NEXT-GENERATION ETHANOL: WHAT'S IN IT FOR INDIA?

13 May 2011

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EXECUTIVE SUMMARY

The agricultural sector has long been the backbone of India's economy. It also now presents a unique opportunity to develop a next-generation ethanol industry over the next decade, with significant potential for the economy, reduction of greenhouse gas emissions and heightened energy security. In this report Bloomberg New Energy Finance explores the industry potential, barriers and policies required to facilitate its development in India over the next decade. This study uses 'industry potential' – in relation to biomass residue availability, next-generation ethanol production, job creation, environmental benefits and other economic impacts – to represent our assessment of a resource. *It is not a definitive forecast of what will happen in the next decade.* This report assumes that no food crop would be used for making next-generation ethanol.

Outcomes

- *Natural resources:* a conservative forecast suggests that between 125m and 183m tonnes of biomass residues will be available annually in India for next-generation ethanol conversion by 2020, **without changing today's agricultural land-use patterns** or cultivating new energy crops. By 2020 the available biomass residue could in theory be converted into between **34bn and 50bn litres of next-generation ethanol** annually although this would require an extremely aggressive programme of development.

- *Job creation*: on this basis the development of India's next-generation ethanol industry could involve creation of jobs for **0.7-1m people** over 2010-20. These jobs would predominantly be in rural areas, therefore enhancing India's agricultural sector.

- *Economic impact*: the development of this new industry would be expected to stimulate innovation and spur economic growth, which could generate up to **$15-20bn of annual revenues** in India by 2020. An inclusive business model incentivising farmers to collect and provide residues would help in enhancing their livelihood and **growth of the rural economy**.

- *Energy security*: next-generation ethanol could **meet up to 59% of India's gasoline demand** in 2020 (in our *Reference Potential* scenario). By this year, the country is forecast to spend $19bn annually on importing crude oil and converting it into gasoline, assuming that oil is then at $100 a barrel. Alternatively it could replace its fossil gasoline consumption with next-generation ethanol which would generate $15-20bn in annual revenue (under both the *Reference Potential* and *Enhanced Potential* scenarios). This would help the country **move from a high dependence on foreign oil towards greater transport fuel self-sufficiency.** India's current policy aims to blend 20% biofuels in its transport fuel mix by 2017, which would necessitate the use of next-generation ethanol.

- *Environmental benefits*: by 2020 next-generation ethanol consumption in India on the scale illustrated in this report could **reduce road transport greenhouse gas emissions from fossil gasoline by 47-69%**, under our *Reference Potential* and *Enhanced Potential* scenarios. Furthermore, CO2 and methane emissions would also decrease as biomass residues would no longer be burned or decompose in the field.

Barriers

While the potential to generate next-generation ethanol is very high, the following barriers present major challenges, which must be addressed if India is to realise the potential.

- **Lack of policy implementation** would be a key barrier to the development of India's next-generation ethanol industry and is a perceived investment risk. In the current environment the policy is in place but there are **no clear long-term mandated targets and penalties to ensure its successful execution.**

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- **The absence of any incentive to collect** agricultural residues and the **requisite infrastructure** to transport them would hinder the development of a next-generation ethanol market in the short term.
- Currently, **next-generation ethanol conversion costs are much higher** than those for first-generation ethanol, posing a challenge for its uptake in the early years.
- With **multiple stakeholders** with different concerns over availability and cost (like the beverages and chemical industries), the government would have to bring the stakeholders to a common platform and reach a consensus on pricing and usage of ethanol.

Policy options

- A first priority for India's policy-makers could be to introduce an **India-wide mandate for next-generation ethanol**, similar to that in the US that lasts until 2022 – especially given the ongoing debate over first-generation ethanol availability. Imposing **penalties on non-compliance** would add teeth to the biofuels mandate.
- Indian policy-makers could also introduce **incentives and infrastructure for the collection of biomass**. This could be done through the existing programmes of the Ministries of Agriculture & Cooperation, Rural Development and New & Renewable Energy.
- **Fuel station owners would also need to be incentivised to sell blended fuels** to accelerate the adoption of ethanol as a transport fuel. In the long run a policy supporting the **use of flex-fuel vehicles** would be an added advantage.

Figure 1 illustrates how India could benefit from developing its next-generation ethanol industry under our *Reference Potential* scenario. The figures show the full potential manufacturing facilities, with the number of potential jobs created and revenues from ethanol sales by 2020.

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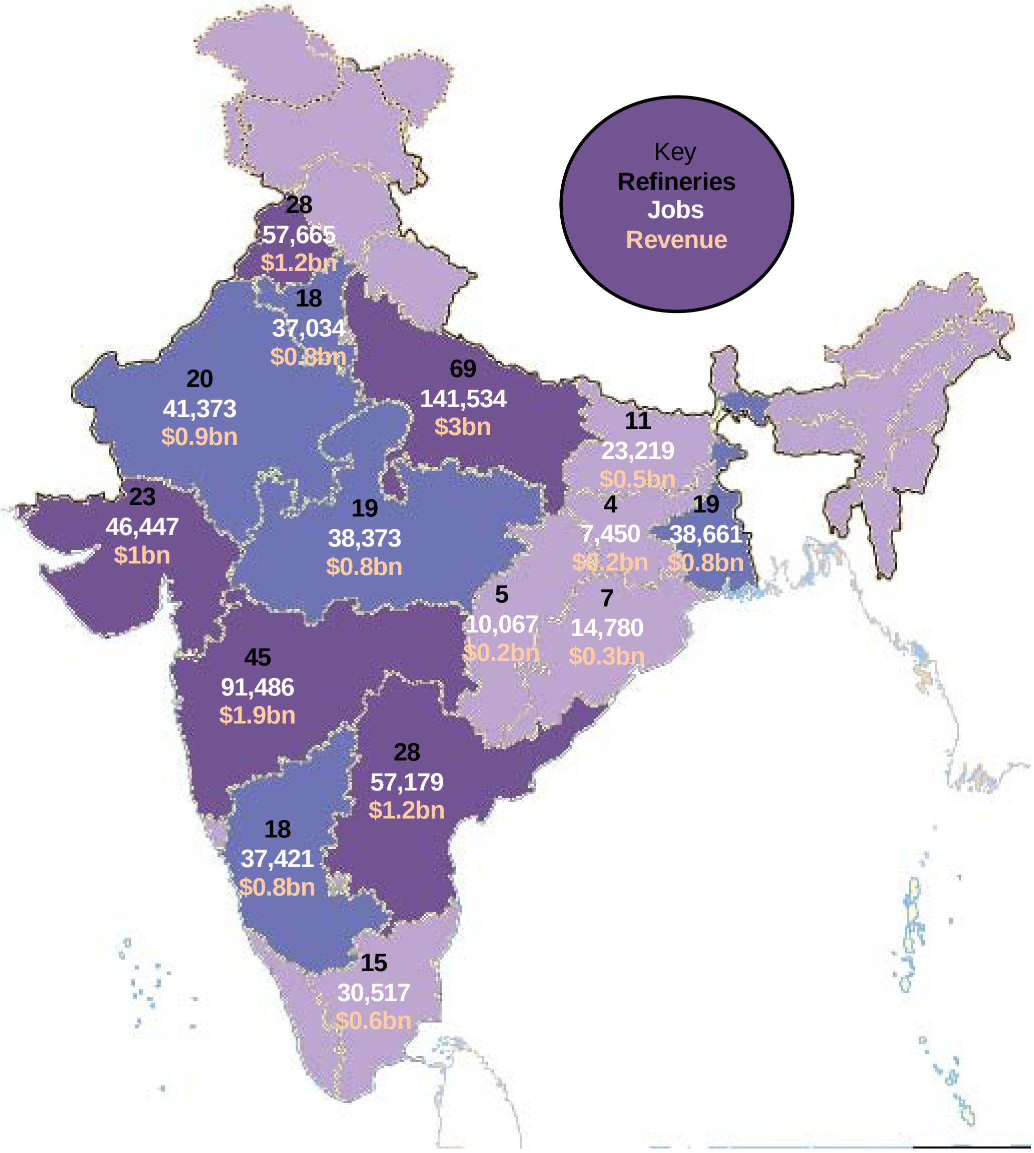
Figure 1: Potential number of facilities, employment and revenue in next-generation ethanol to 2020 (*Reference Potential*)



Source: Bloomberg New Energy Finance Note: Number of facilities is determined by each state's crop residue potential; 'Jobs' represent total man-years of employment over 2010-20, not the number of jobs in 2020 alone; 'Revenue' potential shows maximum potential revenues in 2020 if all biomass available for converting to ethanol is put to use.

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SECTION 1. INTRODUCTION

This report by Bloomberg New Energy Finance explores the potential for developing next-generation ethanol capacity in India over the next decade and potential barriers to the industry's development. India aims to blend 20% biofuels into its transport fuel mix by 2017 but currently has no specific policy framework to foster the development of next-generation ethanol projects (Table 1).

Table 1: Opportunities and challenges of India's current National Policy on Biofuels

Upsides for next-generation ethanol industry	Unclear message
Indicative target of 20% blending of gasoline with ethanol by 2017	No penalty mechanism for strict enforcement of targets especially in case of growing availability of ethanol
Only non-food feedstocks can be used for biofuel production	Targets for using next-generation ethanol as a transport fuel additive are not mentioned
Thrust on research & development of next-generation technologies	No incentive or mechanism defined for collection and storage of biomass residues
Biofuels can be exported after meeting the domestic requirements. Imported biofuels would be taxed to ensure that domestic biofuels are cheaper	No clear mandates for next-generation ethanol which can have an export potential

Source: Bloomberg New Energy Finance, National Policy on Biofuels

The next-generation ethanol industry could harness a modest and sustainable proportion of India's available agricultural residues. It would use new technological processes to convert these residues into next-generation ethanol for the transport fuel pool. Global next-generation ethanol manufacturing capacity at the end of 2010 was 661m litres per annum with 3.4bn litres of potential new capacity in various stages of development. This indicates a growing confidence in current technologies to produce cellulosic ethanol for deployment at scale. Further technological enhancements are expected to increase ethanol productivity per tonne of agricultural residue.

Based on historical agricultural production, Bloomberg New Energy Finance uses two scenarios to explore the potential of next-generation ethanol production: *Reference Potential* and *Enhanced Potential*. We then compare these potential scenarios for supply with demand under a 5% blending scenario and assuming that India meets its biofuel targets of 20% by 2017. The potential benefits of creating a next-generation biofuel industry range from spurring economic growth and creating jobs to reducing greenhouse gas emissions and improving energy security for India.

Our discussion around 'industry potential' – in relation to biomass residue availability, next-generation ethanol production, job creation, environmental benefits and other economic impacts – represents our assessment of a resource. It is not a definitive forecast of what will happen in the next decade and the actual outcome will inevitably be lower, given that many hurdles need to be addressed and there is no secured generation capacity today. Thus, while the theoretical potential for next-generation ethanol production in India is high, multiple barriers and policy requirements need to be addressed to drive its development over the next decade.

Bloomberg New Energy Finance was commissioned by Novozymes to research and write this report. The content and conclusions are those of Bloomberg New Energy Finance alone, based on its own independent analysis.

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SECTION 2. BIOMASS RESIDUE POTENTIAL

2.1. Economic and technical assumptions

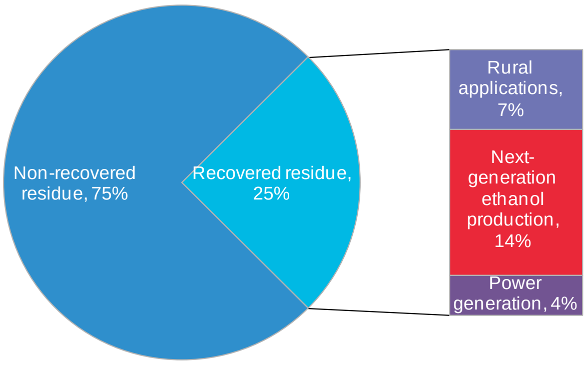
India is the seventh largest country in the world, with a total geographical area of 329m hectares. About 57% of this land is under cultivation, producing nearly 900m tonnes of food and other cash crops. India has 11% of the world's agriculture land and approximately half the population is involved in some way in farming. This substantial agricultural output suggests that a large biomass residue resource could be available for conversion into next-generation ethanol even after accounting for traditional and alternate uses of biomass.

This study assesses only the residues produced from the agricultural crop harvest. Section 7 explains the methodology in more detail. The analysis of biomass residue availability covers 15 food and cash crops, representing around 80% of the net agricultural output (by production quantity in 2008).[1]

Not all surplus agricultural residues available may be converted into ethanol, however. The International Energy Agency's (IEA) study, *Sustainable production of second generation biofuels*, 2010, February[2] assumes that 10-25% of all the agricultural residues generated can be used for production of ethanol with 10% being closer to the reality. The rest of the residue is assumed to be consumed at the site mainly as animal fodder or for rural applications and soil nourishment. In absence of any of these uses the residues are burnt. This happens regularly, according to Badrinath, KVS et al, 2006, '*Agriculture crop residue burning in the Indo-Gangetic Plains* – a study using IRS-P6 AWiFS satellite data'.[3]

Due to prevalent alternative uses of agricultural residues mostly in rural areas, this study assumes that only 25% of residue produced is recovered from the field while Bentsen and Felby[4], 2010, assume 50% recoverability worldwide.[5] Of this 25%, we assume 30% would be marketed for various rural applications (eg, heating, roofing, thatching) and 15% would go towards power generation. The remaining 55% of the recovered residue would then be used for next-generation ethanol production – only 13.75% of total agricultural residue produced compared to the IEA's range of 10-25%. Importantly, the residue available under these assumptions for biomass power is more than double what we estimate was used in 2010 (10m tonnes) based on the average capacity utilisation factors prevalent today.

Figure 2: Assumptions on agricultural residue



Source: Bloomberg New Energy Finance

1 Rice, wheat, millet, maize, sorghum, pigeon pea, lentils, chick pea, groundnut, rapeseed, soybean, cotton, sugarcane, banana and potato
2 http://www.iea.org/papers/2010/second_generation_biofuels.pdf
3 http://www.ias.ac.in/currsci/oct252006/1085.pdf
4 Bentsen, Niclas Scott. And Felby, Claus., 2010, Technical potentials of biomass for energy services from current agriculture and forestry in selected countries in Europe, The Americas and Asia,
5 http://en.sl.life.ku.dk/upload/techpotentbiomasswp55.pdf

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Bagasse and rice husk, by-products from sugar and rice mills respectively, may – at least in theory – be used in their entirety as they are not recovered from the field. However, to maintain uniformity in residue availability methodology we assume that like other agriculture residues, of all bagasse and rice husk generated, only 13.75% would be used for making next-generation ethanol.

Assessments of biomass potential vary widely, with estimates for global potential by 2050 ranging from 33Exa Joules (EJ) per year (Hoogwijk et al., 2003) to a more optimistic 1,500EJ per year (Smeets et al., 2007). Assuming 100m tonnes of dry biomass contain approximately 1.5EJ of energy, by 2020 India would have agriculture residue potential of 13.6-19.9EJ, which is in a similar range to the literature review (Table 5) but is lower when compared with Felby and Bentsen who have estimated that 15.8EJ was available from all Indian biomass residues in 2007.

A rise or decline in traditional uses of agriculture residues could affect its availability for ethanol production. There are signs that current demand for agriculture residues for rural applications could level off or even decline in coming years, as villages develop and find modern alternatives. This could make more of it available for alternative uses.

The World Energy Outlook 2007 drew a similar conclusion reporting that biomass consumption in India's rural households grew at an average annual rate of 1.1% between 1990 and 2005 but is expected to slow to 0.5% per year over 2005-30 mainly due to increased availability of liquefied petroleum gas.[6]

In comparison, we assume that there are more residues available for use in rural applications, with a compound annual growth rate (CAGR) of around 2% up to 2020 in our *Reference Potential* scenario. This is because agricultural output is also assumed to increase by 1.86% as explained in section 2.2. Meanwhile population growth in India has slowed in recent years, according to the latest census.

In addition, agricultural residues constitute a major part of animal fodder and any variation in bovine population directly influences its demand. India had a bovine population of 289m in 1992, which declined to 281m in 2003, and then bounced back to 303m in 2007. But the government is aiming to increase milk productivity per animal and reduce the number of bovines to reduce methane emissions.[7] If the government succeeds, the residues required for animal fodder could decline. Fodder cropping underway in some states may also ease the pressure on supply.

Even if more agricultural residues are used for non-biofuels purposes, the volume of available residue could still increase sharply if collection processes improve. This could be done by offering financial incentives for the collection and delivery of agricultural wastes.

2.2. *Reference Potential* scenario

Under the *Reference Potential* scenario:

- The area harvested remains constant with 2008 levels
- No energy crops are cultivated
- Agricultural crop yields grow through 2020 at the same linear growth rate as over 2003-08.

In its draft paper Anik Bhanduri et al. (Bhanduri, Anik, et al., 2006, *Future of foodgrain production in India,*[8]) estimated that the yields of food grains in 2025 may improve by a CAGR of 1.04% from 2010 in their most conservative scenario and by CAGR of 2.46% in the optimistic scenario.

We analysed agricultural crop data for 2003-08 to estimate the average yield growth and then forecast yields out to 2020. We used a contemporary five-year growth rate because it represents

6 http://www.iea.org/textbase/nppdf/free/2007/weo_2007.pdf
7 http://news4u.co.in/tag/national-dairy-research-institute/
8 http://nrlp.iwmi.org/PDocs/DReports/Phase_01/08-Future%20of%20Food%20grain%20Production-Anik%20Bhaduri.doc

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a realistic illustration of recent improvements in local farming techniques. Thus under the *Reference Potential* scenario, total crop production grows by a CAGR of 1.86% up to 2020. The projected total biomass residue in 2020 under this scenario is 911m tonnes, of which only 125m tonnes (13.75%) are available for ethanol conversion.

2.3. *Enhanced Potential* scenario

The *Enhanced Potential* scenario maintains most assumptions from the *Reference Potential* scenario but adjusts crop yield projections. Specifically, we increase yields by 5% above the recent historical trend to illustrate how improvements in technology and techniques could improve biomass availability.

Historically, agricultural yields in India have been low due to manual farming and poorly developed harvesting techniques. Crop yields have heavily depended on irrigation, which has been an important driver of overall economic growth. This was highlighted in the federal government's 11th Five Year Plan, which also suggested future growth in agriculture production could be linked to private investment. Only a third of India's agricultural land is currently irrigated with a preference going to cash crops such as sugarcane. Most of its other food crops are primarily nourished via rainfall.

The Planning Commission of India[9] has said that India has an ultimate irrigation potential (UIP) of 140m hectares and is estimated to have realised 87.2m hectares by FY 2007 (April 2006-March 2007). This still leaves 52.7m hectares to be potentially irrigated in future.

Improvement and growth in the irrigated land area, biotechnological innovation, multiple cropping cycles, modern irrigation and farming methods in the next decade – alongside more private investment – could easily improve the yields of the crops considered in this study.

In its *Agriculture policy: vision 2020*[10] the Indian Agriculture Research Institute predicts that yields of pulses, oilseeds and sugarcane should improve every year up to 2020 by 6%, 4% and 4% respectively in selected states to avoid shortage of food crops.

Our *Enhanced Potential* scenario is in line with these requirements and assumes a 5% growth rate above the historical average. We believe this is a fair illustration of what could happen if significantly more investment were to flow to the Indian agricultural sector. Such a growth rate would put India on a path to achieving crop yields in 2020 closer to the highest in the world today; though for some crops like rice, wheat and maize they would still be lower (Table 2).

Although biomass residue availability has been designed to vary in our two scenarios, actual agricultural residue production should be closer to the *Reference Potential* scenario volumes than the *Enhanced Potential* scenarios unless a large quantum on investments is made to substantially improve the agriculture productivity. The total 2020 biomass residue availability will be approximately 1332m tonnes in the enhanced condition scenario.

2.4. Substantial resource availability

Our selected crops produced 828m tonnes of agricultural waste in 2008. Three major crops -- wheat, rice and sugarcane -- accounted for 65% of the total agricultural residue that year. Bloomberg New Energy Finance analysed historical agricultural waste patterns and projected biomass residue availability for 2020, under the *Reference* and *Enhanced Potential* scenarios (as explained above). Figure 3 shows the agricultural residue potential in 2020 from various crops.

9 http://planningcommission.nic.in/plans/planrel/fiveyr/11th/11_v3/11th_vol3.pdf
10 http://planningcommission.nic.in/reports/genrep/bkpap2020/24_bg2020.pdf

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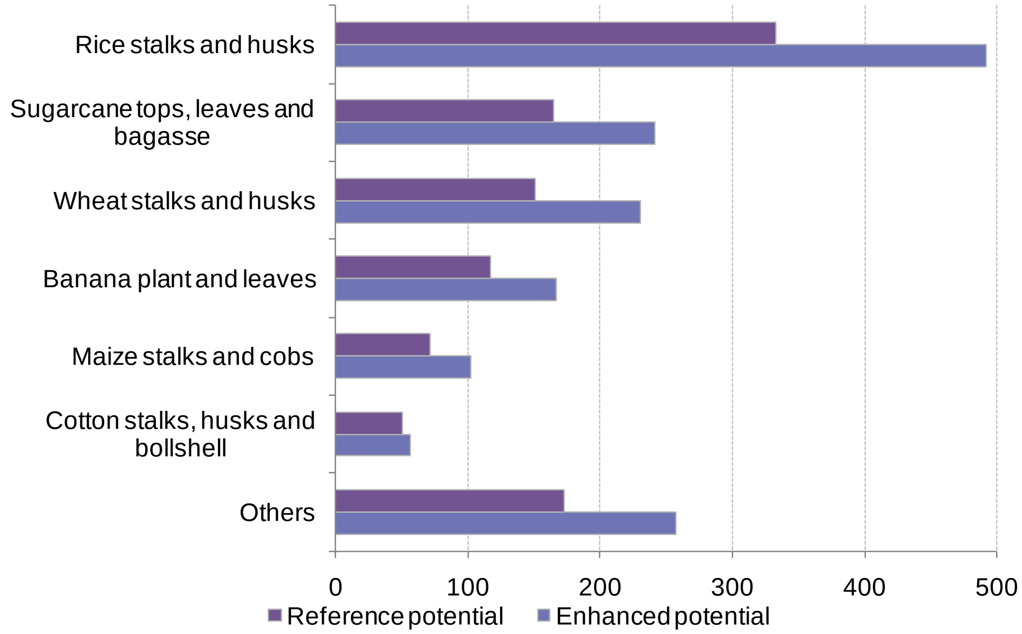
Figure 3: Crop residue potential in 2020 (m tonnes)



Source: Bloomberg New Energy Finance, UN Food and Agriculture Organization (FAO)

Bloomberg New Energy Finance estimates that in 2010 the technical dry biomass residue was 732m tonnes under the *Reference Potential* scenario compared with 791m tonnes under the *Enhanced Potential* scenario. While no reliable source monitors the production and consumption of biomass, the estimates for Indian biomass residue availability vary from 623m tonnes in 2008 (Sukumaran, K, et al., 2009, *Lignocellulosic ethanol in India: Prospects, challenges and feedstock availability*) to 841m tonnes of projected air-dried agriculture waste in 2010 (Ravindranath, NH, et al., 2005, *Assessment of sustainable non-plantation biomass resources potential for energy in India*).[11]

Under the *Reference Potential* scenario we estimate that 911m tonnes of biomass residues were available in 2010 and under the *Enhanced Potential* scenario it was 1,332m tonnes of biomass residues.

Applying our methodology for residue collection, the total 2020 biomass supply potential for ethanol conversion ranges from 125m tonnes in the *Reference Potential* scenario to 183m tonnes in the *Enhanced Potential* scenario (Figure 4).

11 http://eprints.iisc.ernet.in/3831/1/A197.pdf

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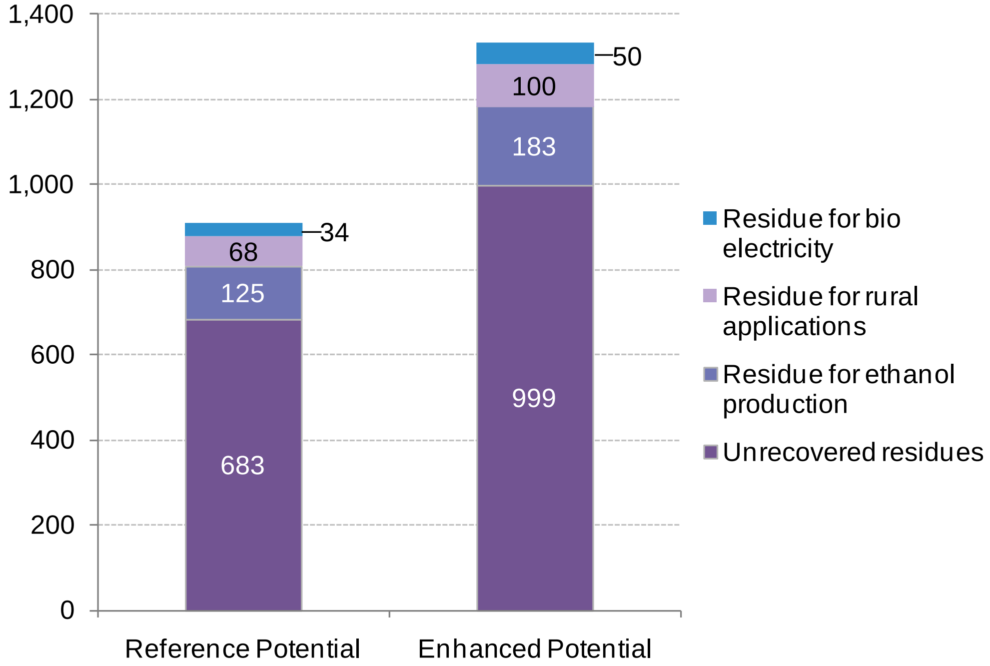
Figure 4: Residue availability (m tonnes)



Source: Bloomberg New Energy Finance Note: Rural applications include heating, roofing and thatching

2.5. Regional biomass potential

India has lower crop yields than developed nations due to manual farming practices and less irrigated agricultural land (Table 2). The states of Uttar Pradesh and Maharashtra are major agricultural production hubs in India and have significant potential for improvement. Despite having a smaller agricultural area, Punjab has a high agricultural output especially for wheat and rice compared to other states. Taken together, these three states are the largest producers of rice, sugarcane and wheat.

Table 2: Major crop yields in India and other countries (tonnes per hectare)

Crop	Maharashtra	Uttar Pradesh	Punjab	India average	China	US	Egypt
Rice	1.9	2.1	4	2.2	6.4	8.1	10.2
Sugarcane	80.9	57.2	60.8	68.9	66.7	77.6	119.5
Wheat	1.7	2.8	4.5	2.8	4.6	2.7	6.4

Source: Directorate of Economics and Statistics

States with the highest yields are those with best irrigation and the most modern farming practices. In the poorer performing state, yields could improve by a factor of five with better watering of crops and an improvement of harvesting techniques. The benefits of such improvements would potentially be twofold – more domestically produced food and more agricultural residues available for ethanol conversion.

Table 3: Indirect land-use change and the Bloomberg New Energy Finance approach

Indirect land-use change (ILUC) occurs when there is pressure on agriculture due to the displacement of previous activity, or when biomass use induces land-use changes. The environmental effects of ILUC are known as leakage – essentially the result of an action occurring in a system that induces indirect effects outside the system boundaries. The displacement of current land use to produce biofuels can therefore generate more intense land use elsewhere.

A certain amount of feedstock is needed to meet a given demand of first-generation biofuels.

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These feedstock quantities can be obtained by biomass use substitution, crop area expansion, shortening the rotation length, and yield increments on the same land. But next-generation technologies open the opportunity to avoid ILUC altogether by efficiently using all the land already used in food production and a small part of the residues produced in the process – instead of using the food part of the crop.

Our methodology assumes agricultural land use patterns do not change between 2008 and 2020 in either scenarios, thereby avoiding the issue of ILUC. The increase in biomass potential in our analysis only comes from yield increments, and therefore does not produce any changes in the carbon stocks and does not affect other valuable ecosystems. In our *Reference Potential* scenario we reflect what happens if the current agricultural system does not change. The increase in biomass availability comes solely from annual yield increases conforming to the yield increments seen between 2003 and 2008.

In our *Enhanced Potential* scenario we have increased agricultural crop yields beyond the historical norm to illustrate how improved farming practices and investment in the low productivity states would improve the supply of suitable biomass. Lifting yields – as opposed to increasing the amount of agricultural crop land or area under energy crops – should circumvent the politically sensitive ILUC issue.

Source: Bloomberg New Energy Finance

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SECTION 3. ETHANOL SUPPLY AND DEMAND

How much ethanol will India require in coming years, given its automobile fleet, economic growth rates and current policies? How much ethanol can be produced domestically to meet that demand? Here we explore various gasoline, first-generation ethanol and next-generation ethanol supply and demand outcomes for 2020.

First, we examine India's potential total ethanol demand under current trends and current market indicators. We then illustrate what proportion could be met by first- and next-generation ethanol.

We then turn our attention to what next-generation ethanol potential supply could become in India, given the amount of biomass available and conversion technologies. These scenarios could then provide a number of benefits, which we will analyse more fully in Section 4.

3.1. Business as usual: limited demand under current conditions

India's road transport sector is set for robust growth mirroring the country's GDP. Demand for gasoline and diesel is expected to double by 2020 from current levels. To limit the country's future carbon footprint and dependence on foreign crude, the Ministry of New & Renewable Energy established a National Policy on Biofuels, which mandated the blending of 10% ethanol with gasoline for 2008 for 20 states and four Union Territories. To date, these targets have not been met due to a lack of supply of ethanol for transport fuel as requirements from the chemical and beverage industries also increased. The government has also proposed an indicative target of 20% ethanol by 2017.

India consumed 17.3bn litres of gasoline in 2010 and Bloomberg New Energy Finance expects this to grow at 8.5% per year through 2020 in line with growth patterns from the past decade. Our gasoline projection is close to the forecasts of the Society of Indian Automobile Manufacturers (SIAM). According to this body, roughly three-quarters of India's passenger vehicles are two-wheelers, which account for about two-thirds of gasoline demand. The GDP increase and growth of the Indian middle class will raise the demand for two-wheelers, making gasoline an even more important transport fuel by 2020.

The Indian government regulates the price of most petroleum products but recently allowed gasoline prices to fluctuate at market rates. Diesel has traditionally been priced lower than gasoline, which has driven an increase in diesel-powered passenger cars in India. However, it is likely that diesel will be deregulated, allowing prices to rise and putting a dampener on the sale of vehicles that use this fuel.

We estimate that in 2020 there will be demand for 40bn litres of gasoline and 3bn litres of ethanol if only 5% ethanol is blended – a plausible outcome if current trends continue. According to a 2003 study, the Planning Commission of India estimates that from those 3bn litres, 1.8bn litres of ethanol for blending could come from first-generation supplies after usage by other industries. The remaining 1.2bn litres of demand should therefore come from next-generation ethanol (Figure 5).

A report released in January 2011 by the Asian Development Bank says that in the last decade, India produced an average of 1.8bn litres of molasses-based ethanol per year.[12] It estimates that this could rise to 3.9bn litres by 2017. There are varying estimates of usage requirements for beverages and chemical industries going up to 3.2bn litres according to one industry association. Thus only 0.7bn litres of ethanol will be available for blending purposes if these estimates are taken into account.

12 http://www.adb.org/Documents/Reports/Consultant/IND/42545/42525-01-ind-tacr-01.pdf

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Figure 5: Ethanol and gasoline demand with 5% blending (bn litres)

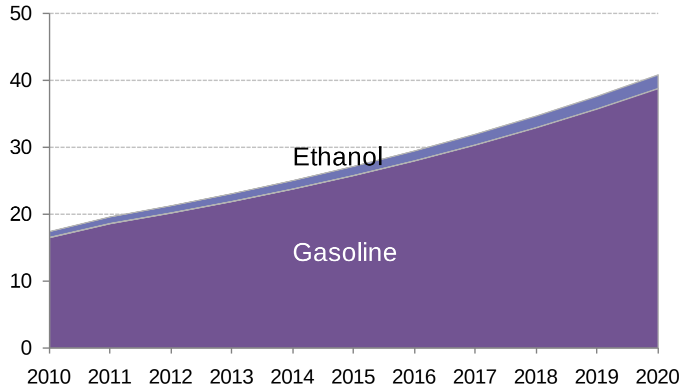
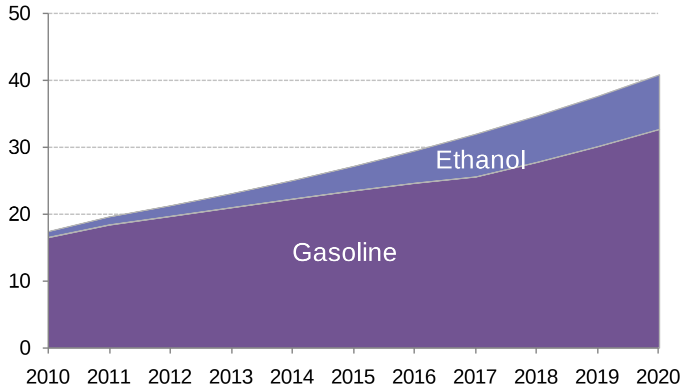


Figure 6: Ethanol and gasoline demand under the National Policy on Biofuels (bn litres)



Source: Bloomberg New Energy Finance, Ministry of Petroleum & Natural Gas, Planning Commission Government of India Note: Gasoline demand is assumed to grow at 8.5% every year after FY 2011; 1 litre of ethanol assumed to replace 0.7 litres of gasoline.

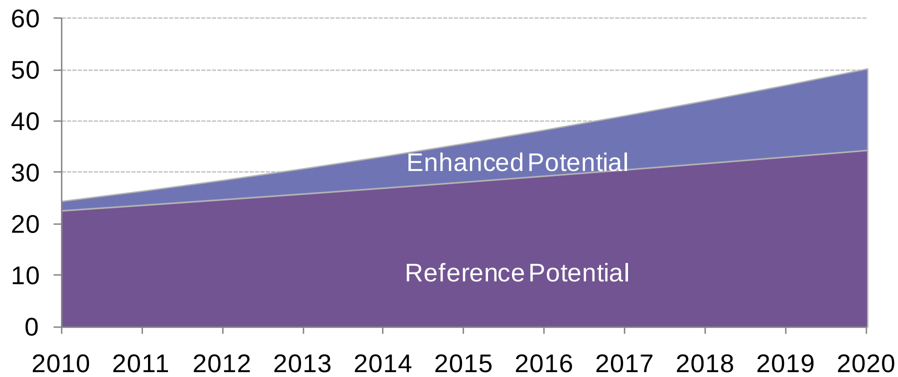
If the government is to achieve the blending targets laid out in its National Policy on Biofuels, ethanol blending will have to grow from 5% in 2010 to 20% in 2017. Under these blending targets the demand for ethanol will grow to approximately 11.6bn litres by 2020. However, as discussed above, the availability of first-generation ethanol could vary between 0.7bn litres and 1.8bn litres meaning 10-10.9bn litres of next-generation ethanol could therefore be required to fill the gap in demand in 2017 (Figure 6).

3.2. Next-generation ethanol: potential to displace gasoline demand

Our 2011-20 next-generation ethanol scenarios (Figure 7) are not actual supply forecasts. Rather, we illustrate how much ethanol could be supplied in the next decade in the context of agricultural residue availability. Policy-makers will set the priorities for various uses of this residue.

In our *Reference Potential* scenario next-generation ethanol supply grows from 28bn litres in 2015 to 34bn litres in 2020. In contrast, due to greater biomass availability, next-generation ethanol supply under our *Enhanced Potential* scenario rises from 36bn litres in 2015 to 50bn litres in 2020. The potential to generate low emission gasoline substitutes from the available agricultural residue is therefore considerable. The next-generation ethanol projections in Figure 7 show how much could be supplied.

Figure 7: Next-generation ethanol potential from agriculture residue (bn litres)



Source: Bloomberg New Energy Finance, UN Food and Agriculture Organization (FAO) Note: Ethanol potential is directly derived from biomass supply potential; we assume ethanol yields from a tonne of biomass will improve from 225 litres per tonne in 2010 to 250 litres per tonne in 2015 and to 275 litres per tonne in 2020.

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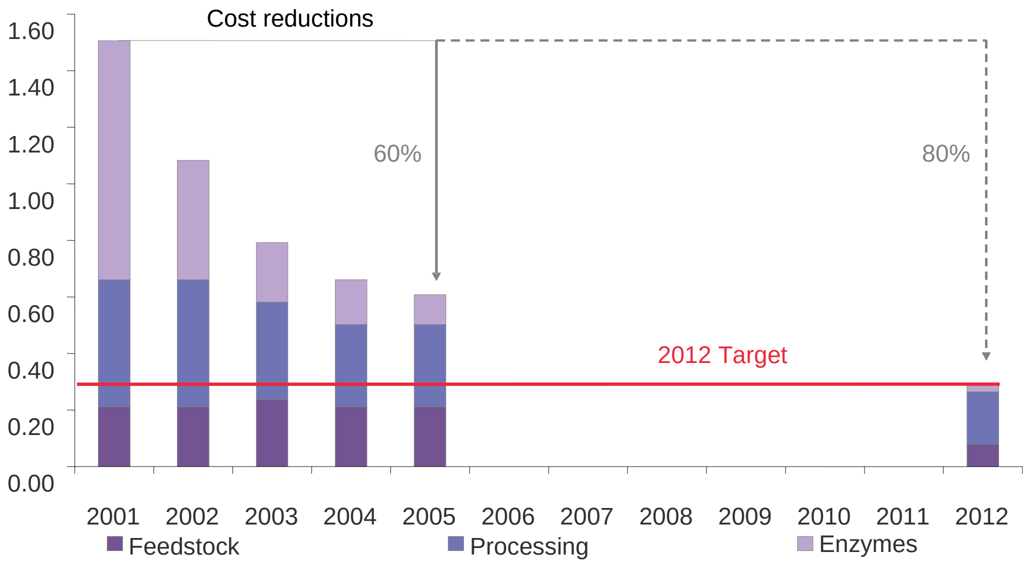
Next-generation ethanol production facilities use special enzymes to break cellulose in the agricultural residues into sugars which are then converted to ethanol through fermentation. The last decade has seen continual improvements in the various enzymatic hydrolysis processes and it seems likely that they will continue to develop over the next decade.

Figure 8 shows the reduction in cost of producing next-generation ethanol from enzymatic hydrolysis process. There has been a constant decline in the cost of enzymes since 2001 and as per National Renewable Energy Laboratory (NREL) overall cost reduction is expected to continue in future as well.

Figure 8: Enzymatic hydrolysis operating costs ($ per litre)



Source: Bloomberg New Energy Finance, National Renewable Energy Laboratory (NREL) Note: NREL operating costs are for enzymatic hydrolysis technology

We assume therefore that ethanol produced per tonne of biomass will improve gradually from 225 litres in 2010 to 250 litres in 2015 and eventually to 275 litres per tonne in 2020. These improvements should come as the first few commercial-scale plants come online. Technology and efficiency improvements will magnify any small growth in biomass supply potential.

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SECTION 4. NEXT-GENERATION ETHANOL POSSIBLE UPSIDES

From the perspective of agricultural residue, the development of next-generation ethanol could have considerable economic and environmental benefits for India. Although biofuel demand remains low today, by 2020 the country could at least theoretically replace 59-86% of its annual gasoline consumption with next-generation ethanol as calculated in our *Reference Potential* and *Enhanced Potential* scenarios respectively. Assuming a cost of crude at $100 per barrel, India is forecast to spend approximately $19.4bn on gasoline imports by 2020 – 80% of its gasoline requirement (Figure 9).

4.1. Possible revenues and exports

In place of the funds spent on importing gasoline, Indian producers of next-generation ethanol could theoretically generate $15-20bn in revenue if India develops a next generation ethanol industry and maximises the potential supply of next-generation ethanol

Figure 9: Potential 2020 gasoline, ethanol consumption costs and sales revenues, without next-generation ethanol ($bn)

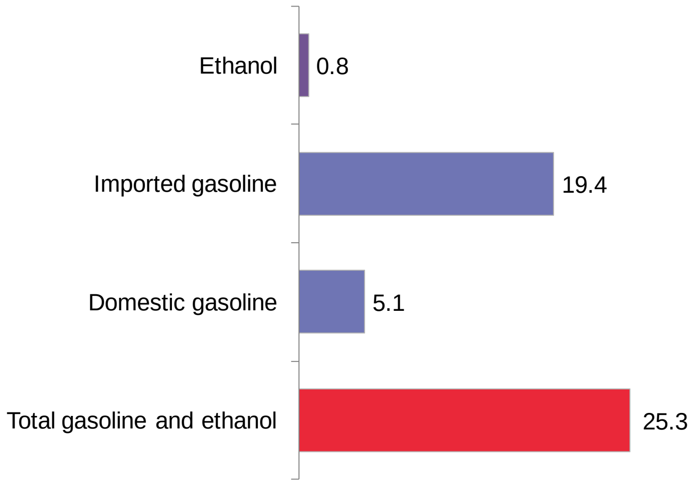
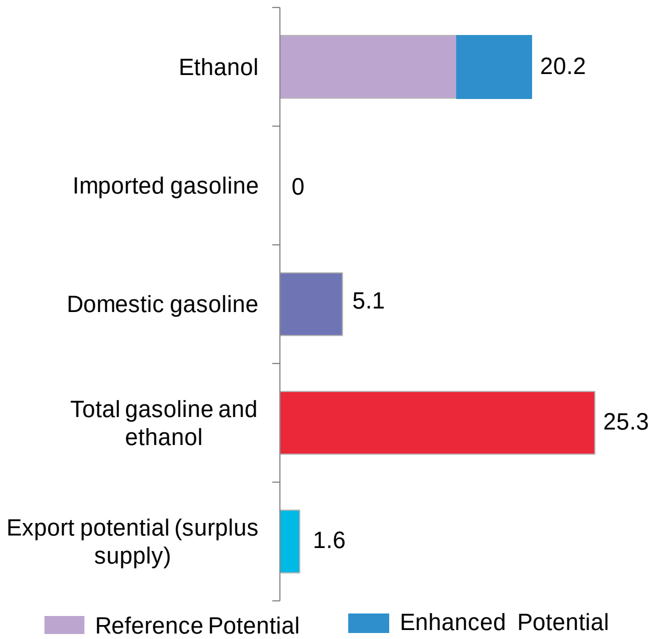


Figure 10: Potential 2020 gasoline, ethanol consumption costs and sales revenues, with next-generation ethanol ($bn)



Source: Bloomberg New Energy Finance, Ministry of Petroleum & Natural Gas Note: 'Total gasoline' accounts for production costs when crude is at $100 a barrel, multiplied by our 2020 gasoline demand forecast; 'Ethanol' revenues assume ethanol represents 70% of the gasoline cost, adjusting for its lower energy MJ content, multiplied by our base case and enhanced conditions ethanol potential scenarios; 'Imports' assume 80% of the gasoline cost – based on FY 2009 data for crude oil consumption and import.

This report uses the 2020 ethanol volumes under the *Reference* and *Enhanced Potential* scenarios as an industry target: we have therefore assumed next-generation ethanol manufacturing capacity will build towards the 34-50bn litres of ethanol potential between 2012 and 2020.

Accounting for the current state of technology development, the study expects the first handful of next-generation ethanol manufacturing facilities to come online by 2014. Construction should therefore begin around 2012 (Figure 12). All our assumptions on capacity and revenues are based on the current state of bioproduct technology development and a crude oil price of $100 per barrel in 2020.

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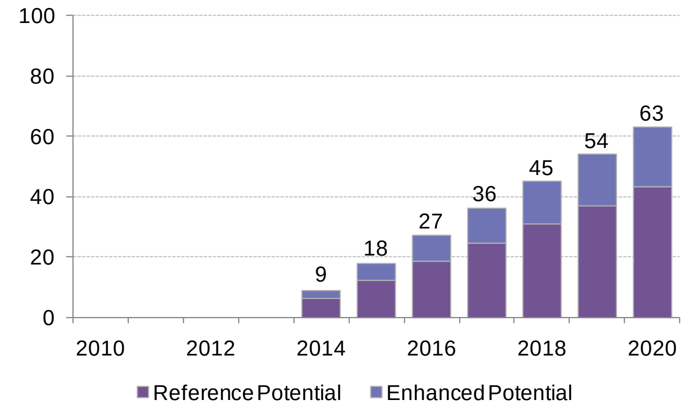
Using the potential scenarios outlined above, 344 next-generation ethanol manufacturing facilities would need to be commissioned under the *Reference Potential* scenario and 504 under the *Enhanced Potential* scenario. If this capacity were built between 2012 and 2020, it would require investment of approximately $43bn and $63bn under the respective scenarios (Figure 1). This calculation assumes that it will cost on average $1.25 per litre of installed capacity to build a freestanding next-generation ethanol manufacturing facility.

Under the *Reference Potential* scenario, cumulative capacity investment reaches from nothing today to approximately $18bn by 2015, rising to $43bn by 2020. This capacity would then generate cumulative revenue of $6bn by 2015 and $60bn by 2020 (Figure 12), assuming an oil price of $100 per barrel. These 2020 revenues could potentially boost India's GDP by approximately 0.2%.

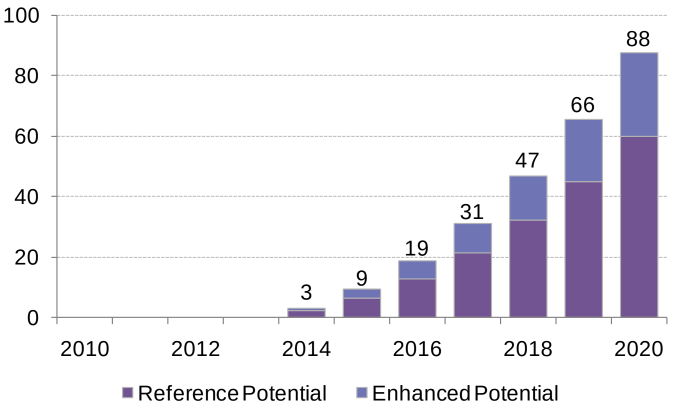
The domestically produced next-generation ethanol could also theoretically supplant crude oil imports, thereby strengthening India's security of supply. In addition, the surplus generated under the *Enhanced Potential* scenario could even generate $1.6bn in export revenues in 2020 (Figure 10). Investment would fall after 2020 in both scenarios as the infrastructure would have been built. But the revenue for ethanol manufacturing plants would remain high.

Figure 11: Total cumulative next-generation ethanol capacity investment, 2010-20 ($bn)



Source: Bloomberg New Energy Finance Note: Both scenarios assume total facility costs will be approximately $1.25 per litre of annual capacity.

Figure 12: Total cumulative next-generation ethanol revenues ($bn)



Source: Bloomberg New Energy Finance Note: This chart represents the revenues achieved from the operational new next-generation ethanol manufacturing facilities, when crude is at $100 a barrel; construction starts in 2012 and two years later (2014) the first next-generation ethanol manufacturing facility comes online.

4.2. Possible environmental benefits

India's emissions grew from 1.2GtCO2e in 1994 to 1.9GtCO2e in 2007, the government reported in a 2009 study.[13] Those for transport only rose from 80MtCO2e in 1994 to 142MtCO2e in 2007, increasing its share of emissions from 6.4% in 1994 to 7.5% in 2007.

Next-generation ethanol could reduce 46-68MtCO2e if it replaced 59-86% of India's annual gasoline consumption. This would be equivalent to cutting 47% (*Reference Potential*) to 69% (*Enhanced Potential*) of gasoline-based transport sector emissions in 2020 (Figure 13).

This study uses the more conservative figure contained in the EU's Renewable Energy Directive (Annex V) which estimates that greenhouse gas emissions for next-generation ethanol are on average 80-90% lower than for fossil gasoline – discounting any indirect land-use change (ILUC) issues. Our methodology assumes agricultural land-use patterns will not change between 2010 and 2020.

13 Excluding land use, land-use change and forestry. http://moef.nic.in/downloads/public-information/Report_INCCA.pdf

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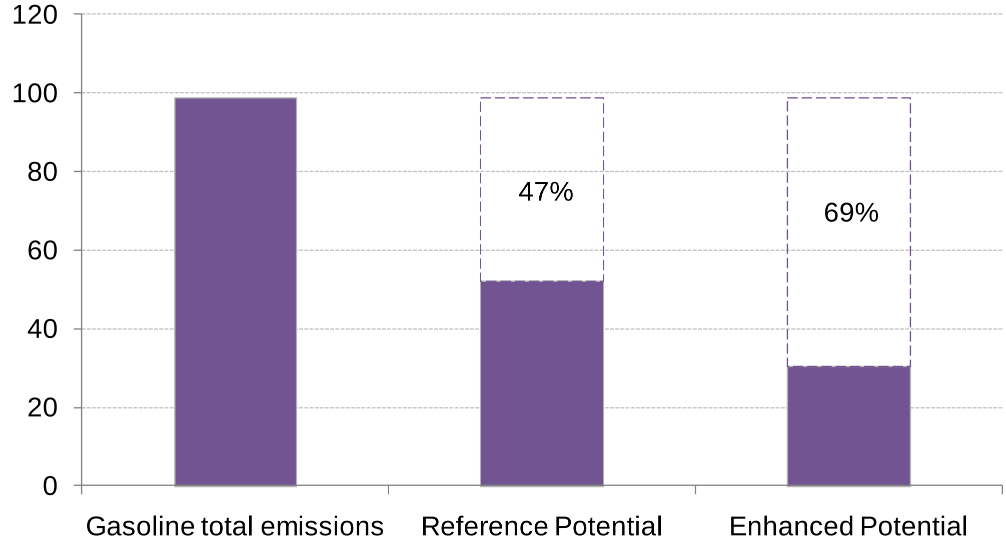
Figure 13: Possible India emission savings from next-generation ethanol, 2020 (MtCO2e)



Source: Bloomberg New Energy Finance Note: Data from the EU Sustainable Transport Group shows a litre of gasoline has a well-to-wheel emissions footprint of 2.42kg / CO2e which we have used in calculation of emissions.

There is one further potential emissions benefit to fostering a next-generation biofuels industry sector in India. In the absence of a productive use of crop residues, farmers have traditionally burned excess residues as a means of quick disposal. This burning generated estimated emissions of 6.6MtCO2e in 2007. Usage of residues in other useful activities like ethanol conversion could reduce these emissions as well.

4.3. Possible job creation

One of the aims of India's National Policy on Biofuels is to stimulate economic development. We find that with the right investment and under the right circumstances a new industry could be created that would create thousands of new jobs. Under our *Reference Potential* scenario, about 700,000 aggregated jobs would be needed between 2010 and 2020, while under the *Enhanced Potential* scenario this figure rises to 1m jobs. By just the end of 2015, the potential employment opportunities could be as high as 95,000 people under the *Reference Potential*. From 2020, the potential number of permanent jobs would stabilise at 126,000 and 185,000 in the *Reference* and *Enhanced Potential* scenarios, respectively. We assume that the first next-generation ethanol production facility comes online in 2014 and by 2020 all the facilities would have begun production.

The new employment opportunities would involve both the building of new biofuels plants and the operation of them in the longer term. In terms of construction jobs, we assume a typical worker keeps his job through the entire 24-month construction period. This means the last recruitment for construction workers will be in 2018. From 2012, 26,000 annual jobs could be created each year in construction activity under the *Reference Potential* scenario. More than 340 ethanol manufacturing plants would be set up in this scenario, potentially creating 180,000 aggregated high- and low-skilled construction jobs by 2020. Under the *Enhanced Potential* more than 500 facilities would be built resulting in 263,000 aggregated jobs in construction. The number of new jobs created start falling as more plants reach the end of their commissioning timelines.

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Figure 14: Annual recruitment created by the next-generation ethanol industry, *Reference Potential*

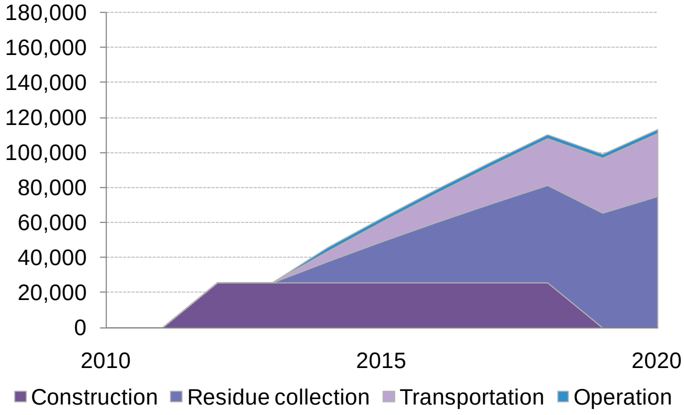
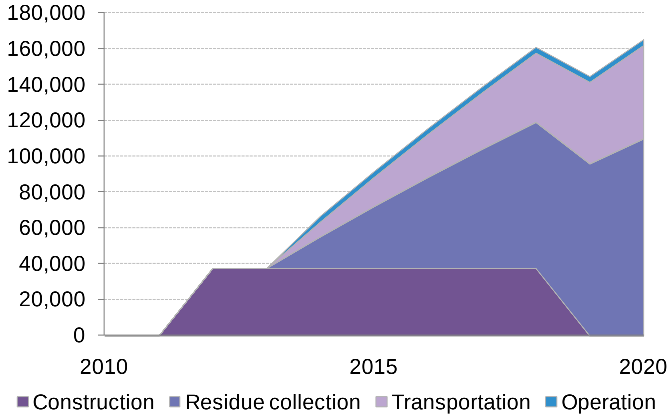


Figure 15: Annual recruitment created by the next-generation ethanol industry, *Enhanced Potential*



Source: Bloomberg New Energy Finance, Danish Construction Association. Note: Total annual jobs, or one man-year, from the bioproduct industry come in two parts – firstly from next-generation ethanol manufacturing facility construction and operation, and secondly from the biomass residue supply chain. We have taken the sum of the total annual jobs created between 2010 and 2020. For further details see the Methodology

Baling, hauling and the transportation of residues as well as operation of the plants would create permanent jobs. As more facilities are commissioned, the total demand for residues could increase creating more jobs in each area. Around 75,000 low skilled people would be required for baling and hauling jobs in 2020 in *Reference Potential*. Under the *Enhanced Potential* scenario 110,000 jobs could be created in 2020. Assuming that a truck in India can carry a load of 6 tonnes and it travels 60km from the field to ethanol manufacturing facility to collect biomass residues 149,000 and 217,000 people could potentially be recruited in the transportation subsector under the respective scenarios.

Figure 16: Total next-generation ethanol job creation, 2010 to 2020, *Reference Potential*

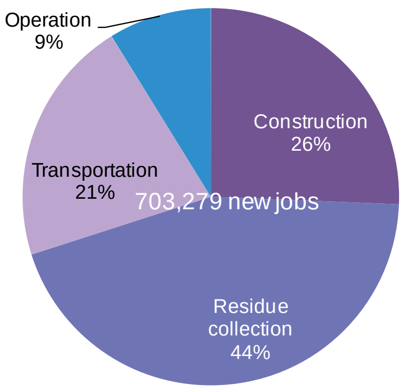
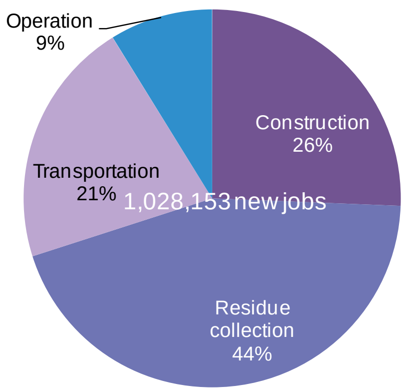


Figure 17: Total next-generation ethanol job creation, 2010 to 2020, *Enhanced Potential*



Source: Bloomberg New Energy Finance, Danish Construction Association Note: Total annual jobs, or one man-year, from the next-generation ethanol manufacturing industry come in two parts – firstly from next-generation ethanol manufacturing facility construction and operation, and secondly from the biomass residue supply chain. We have taken the sum of the total annual jobs created between 2010 and 2020. For further details see the Methodology

The development of next-generation ethanol in India could help to reduce unemployment in rural areas which currently stands at Unemployment rates in rural India are just over 10% compared with 7.3% in urban areas according to the Ministry of Labour & Employment.[14] Indeed the jobs created in the biomass supply chain could not be shifted to urban areas. Agriculture residues must be collected from the fields and then baled and transported to the facility. Since the plant itself would be set up in a region of biomass availability, it would likely be located on the outskirts of a city or in rural areas. All these factors would be expected to increase rural employment in the

14 http://labourbureau.nic.in/Final_Report_Emp_Unemp_2009_10.pdf

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areas surrounding the ethanol production facility. Most of the opportunities would involve low-skilled work; still, there would be employment opportunities for medium-skilled personnel in the plant operation and administration as well as for engineers and the scientific community.

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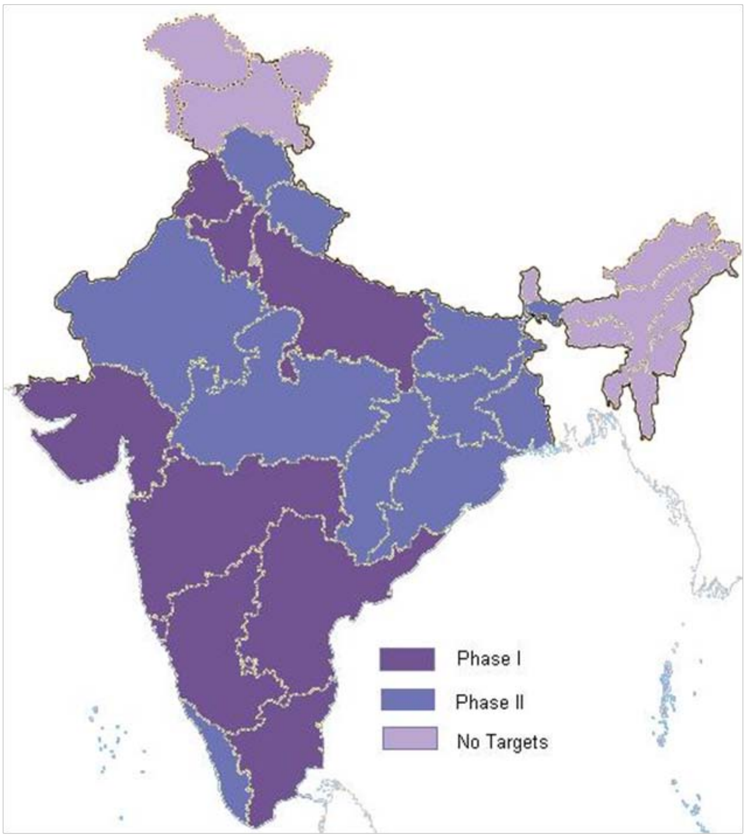
SECTION 5. BARRIERS TO DEVELOPMENT

5.1. Policy: enforcement and coherence required

India does not have a strong track record of fulfilling its biofuel blending ambitions. The first attempt to mix ethanol into the country's fuel supply came in September 2002 when the Ministry of Petroleum and Natural Gas mandated the use of 5% ethanol blends starting the following year. For the first phase, blending was mandated in nine states and four Union Territories (Figure 18). Phase II included another 11 states. The programme started in 2003 but ran into trouble in the following year after a low harvest as a result of which India had to import 447m litres of ethanol from Brazil. In October 2004, government changed the mandate, requiring the 5% target to be met only when enough supply was available. In 2005, 411m litres of ethanol were imported from Brazil, most of which was used by the chemicals industry rather than blending. This was because the various state taxes and levies hindered the movement of ethanol across the borders.[15]

Blending of ethanol into the fuel supply re-started in November 2006 on the expectation of a decent sugarcane harvest which resulted in 2.8bn litres of ethanol production in FY 2007. However, production fell to 1.4bn litres of production in FY 2009 and blending was halted again. The Indian government's success in introducing ethanol blending has been erratic in the past decade, and it does not set a good long-term precedent for potential biofuel investors.

Figure 18: Implementation phases of blending targets



Source: Bloomberg New Energy Finance, Ministry of Ministry of Petroleum and Natural Gas

The Cabinet Committee on Economic Affairs again mandated 5% ethanol blends in November 2009. It was suggested to fix the ethanol price at INR 27 per litre for three years in December 2009. The National Policy on Biofuels was floated on 24 December 2009 with a highly ambitious indicative blending target of 20% by 2017. This renewed focus on blending came as ethanol

15 http://www.adb.org/Documents/Reports/Consultant/IND/42545/42525-01-ind-tacr-01.pdf

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output was again expected to increase due to an expected abundant sugarcane harvest in 2010. In October 2010 a committee advising the government on blending indicated that first-generation ethanol availability was still insufficient.

Today, there is in India no clear signal on the long-term pricing of ethanol. Transporting the fuel within and across state borders is a barrier due to various taxes and regulations and needs streamlining. There is no manufacturer producing flex-fuel vehicles (FFVs) in India that can run on a variation of gasoline/ethanol blends. Meanwhile, the Society of Indian Automobile Manufacturers recommends that those with conventional combustion engines do not put varying levels of ethanol in their tanks.

For potential investors, this adds up to an uncertain environment which is likely to impede the development of India's biofuels industry at least for the short term.

5.2. No market for residues

The current National Policy on Biofuels states that intensive research and development will be conducted on the development of next-generation biofuel technologies. But currently there is no policy mechanism incentivising farmers to collect and deliver biomass residue to a next-generation ethanol plant. If the policy-makers seek to foster an industry longer term, they could create a mechanism whereby cooperatives or farming communities could be involved in the process of collection, storage and delivery of residues.

5.3. Conversion economics

In addition to policy, the development of next-generation ethanol in India will be driven by its production economics, which should be compared with those of the first-generation industry. Based on our Bioenergy Pathways Model and a survey involving 10 leading next-generation ethanol manufacturers between 2009 and 2010, we estimate that the conversion and capital cost is currently $0.43 per litre.

According to our analysis, it costs $0.56 to produce a litre of first-generation ethanol when molasses is priced at INR 4,000 per tonne. By comparison, next-generation ethanol would cost $0.70 per litre today although this figure should fall over the next decade with technology improvements.

Figure 19: First-generation ethanol production costs ($ per litre)

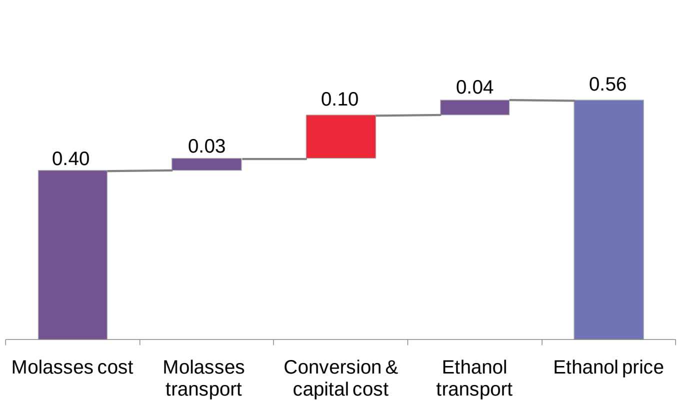
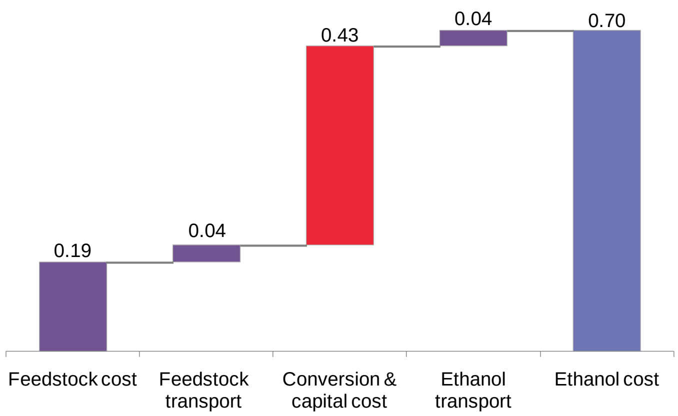


Figure 20: Next-generation ethanol production costs ($ per litre)



Source: Bloomberg New Energy Finance, Planning Commission Note: The costs are from a standalone distillery, an integrated facility with a sugar production plant can have lower costs; an exchange rate of $1 to INR 46 was used; molasses costs were INR 4,000 per tonne; and the ethanol cost reflects production costs in 2010

The price for molasses has varied significantly in the past three years from a low of INR 3,000 ($65) per tonne to INR 5,900 ($128). Prices of biomass residue have also fluctuated, moving

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between INR 1,000 ($28) and INR 3,000 ($65) per tonne in 2009-10. The price of certain biomass residues, such as rice husks, has consistently been considerably lower than that of molasses. Technology improvements should also lower conversion and capital costs. But scaling up is contingent on making the residues available which would need an effective policy mechanism to incentivise the agricultural industry or a significant breakthrough in the technology.

5.4. Technical blending hurdles

Countries around the world have mandated different blending targets for motor fuel consumption. In India, the Society of Indian Auto Manufacturers has agreed that 5% is acceptable for domestic vehicles, but cautions against 10% or higher blends. Elsewhere in the world, it has been shown that blending up to 10% can be achieved without any major adverse affects on vehicles with conventional combustion engines. The US is effectively at a 10% blend and the US Environmental Protection Agency has signalled it could soon move the 'blending wall' to 15%.

Brazil started blending ethanol and gasoline in late 1970s and currently blends up to 25% ethanol into its gasoline supply without any vehicle modifications. (Motorists can also buy 'E-85', or 85% ethanol at the pump if they own a flex-fuel vehicle.) But without any scientific studies demonstrating the optimal mix of ethanol in gasoline, it might not be possible to form a common international consensus on the appropriate ethanol-gasoline proportions.

5.5. Involving multiple stakeholders

In part because biofuels involve both fuel and agriculture, the list of stakeholders involved in determining India's long-term policies in this area is long and varied. It includes a myriad of ministries, departments and industrial associations all in some way involved in potential ethanol demand, supply and pricing. But their perspectives and interests often differ significantly. The Ministries of Petroleum & Natural Gas, Agriculture & Cooperation, New & Renewable Energy and Chemicals and Fertilizers all come at the ethanol issue from different directions and with different agendas. Appendix A: shows key stakeholders who could be involved in making any decision concerning biofuels. Bringing all stakeholders to a common platform and addressing the issues productively is a challenging task in itself and it inevitably delays reaching any consensus.

5.6. Capital shortage

Currently there are no next-generation ethanol manufacturing facilities operating in India and the technology is very much in the developmental stage globally. To add to the complexity, there are issues with feedstock collection and transportation along with no clear mandates or other policies demanding next-generation ethanol consumption in India. All of the above makes it difficult for project developers to secure financing. Investors’ lack of familiarity with the technology means projects are vulnerable to very steep lending rates, which places a considerable burden on a technology in the developmental stage.

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SECTION 6. A ROADMAP FOR DEVELOPMENT

6.1. Lessons from abroad

In response to an oil price shock, in 1975 Brazil established its National Alcohol Programme (PROALCOOL), which defined where production plants would be set up and how much ethanol would be produced per year. The price of the fuel and its demand were also set. The government-controlled BNDES financed new plants with interest rates lower than the market. 1978 saw a second oil shock and the following year vehicles running on neat ethanol were introduced with lower taxes than other types of vehicles. PROALCOOL also started incentivising the use of such vehicles and in 1986, 96% of all new vehicles sold were ethanol-only. New opportunities became available for ethanol manufacturers in 1990 when ethanol was allowed to be exported. With two decades of experience in the use of fuel ethanol, Brazil raised mandatory blending levels to 20-25% in 1993. Subsidies were provided to the ethanol industry to match the prices of conventional fossil fuel but in 1999 the government de-regulated fuel prices and ended subsidies for ethanol. 2003 saw the introduction of flex-fuel vehicles in Brazil, which can run on any blends of ethanol and gasoline. This helped to buffer consumers from disruptions in the ethanol supply chain or a substantial fall in the oil prices. The country had the potential to grow the first-generation ethanol industry and the policy support proved critical for increasing investments. A similar support for next-generation ethanol would help in raising investor and manufacturer confidence.

Table 4: Major biofuels policy drivers around the globe

Policy	US	EU-27	China	Brazil	India
Next-generation fuel mandate	Yes	Up to 4%	No	No	No
Next-generation ethanol weight in meeting renewables-in-transport target	Same as first-generation	Double of first-generation	Not applicable	Not applicable	No targets for next-generation renewables in transport
Price control of fuel ethanol	No	No	Fixed prices set by the government for different regions	Price control on fuel ethanol was lifted after decontrol of fossil fuels	Recommended INR 27 per litre of ethanol for three years
Centralised buying of fuel ethanol	No	No	Yes	Centralised buying was promoted in the initial years but is not practiced now.	Oil marketing companies to call tenders for supply of ethanol
Penalty for non-compliance of blending targets	Yes	EU can penalise the country which does not meet Renewable Energy Directive	Yes	Financial penalties which could also result in cancellation of licenses.	No
Tax incentives to biofuels industry	Yes	Germany has lower tax rates for biofuels	Yes. 17% VAT reimbursement, 5% consumption duty is free	Lesser taxes on commercialization value chain	Policy highlights a reduced excise duty of 16%.
Use of flexi-fuel vehicles (E 85)	Yes	Experimental phase	No	Yes	No
Mandating vehicle readiness by manufacturers for E10 or higher blends	15% for cars made after 2001. 10% for older cars	No, but generally cars are ready for E10	No, but the vehicle owners can get their vehicles modified easily.	Yes	No
Subsidies for fuel ethanol	Blending credit of $0.12 per litre for first generation and 0.26 per litre from next generation ethanol.	Yes (member-state-dependent)	Yes	Minimum support prices for some old ethanol manufacturers.	Yes (via fixed ethanol price)
Option for rolling back targets	Yes	No	No	Yes	Yes

Source: Bloomberg New Energy Finance

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While a growing number of countries are looking to integrate biofuels with conventional fuels for multiple reasons, further policy support will be needed to continue the momentum. Many of the subsidies given have come at the national level in various countries but there have also been state- and even municipal-level supports. In India, states may also choose to accelerate biofuels development through specific, local policies.

In October 2010, the US raised its allowable ethanol blending level to 15% for all vehicles manufactured in or after 2001. To accelerate ethanol development and deployment, India could consider creating a voluntary or mandatory blend for newer vehicles as well.

In November 2010, Japan introduced a national target for consumption of ethanol in the transport sector. The ethanol would be imported from Brazil and would gradually reach 500m litres by fiscal 2017-18. This will help Japan to meet its emission targets established under the Kyoto Protocol. India has the option of importing biofuels, along with fossil fuels, to meet its energy needs in the short run while the domestic ethanol manufacturing industry is still in developing stage.

In the EU, renewables-in-transport targets allow next-generation biofuels to be counted as twice the value of first-generation ethanol which also reduces overall quantum of the target. While this policy has not been particularly useful in spurring investment in next-generation ethanol in Europe, it could have more success elsewhere.

Imposing a penalty on non-compliance of blending could help to ensure indicative targets are met. China has a penalty on oil marketing companies for not selling a qualified product. Similarly, the EU has a provision to levy fines on countries that do not meet the standards of biofuels consumption laid out in the Renewable Energy Directive. India has no such mechanisms in place.

A thrust on building ethanol storage infrastructure for periods when there is a shortfall in sugarcane or crops could ease the pressure on supplies in ethanol-deficit years. Likewise fuel station owners could be incentivised to sell blended fuels along with conventional fuels.

Most countries that have successfully implemented ethanol blending programmes have also mandated that filling stations inform customers when they are buying gasoline blends containing 10% ethanol. When blended and labelled appropriately – and priced lower than the conventional fuel – consumers have shown they will opt for this biofuel. This model has been successfully implemented in Brazil and is being tested in other countries like China.

There could be some lessons to be learnt from these experiences, particularly from Brazil in terms of the implementation and escalation of blending targets. India has still not been able to implement the 5% nationwide target successfully. Although, National Policy on Biofuels recommends maintaining records of feedstock availability, processing facilities and offtake to avoid mismatch between demand and supply. But the country does not yet have an effective mechanism to monitor and record ethanol production and consumption by various industry sectors. Proper demand assessment based on available supply has been crucial to the success of biofuels in Brazil and will likely be the same for elsewhere.

6.2. Technical impediments

Detailed technical studies outlining feasible ethanol blending levels are needed to reassure consumers about the safety of using higher ethanol blends. The studies could allow warranties, issued by automobile manufacturers, to treat blended fuels on a par with conventional fuels. Subsidies on some automobile components could help to make the existing vehicle fleet ready for higher percentage ethanol blends. Proper conventions on using ethanol as an additive fuel and strict emission standards could strengthen its suitability as an alternative to conventional fuel. Another option would be to promote flex-fuel vehicles as has been done in Brazil and Sweden, where 80%[16] and 12%[17] of new cars sold in 2010 were flex-fuel.

16 http://www.anfavea.com.br/tabelas/autoveiculos/tabela10_producao.pdf

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6.3. Creating a specific next-generation biofuels mandate

If India wants to ramp up its output of next-generation biofuels, it would need coherent, innovative and sustained policies at the federal and state levels. Clear legislation, with penalties for non-compliance, would give investors greater certainty and could stimulate the deployment of funds.

India's current policy on biofuels does not include next-generation ethanol supplies. To exploit this biofuel resource, it could require a next-generation biofuel mandate comparable to that which is on the books in the US. The latter policy mandated highly ambitious 40bn litres of next-generation ethanol consumption by 2020. Yearly targets for the next decade specifying the use of next-generation ethanol in transport would give regulatory certainty for the industry.

New Delhi has successfully implemented a programme in which all the public transport vehicles are running on compressed natural gas rather than traditional fossil fuels. A similar programme using ethanol as a substitute fuel would benefit the industry and urban emission levels.

6.4. Incentives for residue collection

The poorly coordinated biomass collection market could be transformed into an organised trade. For example authorities could issue tendering contracts to local private organisations for the collection of excess biomass agricultural residues. The government could incentivise the proposed biomass aggregators to set up facilities for processing and storing biomass. State governments could also build biomass residue collection centres or depots in villages and could incentivise farmers to bring agriculture residue to these depots.

The US government introduced the Biomass Crop Assistance Program which provides a matching payment of up to approximately $50 per dry tonne for producers harvesting biomass. An initiative like this would likewise improve biomass transportation from aggregation hubs to a biorefinery. Such a policy could help in building a robust supply chain for biomass residues and provide rural employment along the supply chain. Following biomass aggregation, retail auctioning or wider residue sales would allow farmers to get good prices for their agricultural residues.

6.5. Driving new investment

A next-generation biofuels mandate would create an assured demand and build confidence among developers and backers of next-generation ethanol manufacturing facilities. Government entities such as the Indian Renewable Energy Development Agency could grant low-interest loans to projects demonstrating the technology to allay bankers' concerns over technology risk. The foreign exchange savings from reduced imports of crude oil could be diverted to support the next-generation ethanol industry. Tax exemptions and recognition of next-generation ethanol manufacturing as an industry should further ease financing constraints and increase the attractiveness of the biofuels sector in India.

6.6. Aligning multiple interests and stakeholders

If India wishes to maximise its next-generation ethanol potential, it needs to align the interests of the multiple stakeholders who include the chemical, beverage, ethanol producer and oil industries and various ministries and governmental departments. Discussion forums organised by industry associations could give them the chance to tackle important issues concerning ethanol availability and pricing. The ethanol pricing committee should include adequate representation from all the concerned parties. A biofuels steering committee, and its coordinating ministry, could organise participation from every relevant arm of the government.

17 http://viewswire.eiu.com/index.asp?layout=ib3Article&article_id=1007857885

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Currently the biggest consumers of ethanol are the beverage and chemical industries. There will be growing competition over the available ethanol as the oil industry starts blending higher volumes of biofuels. Diverting ethanol supplies to transport, at the expense of the chemical and beverage industries, does not currently seem like a viable option for India given the supply shortages that these industries claim to face. Next-generation ethanol supplies would help the beverage and chemical industries hit their respective demand ceilings, which means any excess supply could flow into the transport sector. This should help to ensure that all national ethanol demand is met, which should lessen the potential for conflict among the beverage, chemical and transport sectors.

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SECTION 7. METHODOLOGY

7.1. Agricultural residue potential

7.1.1. Summary

Crops are made up of two parts: the produce (grain/food) and the residue (stalks, husks, etc.).To calculate the agriculture residue potential in India, we first measure the ratio between the weight of the total harvested crop and that of the grain/food component. Typically, the latter accounts for one-third of the total harvested crop, with the remainder classified as agricultural crop residue. The ratio of the weight of residue to food is called the Residue Product Ratio (RPR) and partly depends on technology and how each crop is harvested.

Not all crop residues can or should be removed from the field as typically some is left in place to return nutrients to the soil and keep the soil moist. Based on our literature review we assume that 75% of the total agriculture residues will not be diverted due to scattered production and non-availability of transport infrastructure. These are used to meet a large part of the dry fodder demand in India but the rest might be burnt on the fields as is the case today. Thus we assume that only 25% of the agriculture residues are recovered from the field and we refer to this variable as the 'recoverability index'. Of the recovered residues, we assume that 15% is used to generate power and 30% for rural applications such as roofing, thatching etc. The remaining 55% is therefore available for next-generation ethanol production – 13.75% of the total agricultural residues.

Bagasse and rice husk are by-products of the sugar and rice industries respectively. These are collected from processing units, meaning that all of it may be recovered. To maintain uniformity in our residue availability methodology we assume that like other agriculture residues, of all bagasse and rice husk generated, only 13.75% would be used for making next-generation ethanol.

The RPR ratio for cotton was reported in terms of its area of production (in tonnes/hectare) since the residue production is not proportional to the weight of the cotton produce.

7.1.2. Detailed calculations

To assess the amount of agricultural residue, we shortlist the major crops based on their production quantity in 2008 using the UN Food and Agriculture Organization's database. We obtained historical annualised data for 1990-2008 for the area harvested, in hectares ($A_{Hectares}$), and the yield, in hectograms per hectare ($Y_{Hectograms}$), for the following agricultural crops: rice, wheat, millet, maize, sorghum, pigeon pea, lentils, chick pea, groundnut, rapeseed, soyabean, cotton, sugarcane, banana and potato. We selected these 15 crops because they are the most widely produced food crops in India and should therefore be the principal sources for agricultural biomass residues. The multiple of these two items equals the amount of crops produced:

$$Q_{Crop} = A_{Hectares} * Y_{Hectogram}$$

where, Q_{crop} is the total production of food or grain.

Thus, we developed a Residue Product Ratio (RPR) to determine the agricultural residue potential under the *Reference Potential and Enhanced Potential* scenarios. For example: in a wheat harvest about one-third of the crop is grain and two-thirds is the stalk and husks. Therefore the RPR ratio for wheat would be 2. The RPR partly depends on the technology and agricultural practices in a country. Thus, we calculate the RPRs for the crops grown in India and compare them with the available literature (Ravindranath et al., 2005).

$$Q_{Residues} = Q_{Crop} * H_{Recoverability} * RPR$$

where, $Q_{Residues}$ is the quantity of residue produced from the selected food crops.

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The recoverability fraction $H_{Recoverability}$ is defined as the ratio of the crop residue that can be realistically be recovered from the fields.

We assume a recoverability fraction of 25% meaning that of all the agriculture residues produced in India only 25% will be physically recovered from the field for useful application. We make the same assumption for all types of crops in this study. The RPR is defined as the weight of the residue part of the plant ($W_{Residue}$) which usually comprises of straws, stalks and husks to the ratio of weight of edible or food part of the plant (W_{Food}).

$$Q_{Residues} = Q_{Crop} * H_{Recoverability} * (W_{Residue} / W_{Food})$$

Cotton stalk production depends on the area harvested – not on the crop production. Thus for calculating the agriculture residues available from cotton stalks we ascertain the total area of cotton harvest in a year and then multiply it by the RPR of cotton stalks which is available in terms of tonnes per hectare harvested.

$$Q_{Cotton\ Residues} = A_{Cotton} * H_{Recoverability} * (W_{Residue} / W_{Food})$$

Where $Q_{Cotton\ Residues}$ is the residue available from cotton stalks and A_{cotton} is the total cotton harvest area in hectares.

Table 5: Biomass residue availability literature review, 2007-50[18]

Reference	Modelling type	Potential type	Area type	Geographical scope	Year	Min potential (EJ)	Max potential(EJ)
Campbell et al., 2008	GEO	SUS	Abandoned agriculture (crops and pasture)	World		0.032	0.041
Smeets et al., 2007	GEO/TECH	TECH	Energy crops + agricultural and forest residues + surplus forest growth	South Asia	2050	23	37
Schubert et al., 2009	GEO/ECON	SUS	Agriculture + forest + waste	World	2050	80	170
Hoogwijk et al., 2003	TECH	TECH	Agriculture residues	World	2050	10	32
			Energy crops + agricultural and forest residues + surplus forest growth	South Asia	2050	14	46
Doornbosch and Steenblik, 2008	TECH	TECH	Total	Asia		20.8	NA
				World		244.6	NA
Dornburg et al., 2008	TECH/ECON	ECON	Agriculture + forest residues + waste	World	2050	40	170
Fischer and Schrattenholzer, 2001	TECH/ECON	ECON		World	2050	350	450
Hoogwijk et al., 2005	GEO/ECON	GEO		World	2050	311	657
					2100	395	1115
		TECH			2050	234	493
					2100	297	838
Felby and Bentsen	TECH	TECH	Agriculture residues	India	2007	15.8	NA
Sukumarann et al., 2010			Agricultural residues	India	2010	9.34	NA
Bloomberg New Energy Finance	TECH	TECH	Agriculture residues	India	2020	13.66	19.98

Source: Bloomberg New Energy Finance, Bentsen, Niclas Scott. and Felby,Claus,2010, Technical potentials of biomass for energy services from current agriculture and forestry in selected countries in Europe, The Americas and Asia, University of Copenhagen

18 http://en.sl.life.ku.dk/upload/techpotentbiomasswp55.pdf

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7.2. Municipal solid waste

Biomass residues primarily comprise agricultural, forestry and municipal solid waste. This report does not consider biomass residues generated from municipal solid waste as per capita waste generation in major cities ranges over 73-220 kg/yr – about a third of the municipal solid waste generated in the developed world. The solid waste is accessible only in major cities due to a lack of proper municipal waste collection facilities in other areas and whatever is available is devoid of most of its useful products due to handpicking by unorganised waste collectors.

7.3. Forestry residues

This study does not consider forestry residues in the estimates of biomass residue. Forestry residues consist of wood fuel and round wood which have existing usage and are currently not diverted for other further use. As per Food and Agriculture Organization, in 2008 the total wood fuel production was 308m cubic metre and round wood production was 331m cubic metre. The International Energy Agency's study on *Sustainable production of second-generation biofuels potential and perspectives in major economies and developing countries* says that forest residues are consumed by the population residing in or near the forests and that the plantation products are used by timber, paper and pulp industries. Although round wood has several industrial applications, it produces insignificant amounts of residues that can be used for other processes.

7.4. Job creation methodology

Jobs created in the ethanol manufacturing industry are spread across various subsectors such as plant construction, biomass supply chain and operation of the ethanol manufacturing plant. Jobs along the biomass supply chain include collecting and transporting the residues. Residue collection involves biomass aggregation from the field: hauling the residues to a central location and baling or bundling them for transportation.

This report assumes that all next-generation ethanol manufacturing plants that begin operations up to 2020 have an average annual production capacity of 100m litres. We expect construction of each ethanol manufacturing facility to last 24 months, creating temporary construction jobs for that period. The collection and transportation of the agriculture residues and operation of the plant will create permanent jobs for the facility's lifetime and will increase with commissioning of every new next-generation ethanol manufacturing facility. To understand the jobs created in the ethanol manufacturing facility one must distinguish between construction jobs and operation jobs at the facility.

7.4.1 Ethanol facility module

Direct construction jobs source: Danish Construction Association, Inbicon and 3F (assuming EUR 1 = $1.3529)
Operational jobs source: NREL, *25m annual gallons fuel ethanol from corn stover operating costs*

The Danish Construction Association projected in 2010 that every EUR 1bn spent in the construction industry creates 5,665 direct construction jobs in the EU-27. Hence we assume that for every $1bn spent in the construction sector will create 4,187 jobs. The total annual amount spent on ethanol manufacturing plants construction between 2012 and 2020 thus provides the number and timeframe of construction jobs created.

The methodology assumes from zero production capacity in 2010, 2011, 2012 and 2013 towards the target production volume in 2020. This provides an annual capacity which builds towards the 2020 next-generation ethanol target. We assume next-generation ethanol manufacturing plant construction could start in 2012 and will last two years. We expect the first ethanol manufacturing plants will therefore be operational by 2014. To meet the 2020 bio-ethanol target of 34bn litres (*Reference Potential*) or 50bn litres (*Enhanced Potential*), 100m litre ethanol manufacturing plants must become operational each year over 2014-20. This leaves us with between 344 and 504 new build ethanol manufacturing plants by 2020. We assume it costs $125m to build each 100m litre

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ethanol manufacturing plant; it is therefore possible to calculate the aggregate capital costs for the annual construction of this ethanol manufacturing plant capacity.

It is commonly understood in the industry that each ethanol manufacturing plant of 100m litre capacity will create approximately 45 jobs in operations.[19] Therefore, the cumulative commissioned end-of-year capacity multiplied by 45 gives the annual and aggregate number of operations jobs created. NREL projects 10 operators and four maintenance workers will be required per shift; these jobs make up 70% of the operations jobs (excluding senior management). We assume that in any given day there are two shifts. There are therefore 20 operators and eight maintenance workers required per shift. 28 workers make up 70% of the total operations jobs, meaning there are 40 non-senior operational jobs in all. We have assumed five jobs for senior management, one overall plant manager and four supervisors. This brings the operational jobs to 45.

The total number of jobs created in the above mentioned methodologies is based on the studies on European markets where there is considerable mechanisation of work. The potential number of jobs created in India could be more since many jobs will be performed manually.

7.4.2 Biomass supply chain module

Agriculture residue module
Source: NRG Consultants
(http://www.nrg-consultants.com/chppowerplantscogeneration/wholestrawbalegasifiers/handlingofstraw/index.html)

Most farmers in India do not have modern harvesting and residue collection machinery. We assume that:

- Residues are mostly aggregated manually and are hauled 1km to a central location where they are bailed.
- Farm residues are baled using a small baler prior to being shipped to a next-generation ethanol manufacturing facility.
- These bales are then manually loaded on to a truck for transportation.
- The overall manpower required for all these activities is 72 minutes per tonne of dry agriculture residues.

Our estimates for cumulative agricultural residues give us the tonnes required per year from 2014 when the first ethanol manufacturing plant begins operations. The above mentioned factors give the number of minutes or 'manpower' to complete the baling, hauling and handling processes. If we assume 120,000 minutes in a 'working year' (200 days x 10 hours x 60 minutes) we can calculate the number of jobs created in baling, hauling and handling agriculture residues. This methodology is used for all types of crop residues.

7.4.3 Transportation module

Source: FAOSTAT (http://faostat.fao.org/)

This report assumes that:

- A typical truck in India has a load carrying capacity of 9 tonnes per full truck load. The same truck therefore carries 6 tonnes of biomass from an agricultural storage centre to the ethanol production facility. The decrease in weight-carrying capacity is due to the lower weight-to-volume ratio of biomass.
- The truck loaded with biomass residues travels 60km on average from an agricultural storage centre to the gate of the ethanol production facility.
- Transport workers have a 10-hour working day.

19 http://nercrd.psu.edu/Biofuels/Swenson.pdf

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- The average time taken by each truck to travel from field to manufacturing facility is approximately 1.7 hours.

From our cumulative agricultural residues for India, actual production figures (starting in 2014), we also know how many tonnes are collected and transported per year. From these factors we get the number of minutes or 'manpower' it took to complete this process. If we assume 120,000 minutes in a 'working year' (200 days x 10 hours x 60 minutes) then it is possible to calculate the number of jobs created.

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APPENDICES

Appendix A: Key stakeholders

Agency	Function	Possible roles in development of biofuels
Ministry of Petroleum and Natural Gas	Monitoring of exploration and exploitation of petroleum resources. Also monitors production, distribution, marketing and pricing of petroleum products	Determining the quantum of blending to be done
Ministry of Road Transport & Highways	Formulating and administering policies for road transport, national highways and transport research	Amending rules to allow norms for vehicles to run on biofuels
Ministry of New & Renewable Energy	Facilitates develops and deployment of new and renewable energy technologies for supplementing the energy requirements of the country	Coordinating ministry for National Biofuel Program. It could support studies related to biofuels and promote development of appliances to run on biofuels
Ministry of Agriculture & Cooperation	Formulation of policies programmes and measures for accelerated and diversified agricultural development	Develop policies and programmes for aggregation of agriculture residues
Ministry of Finance	Formulation and monitoring of macroeconomic policies. Pre-sanction and appraisal of major schemes/projects. Exercises control in respect of matters relating to all the direct and indirect union taxes	Review taxation and make financing available for policy implementation
Ministry of Rural Development	Designs policies to alleviate rural poverty	Could create programme for residue collection and also alleviate hurdles in the biomass supply chain
Ministry of Environment & Forests	Administrative structure of the central government for the planning, promotion, co-ordination and overseeing of implementation of environmental and forestry policies and programmes	Facilitate measurement of emission reductions and improvement in air quality
Ministry of Law & Justice	Advise on legal aspects and drafting of principal legislation	Advise on legal aspects of biofuel programme. In case of dispute, advises government on interpretation of the law
Ministry of Information & Broadcasting	Mass communication media consisting of radio, television, films, the press, publications and advertising	Educating farmers on the use of biomass and policies related to cellulosic ethanol
Ministry of Statistics and Programme Implementation	Responsible for coverage and quality aspects of various statistics in India	It could maintain a national database on production and consumption of ethanol
Ministry of Consumer Affairs	Formulation of policies for monitoring prices, availability of essential commodities, consumer movement in the country and controlling of statutory bodies like Bureau of Indian Standards and Weights and Measures	Ensure fair remuneration, contracts and quality of products for farmers, biofuel manufacturers and end consumers
Department of Land Resources	Policies aimed at sustainable development of land resources in rainfed/degradable areas of rural India. Aims to build an integrated Land Information Management System	Could be involved in crop residue collection, energy crop plantation on degraded land
Department of Agricultural Research and Education	Promotes agricultural research and education in the country. Controls Indian Council of Agricultural Research and Central Agricultural University	Commissioning studies for collection and use of agriculture crop residues
Department of Science & Technology	Nodal department for organising, coordinating and promoting science and technology activities	Promote development of technology and entrepreneurs in biofuels industry
Council for Science & Industrial Research	Undertake research and development work in petroleum refining and conduct market demand surveys and techno-economic feasibility studies for petroleum products	Undertake study on techno-economic feasibility of biofuels
Planning Commission	Planning Commission plays an integrative role in the development of a holistic approach to the policy formulation in critical areas of human and economic development	Delivering research papers on economics and potential of biofuels which will help in building supportive policies for the industry
Bureau of Indian Standards	Development of standardisation, marking and quality certification	Develop quality standards for biofuels
Central Pollution Control Board	Advise the Central Government on any matter concerning prevention and control of water and air pollution and develop appropriate policies	Monitor environment and health effects of emission mitigation from biofuels
Indian Renewable Energy Development Agency	Gives financial support to specific projects and schemes for generating electricity and / or energy through new and renewable sources	Support companies wishing to establish technology centres or biofuels manufacturing facility by providing loan at lower interest rates
Small Industries Development Bank of India	Financing, promoting, development and coordination of small scale industries	Support financing of biofuel manufacturing units and residue collection centres

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Agency	Function	Possible roles in development of biofuels
Petroleum Conservation Research Association	Functions as a think tank to the government for proposing policies and strategies on petroleum conservation and environment protection aimed at reducing excessive dependence on oil	Carry out studies on technical levels of blending
Indian Agricultural Research Institute and Indian Council of Agriculture Research	Research institute for studying improvements in agricultural productivity and other agricultural applications	Study technological developments for conversion of agriculture residue into clean biofuels
Indian Oil Corporation, Bharat Petroleum Corporation, Hindustan Petroleum Corporation	Oil marketing companies responsible for refining, marketing and distribution of petroleum products	Carry out prescribed blending targets and procure biofuels from producers at government approved prices. Setting up storage facilities for biofuels
Indian Institute of Petroleum (IIP) & Indian Institute of Chemical Technology	Research institutes	Carry out studies related to use of biofuels in the transport sector
Indian Sugar Mills Association	Industry association representing to the government on policy issues relating to sugar and sugar cane	Should be involved in the pricing of ethanol and monitoring molasses consumption
All India Distillers Association	Industry association for the alcohol and liquor industry in India	Should be involved in the pricing, production and consumption of ethanol
Indian Chemicals Manufacturers Association	Industry association dedicated to the growth of the Indian chemical industry	Should be involved in the pricing and consumption of ethanol
Society of Indian Automobile Manufacturers	SIAM is an industry association which works on the development of a stronger automobile industry in India	Determination of ethanol blending levels which can be used without adversely affecting the vehicle components and in providing vehicle warranty for the same. Help in manufacturing of automobile components which are suitable for multiple blending levels of petrol
State excise departments	Administers manufacturing, possession, sale, import, export and transport of liquor, intoxicating drugs and collection of revenue from each of these sources	Ease the movement of biofuels or its raw materials within and amongst the state borders

Source: Bloomberg New Energy Finance, Stakeholder websites

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