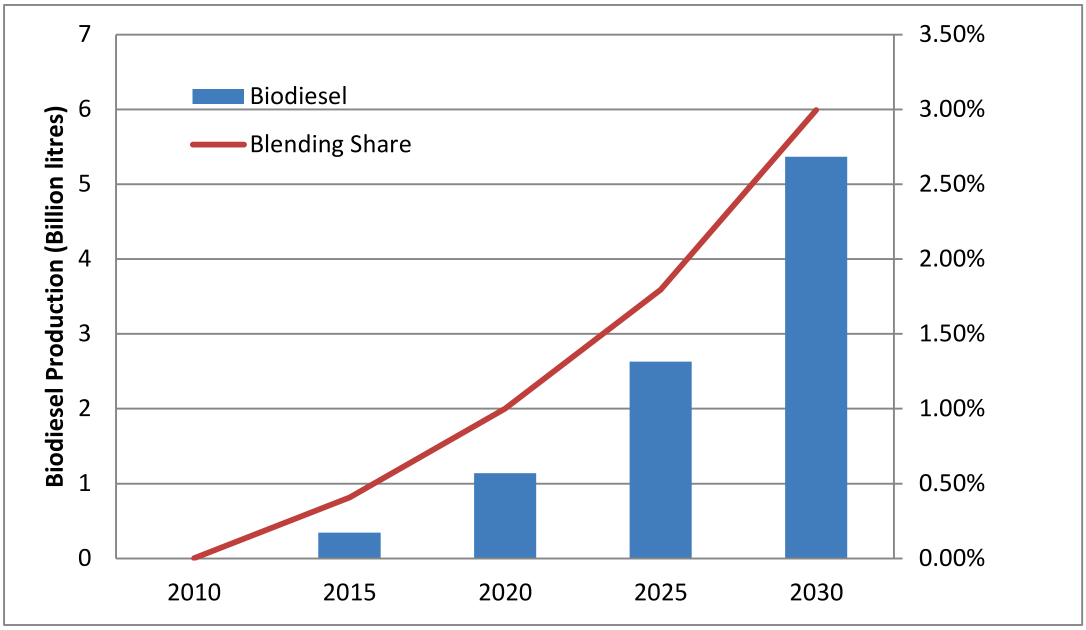


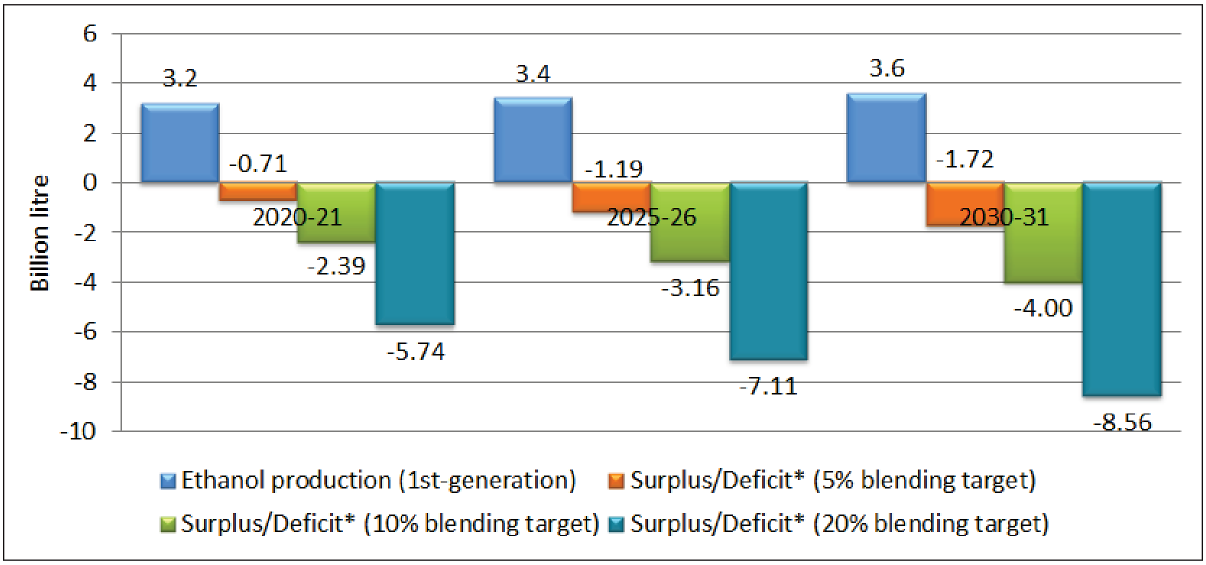

Photo credit: FAO Aquaculture Photo Library

5. Biofuel Roadmap for India

In 2014, global biofuel production reached around 123.7 billion litres, of which 94 billion litres were ethanol and 29.7 billion litres were biodiesel (REN21, 2015). These biofuels were almost entirely first-generation, based mostly on sugarcane and corn, and to a lesser extent on canola, sunflower and other agricultural feedstocks. Research and development is ongoing on various second-generation biofuel processes, such as bio-chemical and thermo-chemical routes. Lignocellulosic ethanol (based on bio-chemical process) and BTL-diesel (based on thermos-chemical process) are the most widely discussed second-generation biofuel options as they can be used pure or blended with conventional gasoline and diesel (IEA, 2010). Both the private and public sectors of the Indian biofuel industry claim to be successful in developing and customizing technology for converting lignocellulosic materials. Trials are underway to process municipal solid waste, micro-algae, and photosynthetic organisms into advanced biofuels.

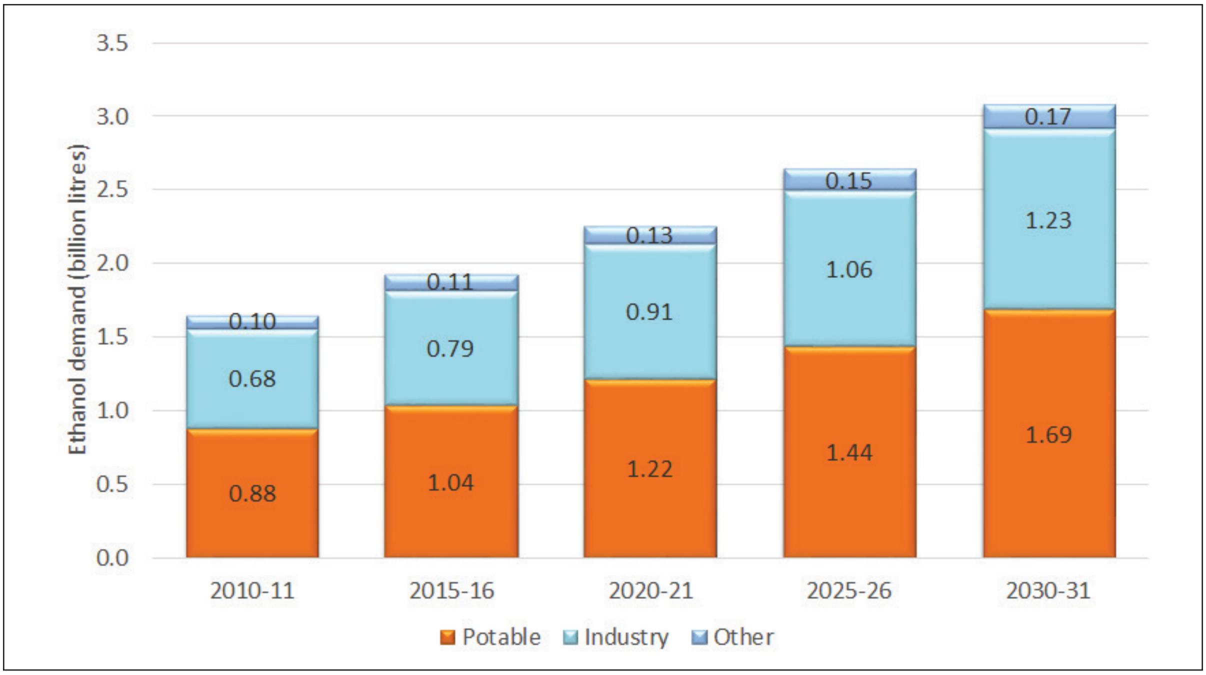
As discussed in Chapter 2, the current ethanol (from sugarcane) and biodiesel (from Jatropha) availability is not sufficient to meet the NPB's target of 20 percent blending by 2017. Figure 14 presents the surplus and deficit of ethanol according to different blending requirements, after taking into account the demand for ethanol in potable, industrial and other applications. The shares of molasses being used for potable, industrial, and other applications are 32.5 percent, 25 percent, and 3.5 percent, respectively. The available surplus alcohol is being diverted for blending with transportation fuel. The rate of growth in demand for ethanol increased by three percent for industrial and other uses and 3.3 percent for potable use (Shinoj et al., 2011). These growth rates are expected to continue over the next several years and are incorporated in the estimates presented in this study. Figure 15 presents the ethanol demand for potable, industrial and other applications. To meet the 20 percent blending targets by 2020–21, an extra 5.74 billion litres of ethanol will required from advanced or second-generation processes. This does not seem realistic, as ethanol production through biomass has not yet started in India. As of today, there is only one second-generation cellulosic ethanol demonstration plant under construction by Praj Industries in Pune, Maharashtra. This demonstration project will use a variety of biomass with a capacity of 100 dry tonnes of biomass per day, including agricultural residues such as corn stover, cobs, and bagasse. Praj expects the project cost to be in the region of US$ 25 million.

Figure 14: Surplus/Deficit of ethanol with different blending requirements



**Ethanol demand for potable, industrial and other applications is also considered.*

Figure 15: Current and future ethanol demand for potable, industry and other uses



To meet the 20 percent blending targets as stipulated by NPB, an estimated area of 25.2 Mha and 39.7 Mha would need to be planted with Jatropha by the year 2020–21 and 2030–31, respectively, as discussed in Chapter 2. The FAO/IIASA global agro-ecological zone modelling framework (GAEZ v3.0) assessed the spatial availability and suitability of culturable wastelands for Jatropha production in India. Using district-level statistical data from 2006–07, the non-food/non-forest land amounts to 102 Mha

(Fischer et al., 2012). Of this land, approximately 11.1 Mha was assessed as very suitable and suitable (1.9 Mha), or as moderately suitable (8.2 Mha), with an estimated production potential of 11.2 billion litre of Jatropha oil (Purohit and Fischer, 2014). This would be sufficient to meet only 10 percent of the blending targets by 2020–21. For the 20 percent blending target, approximately 20 billion litre of biodiesel will be required, which is not possible through TBOs due to land availability constraints. Though the GoI[5] has deregulated the price of diesel in line with gasoline, meeting a five percent biodiesel blending target by 2020 would require a dedicated plantation of energy crops or a probable switch to alternate sources of biodiesel from locally available TBOs, using multiple feedstock and imported biodiesel. So far, there has been no commercial sale of biodiesel to state-owned transport companies except for trials. As per the estimates presented in Chapter 3, agricultural residues can produce 37 and 50 billion litres of lignocellulosic ethanol/BTL in 2020–21 and 2031–31, respectively, which would be sufficient to meet the NPBs 20 percent blending by 2030–31 (8.6 billion litres of ethanol and 32.1 billion litres of biodiesel).

In this roadmap, we have assumed that in order to reach the blending targets it will be necessary to go beyond first-generation solutions. For this reason, we analyzed the economic potential for second-generation biofuels and these are the basis of blending targets for the BAU scenario (Section 4). Under the BAU scenario therefore, India will meet five percent, 10 percent, and 20 percent gasoline blending targets by 2020, 2025 and 2030, respectively. Similarly, since the economic potential for second-generation biodiesel is low (Figure 13), targets for biodiesel in BAU would be one percent, five percent and 10 percent by 2020, 2025 and 2030, respectively. In 2030–31, ethanol demand in India will be 8.6 billion litres which is less than 10 percent of the 2014 global ethanol production of 94 billion litres (REN21, 2015). Likewise, biodiesel demand to meet the BAU targets would necessitate three full-scale bio-refineries with a capacity of 500[6] million litres of ethanol/BTL per year by 2020. Daugaard et al. (2015) observed that optimal bio-refinery capacities range from 16 million gallons (61 million litres) per year for small-scale facilities, to 210 million gallons (795 million litres) per year for large-scale gasification facilities. The NPB scenario assumes that GoI will meet its 20 percent blending targets by 2020. Under this scenario, by 2020–21, the demand for ethanol and biodiesel will be at 5.7 and 19.8 billion litres, respectively. This would necessitate 51 full-scale bio-refineries with a capacity of 500 million litres of ethanol/BTL per year by 2020.

The above-mentioned targets seem realistic, as oil companies were able to meet the GoI's two percent ethanol/gasoline blend target (GoI, 2014). OMCs expect to purchase an estimated 800 million liters of ethanol and achieve 2.8 percent fuel ethanol market penetration in 2015 (USDA, 2015). In order to achieve NPB's 20 percent blending targets, 79 bio-refineries need to be installed by 2030. The stringent/optimistic policy scenario strictly follows the NPB targets stipulated (20 percent blend by 2017). In the NPB scenario, the ethanol requirement is estimated at 5.7, 7.1 and 8.6 billion litres by 2020, 2025 and 2030 respectively (as sited in Chapter 2), whereas biodiesel requirement is estimated at approximately 20, 25 and 31 billion litres for the same years. This means 50 bio-refineries with a cumulative capacity of 25 billion litres ethanol/BTL need to be installed by 2020. The above discussions clearly show what needs to be done; next we will explore how to translate this need into action.

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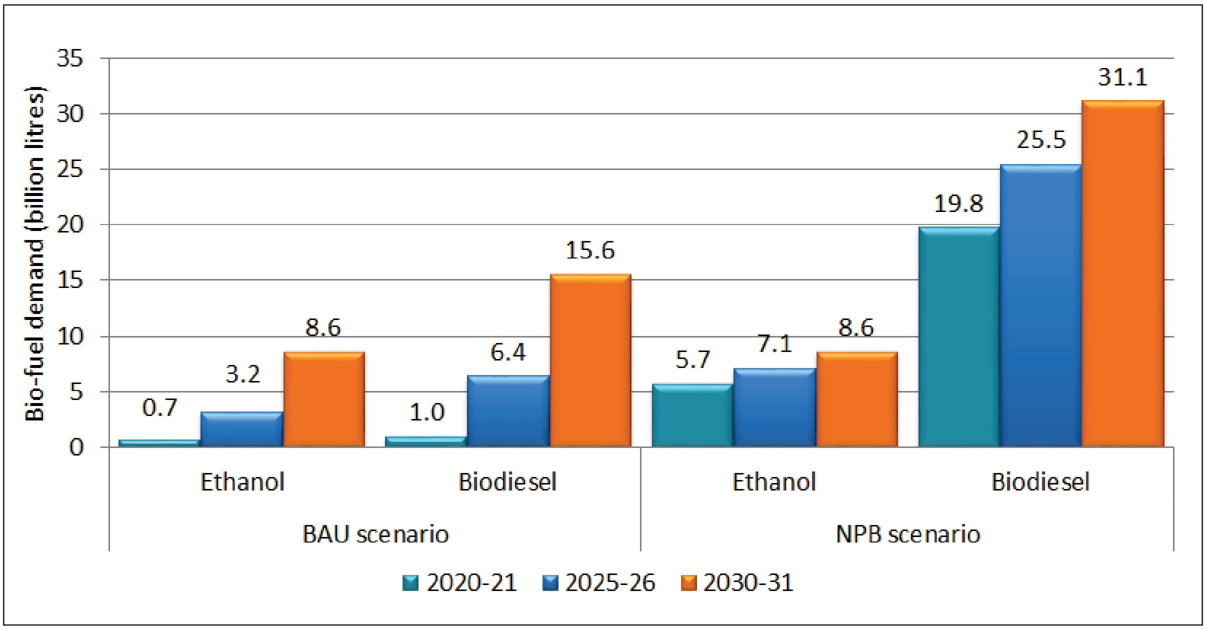
5 GoI controlled OMCs have issued tenders to purchase up to 225 million gallons per year of biodiesel in August 2015 as an important step toward implementing a five percent biodiesel blend policy.

6 In this analysis, the capacity of a full-scale bio-refinery is assumed to be 6,400 dry tonnes per day, which corresponds to 500 million litres, or 132 million gallons of ethanol/BTL per year for a conversion yield of 214 litre ethanol/BTL per dry tonne of biomass feedstock.

Figure 16: Ethanol and biodiesel demand up to 2030



5.1 Future would depend on second-generation biofuels

The future of biofuels lies with second-generation biofuels for two reasons: resource constraints and the lack of biomass feedstock.

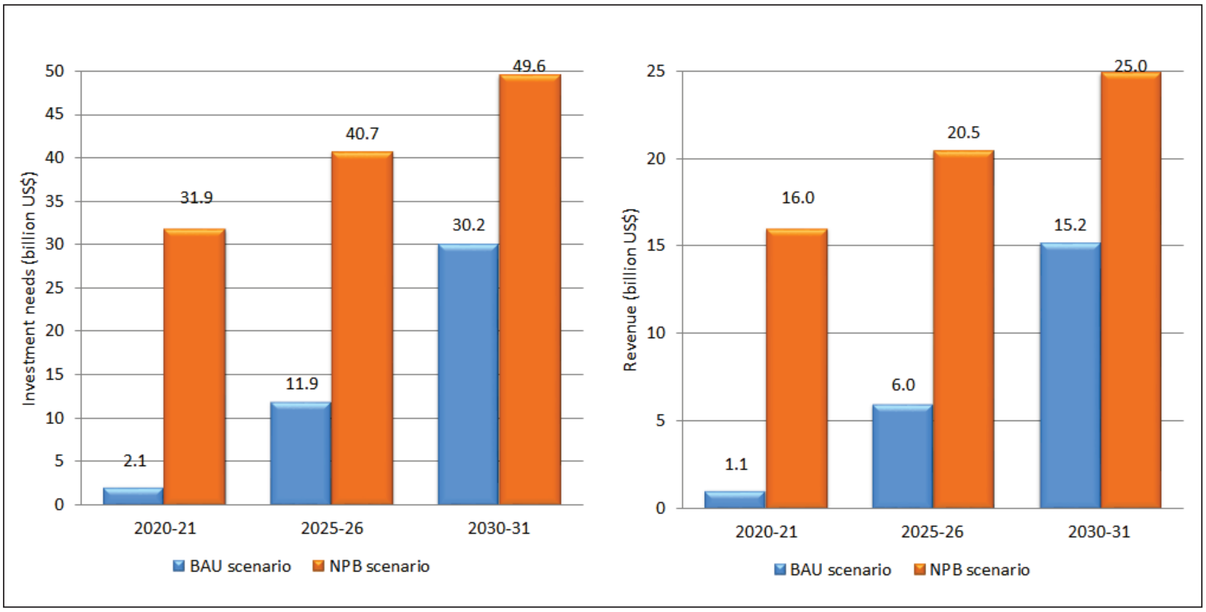
Resource constraints: A major criticism of the NPB is that it has largely been sugarcane-centric, which negates the goal of using degraded and less fertile land for biofuel production. It has become apparent that ethanol production based solely on sugarcane molasses is neither economically viable, nor sufficient and sustainable in the long run. Similarly, as discussed above, several obstacles hamper the Jatropha-based biodiesel production program. While biomass seems to be the only feasible renewable resource for producing transport fuels, the lack of cost-effective technologies for biomass fuel conversion has hindered progress in this direction. The available data confirms that for the most part, land in India is already intensively used and scarce water resources are being exploited beyond sustainable levels. With a growing population and rising per capita incomes, food demand in India will continue to increase substantially in the following decades.

Availability of biomass: Despite having high potential for supplying several different types of feedstock (particularly agricultural residues), India struggles to ramp up feedstock collection to levels needed to meet the growing domestic bioenergy demand (IEA, 2013b). Our conservative estimates of future crop residue supply suggest that India has the biomass resources to produce approximately 50 billion litres of biofuel from second-generation sources in 2030–31, which will be sufficient to meet the 20 percent nation-wide blending target. Therefore, it is critically important to establish a proper mechanism for collection, transportation and handling of biomass feedstock, allowing the country become a player in second-generation biofuel production.

5.2 Stable policy framework

Under the BAU scenario, ethanol and biodiesel production will require sizable investments in second-generation biofuels. A cumulative investment of US$ 2 billion is needed by 2020–21 under the BAU scenario, whereas under the NPB scenario a cumulative investment of US$32 billion required by 2020–21 (Figure 17). These figures are based on the assumption that there will be an average investment of US$1.25 per litre of installed capacity to build a freestanding next-generation ethanol/BTL manufacturing facility (Bloomberg New Energy Finance, 2011).

Figure 17: Total cumulative investment on second-generation biofuel industry in India under BAU and NPB scenarios



Second-generation biofuel investments are capital-intensive, involve large risks, and have a long time-to-market. Uncertainties about policy support, future crude oil prices, and the implementation of existing policies are key barriers to the development of India's second-generation biofuel industry, and are perceived as investment risks. Currently, the policy is in place, but there are no clear long-term mandated targets or penalties to ensure its successful execution. The government should create a stable, long-term policy framework for biofuels in order to increase investor confidence and allow for the sustainable expansion of biofuel production. Imposing penalties will be fair to stakeholders.

Market certainty means policy certainty for second-generation biofuel technologies (Huenteler et al., 2014). Given the ongoing debate over first-generation biofuel availability, a first priority for India's policy-makers should be to introduce an India-wide mandate for second-generation biofuels. Indian policy-makers could also introduce incentives and infrastructure for the collection of biomass feedstock. This could be done through the existing programs (i.e. MGNREGA) developed by several federal and state ministries. Further, active involvement of the private sector and public-private partnerships could help accelerate the penetration of second-generation biofuels, which may be essential to tackle the challenges of India's transport fuel security.

5.3 Social value of carbon

Second-generation biofuels have much lower CO_2 emissions as their conventional counterparts (gasoline and diesel). Second-generation biofuels could reduce 3.5 Mt CO_{2e} in the BAU scenario and 53 Mt CO_{2e} in the NPB scenario by 2020–21. Under the BAU scenario, which projects 20 percent ethanol and 10 percent biodiesel blending in 2030, second-generation biofuels can reduce approximately 50 Mt CO_2 emissions[7] on an annual basis. The social value of carbon for India in a low carbon world has been estimated as US$ 13 per tonne of CO_2 in in a sustainable scenario and US$ 60 per tonne of CO_2 in a conventional scenario (Shukla et. al., 2015). If this social value is internalized in the energy sector it can create a strong incentive for biofuels.

There is one further potential pollution-related benefit from fostering a second-generation biofuels industry in India. In the absence of a productive use of crop residues, farmers have traditionally burned excess residues as a means of quick disposal. The burning of agricultural residues emitted 141.2 Mt of CO_2, 8.57 Mt of CO, 0.04 Mt of SOx, 0.23 Mt of NOx, 1.21 Mt of particulate matter for the year 2008–09 (Jain et al., 2014). Using these residues in useful activities like ethanol/BTL conversion could reduce both air pollution and GHG emissions.

5.4 Demonstration projects

At present, India lacks mature technologies for second-generation biofuel production from lignocellulosic biomass, which is an abundant potential source of renewable energy. Agricultural residues are produced and can be exploited in most parts of the country. Although biomass itself is cheap, its processing costs are relatively high. Technologies for biomass-to-biofuel conversion are still at various stages of development, and a large-scale proof of implementation is lacking.

5.5 Private sector

Private investors (especially petroleum companies) should be encouraged to invest in biofuel programs, and government policies should be conducive to their participation. Active involvement of the private sector and private-public partnerships could help accelerate the commercialisation of second-generation biofuel technologies. A biofuels policy framework that supports second-generation biofuels would facilitate a stronger public-private partnership for the early deployment of advanced biofuels in India.

5.6 Supply chain for biomass

India has skilled labour and substantial financial resources, which can be channelled into ramping up the collection of feedstock from crop residues; establishing collection infrastructure, and transporting and handling of large amounts of biomass. These are indispensable steps towards boosting biofuel use in India and will help the country to enter into second-generation biofuel production.

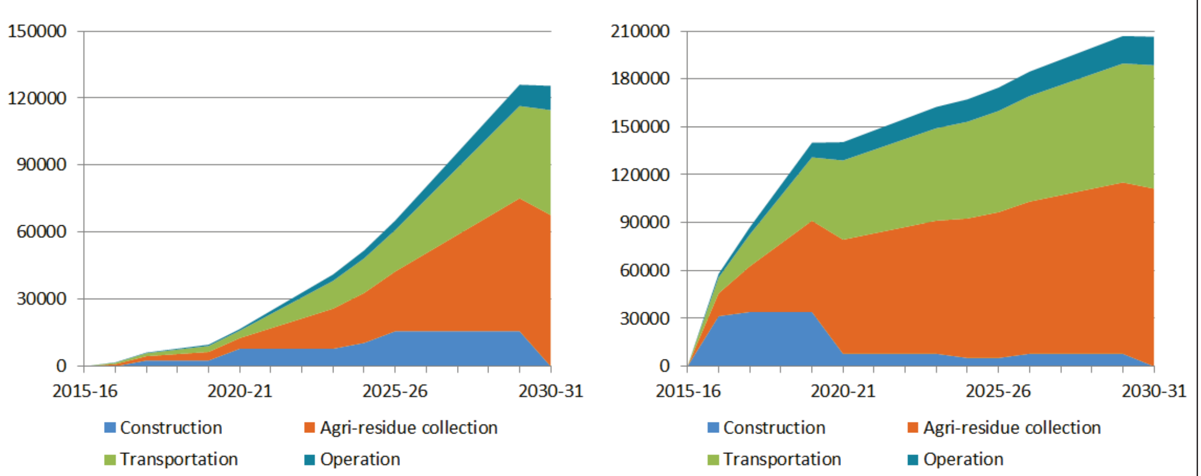
7 As per the EU's Renewable Energy Directive (Annex-V), GHG emissions for next-generation ethanol are on average 80 to 90 percent lower than for fossil-fuel gasoline, discounting any indirect land-use change issues. It is assumed that agricultural land-use patterns will not change between 2010 and 2030.

5.7 Enabling employment generation

One of the aims of India's NPB is to stimulate economic development and create jobs, especially in rural areas. Employment generated in the biofuel manufacturing industry is spread across various sub-sectors such as plant construction, biomass supply chain and operation of the bio-refinery. Jobs along the biomass supply chain include residue collection and transportation. Agricultural residue collection involves biomass aggregation from the field, i.e., hauling the residues to a central location and baling or bundling them for transportation. This report assumes that all second-generation bio-refineries that begin operations from now until 2030 will have an average annual production capacity of 500 million litres. We expect construction of each bio-refinery to last 24 months, creating temporary construction jobs for that period. The collection and transportation of agricultural residues and plant operation will create permanent jobs during the facility's lifetime, and will increase with the commission of every new second-generation bio-refinery. To understand the scope of jobs created in bio-refineries, one must distinguish between construction jobs and operation jobs.

Figure 18 presents the annual employment created by the second-generation biofuel industry. In 2010, The Danish Construction Association projected that every 1 billion Euro spent in the construction industry creates 5,665 direct construction jobs in the EU-27. Therefore, we assume that every US$ 1 billion spent in the construction sector will create 4,187 jobs, assuming a similar level of mechanization in construction technologies (Bloomberg New Energy Finance, 2011). According to our projects, over 126,000 construction jobs will be needed between 2017 and 2030. Baling, hauling, residue transportation, and plant operation would create permanent jobs. As more facilities are commissioned, the total residue demand would increase, creating more jobs in each area. Taking into consideration the lack of modern harvesting and residue collection machinery among most Indian farmers, it is assumed that 72 minutes per tonne of dry agriculture residues are required for baling, hauling, and residue transportation on the farm. Over 4,700 and 71,000 low-skilled laborers would be required for baling and hauling jobs in 2020 under BAU and NPB scenarios respectively. Those numbers are expected to increase by 67,000 and 111,000 in 2030 in BAU and NPB scenarios respectively.

Figure 18: Annual employment created by the second-generation biofuel industry



a) BAU scenario **b) NPB scenario**

Each ethanol manufacturing plant with a capacity of 100 million litres will create approximately 45 jobs in operations, assuming that on any given day there are two shifts (McAloon et al., 2000 and Bloomberg New Energy Finance, 2011). Therefore, each bio-refinery with a capacity of 500 million litres will create approximately 225 operational jobs. Under the BAU scenario, there will be approximately 11,000 operational jobs by 2030–31, whereas in the NPB scenario operational jobs will be roughly 18,000 by 2020–21. Assuming that in India a truck can carry a load of 6 tonnes and travels 60 km from the field to bio-refinery to collect biomass residues, 47,000 people could potentially be employed in the transportation sub-sector by 2030–31. Note that transport workers have a 10-hour working day and the average time taken by each truck to travel from field to bio-refinery is approximately 2.5 hours (including loading and unloading agricultural residues). The total number of jobs created in the above-mentioned methodologies is based on the studies on European market's where there is considerable mechanization of work. The potential number of jobs created in India could be more, since many jobs will be performed manually.

5.8 Research and Development

According to the NPB, substantial research thrust in the development of second- and third-generation feedstocks is needed to address the country's future energy needs, particularly in regards to future transport fuel needs. Some of the research can be in partnership with the private sector, however publicly funded laboratories would also need to take an active role. In order to achieve economically sound production processes, specific R&D needs to focus on proving the industrial reliability as well as technical performance and operability of the conversion routes.

5.9 Transport and Distribution Infrastructure and End Use

Ethanol and biodiesel are not fully compatible with conventional petroleum infrastructure, therefore, the transportation of these biofuels requires a separate infrastructure. Long-distance transport of current biofuel products at scale requires infrastructure that is either limited in capacity (e.g., rail) or unavailable at sufficient scale (e.g., dedicated pipelines). Further, to avoid bottlenecks caused by incompatibility with deployed biofuels, it is essential to attend to distribution infrastructure and end use technology issues. The ethanol "blending wall" (the limiting of ethanol in gasoline to 10–15 percent) due to vehicle compatibility constraints (OECD/IEA, 2011 is one example of potential infrastructure bottlenecks that need to be addressed. As has been successfully demonstrated in Brazil and Sweden, the introduction of flex-fuel vehicles (FFV) and high-level ethanol blends are good ways of avoiding ethanol infrastructure incompatibility issues. Policy measures may be required, such as obligations for retailers to provide high-level biofuel blends (e.g. E85) or tax incentives for FFVs.

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Information about the project:

UNEP Transport Unit in Kenya, UNEP DTU Partnership in Denmark and partners in India have embarked on a new initiative to support a low-carbon transport pathway in India. The three-year EUR 2.49 million project is funded under the International Climate Initiative of the German Government, and is designed in line with India's National Action Plan on Climate Change (NAPCC). This project aims to address transportation growth, development agenda and climate change issues in an integrated manner by catalyzing the development of a Transport Action Plan at the national level and Low-Carbon Mobility plans at the cities level.

Key local partners include the Indian Institute of Management, Ahmedabad, the Indian Institute of Technology, Delhi and CEPT University, Ahmedabad. The cooperation between the Government of India, Indian institutions, UNEP, and the Government of Germany will assist in the development of a low-carbon transport system and showcase best practices within India, and for other developing countries.

Homepage : www.unep.org/transport/lowcarbon

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