

A REVIEW OF BIOFUELS IN INDIA: CHALLENGES AND OPPORTUNITIES

R Blanchard¹, S C Bhattacharya², M Chowdhury³, B Chowdhury⁴, K Biswas⁵, B K Choudhury²

1 Centre for Renewable Energy Systems Technology, Loughborough University, UK

2 Department of Energy Management, Indian Institute of Social Welfare and Business Management (IISWBM), Kolkata, India

3 Department of Chemical Engineering, Jadavpur University, Kolkata, India

4 Chemical Engineer and Researcher, USA

5 Assistant Technology Manager, Department of Agriculture, Government of West Bengal, India

ABSTRACT

Economic development in India has raised millions of people out of poverty and brought about the modernization of society. Economic ambition though has not been reached without costs. India has become more reliant of imports of energy which affects energy security. Pollution from industry, transport and traditional cook stoves affects air quality and is increasing emissions of greenhouse gases and contributing to climate change. .

India initiated bio-fuel production nearly a decade ago to reduce its dependence on imported oil and thus improve energy security and is now one of the largest producers of Jatropha oil. The country began 5% ethanol blending (E5) pilot program in 2001 and formulated the National Mission on Biodiesel in 2003 to achieve 20% biodiesel blends by 2011–2012 (Government of India, 2002, 2003). Similar to many countries around the world, India's biofuel programs experienced setbacks, primarily because of supply shortages and global concerns over food security. India's National Policy on Biofuels in 2009 proposed a non-mandatory target of a 20% blend for both biodiesel and ethanol by 2017, and outlines a broad strategy for the biofuels program and policy measures to be considered to support the program.

The aim of the paper is to review the potential for biofuels to off-set the use of fossil fuels and reduce greenhouse gas emissions in India. The recent historic use of biofuels in the context of Government policy developments will be presented. Example materials (crops, wastes, residues) that can be used for biofuels will be reviewed taking a systems approach through whole lifecycle assessment. Case studies highlighting failure and successes with biofuel utilization will be presented as examples of the challenges and opportunities for the use

of biofuels in India, with suggestions made on the role of biofuels in the future.

Keywords: India, Bio-fuel potential, Barriers, opportunities, Policy issues, Need for technology transfer/adaptation

INTRODUCTION

India with a population of 1.27 billion people is set to become the most populous in the world [1]. In recent years the economy has been growing at roughly 8% per annum [2] which is matched by increasing energy consumption at 8.5% per annum [3]. India depends heavily on fossil fuels for meeting its energy demand. As shown in Fig. 1, shares of coal, oil, gas, nuclear, hydro, biomass/waste and other renewables in the total primary energy demand in 2012 were 45%, 23%, 6%, 1%, 1%, 24%, and below 0.5% respectively. India has very low reserves of fossil fuels and has to import oil, coal as well gas, the import dependence being particularly high in the case of oil. In 2012, imports accounted for about 75% of India's oil demand; it is projected that the import dependence will grow to 92% of demand in 2035 [4]. About 50% of the total oil demand is consumed in the transport sector followed by agriculture (18%) and industry sector (11%). India has been enjoying quite fast economic growth in recent years; commercial energy consumption of the country has also been growing fast, keeping pace with its economic growth. For India, it is vital to reduce dependence on oil for reducing its energy import bill, enhancing energy security and mitigating greenhouse gas (GHG) emissions. Promoting biofuels is thus very important in the case of India.

The aim of this paper is to present a broad review of biofuels in India, including history, current status and

feedstocks used, national policy, technology, and environmental issues.

2. Biofuel Policy

2.1 History of Biofuel in India

India initiated its biofuel programme more than a decade ago and launched several policy measures to promote biofuels since then. In 2002, India launched its “Ethanol Blending Programme” and mandated a 5% blending of ethanol (E5) with petrol in nine States and four Union Territories with effect from January 2003 [5]. The Planning Commission of India constituted a Committee on Development of Biofuels in July 2002. The report of the Committee, released in 2003, recommended India to progressively move towards higher targets regarding blending of biofuels, including strengthening of the ethanol blending programme.

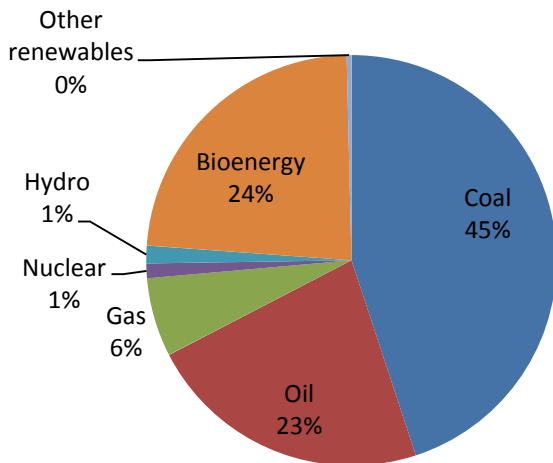


FIGURE 1. PRIMARY ENERGY DEMAND OF INDIA IN 2012 [6]

However, the 5% blending mandate in the case of ethanol could not be met due to shortage of bioethanol supply; in October 2004, the mandate was amended “requiring E5 blends only when adequate ethanol supplies were available” [7]. In 2006, the 5% blending mandate was extended to cover 20 States and 8 Union Territories; again this target could not be met due to shortage of bioethanol supply. In September 2008, the Union Cabinet set a target of 5% blending across the country. Although the 5% target could not be realized, the Government set a target of 10% blending in October 2008.

The Planning Commission report of 2003 recommended launching of a National Mission on Biodiesel to be based on non-edible oil and identified *Jatropha curcas* as the most suitable tree-borne oilseed for biodiesel production [8]. One aim of the Mission was to gradually raise the blending target to 20% by the year 2012. The Planning

Commission estimated that 11.2 million hectare of land would be required for *Jatropha* plantation to achieve the 20% target by 2012 and identified 13.4 million hectare of land that could be actually used for plantation. In October 2005 the Ministry of Petroleum and Natural Gas announced a biodiesel purchase policy, which required Oil Marketing Companies to procure biodiesel in the country for blending with diesel with effect from January 2006.

In order to strengthen the faltering ethanol and biodiesel blending programs, India’s National Biofuel Policy was approved by the Govt. of India in December 2009.

2.2 National Biofuel Policy

The Goal of the policy is to ensure the ready availability of biofuels to meet demand and proposed an indicative target of 20% blending of biofuels, both for bio-diesel and bio-ethanol, by 2017. The blending target for bio-diesel was intended to be recommendatory, while the target for bio-ethanol was supposed to be mandatory.

Salient features of the biofuel policy include:

1. Biofuels are to be based solely on non-food feedstocks to be raised on degraded or wastelands that are not suited to agriculture, thus avoiding a possible conflict of fuel vs. food security.
2. Cultivation / plantation of non-edible oil seeds to produce bio-diesel will be encouraged through a Minimum Support Price.
3. Plantations that provide the feedstock for bio-diesel and bio-ethanol will be supported through a Minimum Support Price for the non-edible oil seeds used to produce bio-diesel. Further, appropriate financial and fiscal measures will be considered from time to time to support the development of biofuels in the country.
4. Research, development and demonstration will be supported to cover different aspects of feedstock production and processing of biofuels, including development of second generation biofuels.

The Policy document also included interventions and enabling mechanisms regarding plantations, processing, distribution and marketing, financing, financial and fiscal incentives, and research and development.

However, the biofuel industry is in a sad state of development currently. In the case of ethanol, the 5% blending target has remained elusive even today. Biodiesel blending in the country remains insignificant; only about half a million hectare has actually planted with *Jatropha* so far and biodiesel production in the country remains negligible [9]

BIOFUEL RESOURCES

Bio-fuel is most commonly defined as a renewable source of energy which is produced from biological materials or biomass, such as sugar cane, corn or vegetable oils. The strategic goal of Bio-fuel is to supplement or even replace fossil fuels. But the policies focus on the use of non-food biomass for biofuels. India has a plethora of species that can be used produce from conventional oil seeds, woody materials, and wastes from agriculture and municipal solids. Indeed, there are over 300 oil-seed bearing tree species in India [10].

India is rich in biomass and majority of Indian population used bio-fuels traditionally but in many cases inefficiently which led to a couple of major social problems particularly health effects of air pollution. Appropriate technology for making bio-fuels available to the people and its effective utilization would have significant impact on India's socio-economic conditions. Bio-fuels production technologies include the following:

1. Energy plantation
2. Accumulation and/or reclamation of wastes
3. Conversion of biomass to bio-fuels
 - A. Using mechanical process
 - i. Extraction (Eg. bio-diesel)
 - ii. Compression (Eg. Pelletization)
 - B. Using chemical process
 - i. Liquefaction (Eg. Conversion of cellulosic biomass to oil)
 - ii. pressurized water reactor in a hydrothermal medium
 - a. hydrolysis
 - b. fractionation
 - c. gasification and
 - d. reaction
 - C. Using bacteria (Eg. Biogasification through biomethanisation)
 - D. Using algae for Conversion of micro-algal biomass to biofuels
 - i. Oil extraction from microalgae
 - ii. Microalgal wastewater treatment
 - a. Hydrothermal gasification
 - b. super-critical water as reaction medium
 - c. ultrasonic treatment

Bio-fuels utilization technologies include the following:

1. Direct burning, combustion or gasification for heating or power generation or both (co-generation)
 - a. Co-firing along with fossil fuel(s)
 - b. Fluidized bed
 - c. Transported bed
 - d. Circulating fluid bed
 - e. Ablative (vortex and rotating blade)
 - f. Rotating cone
 - g. Vacuum
2. Bio-gas for cooking or fuel cells for power generation or co-generation
3. Transport fuels

There are a number of routes to produce biofuels from biomass. These are shown in Table 1 to give an illustration of the methods that can be employed for transport fuels.

TABLE 1 SELECTED BIOMASS TO BIOFUEL ROUTES

Resource	Technology	Product	End use
Oil seed, Algae	Trans-esterification	Biodiesel	Diesel engine
Algae, Cattle slurry, Domestic waste	Anaerobic Digestion	Biogas	Gas engine or petrol engine if gas to liquid Fischer Tropsch reaction
Wood, agricultural residues, municipal waste	Gasification	Syngas	As above
Cellulosic biomass	Fermentation	Ethanol	Petrol engine

CASE STUDIES

Anaerobic Digestion: This is a process where biomass is broke down with methanogenic bacteria to produce biogas under anoxic conditions. This process produces Biogas containing approximately 60:40 mixtures of methane (CH₄), and carbon dioxide (CO₂) and simultaneously generating an enriched sludge fertilizer-with an energy content of 22.5 MJ/m³.

The Ministry of New and Renewable Energy is implementing the National Biogas and Manure Management Programme (NBMMP) in all the States of the country. Up to 2008, more than 4 million biogas plants were installed [11] and by 31st March, 2014 about 4.75 million biogas plants have already been installed in the country. This means, the growth significantly dropped after 2008. During the year 2014-15, a target of setting up 110,000 biogas plants had been set and actual achievement data are awaited. The biogas plant is the best option for households having feed material, to become self-dependent for cooking gas and highly organic enriched bio-manure. It provides the solution to protect the households from the problems of indoor air pollution and while saving on cost of refilling of LPG cylinders. The Ministry provides subsidy for family type biogas plants [12]. A number of studies have shown the potential of biogas in India [13-17].

As per the reports of the Ministry of Non-Conventional Energy Sources of India, studies have shown that the digested slurry obtained from biogas plants contains 80% carbon, 1.8% nitrogen, 1% phosphorous and 0.9% potash making it an excellent source of not only humus but also micronutrients for crops. Substitution of inorganic fertilizer by biogas slurry helps towards organic farming.

Biodiesel: Vegetable oils from food (1st generation) and non-food (2nd generation) sources, such as *Jatropha* and *Karanja* can be converted to biodiesel. The main conversion is through transesterification where the oil is mixed with alcohol and an alkaline catalyst to produce a fatty acid methyl-ester which has properties similar to fossil fuel diesel [18]. India's policy is to use 2nd generation plus waste vegetable oil (WVO). WVO is 2-3 times cheaper as a feedstock [19] and can yield a quality biodiesel [20] with a lower pollution potential [21-24].

Bioethanol: As with biodiesel, bioethanol can be divided into ethanol derives from food (1st generation) and non-food (2nd generation) sources. India produces 1.3 billion litres of ethanol from cane molasses against an installed capacity of 3.2 billion litres currently. India is adopting a new policy for ethanol production from cellulosic biomaterials, which is an E20 by 2017 and targets to produce more than 4 billion gallons per year by 2017 [25]. Sugarcane and wheat are the major feedstock for bio-fuel production in India. In India [26], about 121 GJ fuel ethanol is produced annually by means of sugarcane [27] from an estimated 199.1 million metric tons (MMT) of sugarcane cultivated in India [28]. As a consequence of the production of sugarcane, the generation of surplus amounts of harvested agricultural residue such as sugarcane tops (SCT) (i.e. leaves including top portion of plant, which is cut away) equate to around 75(MMT) of SCT being available in India [29].

Globally many cellulosic agro-residues have been used to produce bio-ethanol such as rice-straw, wheat straw, sugarcane bagasse, sugarcane tops, cotton stalk, soft bamboo, bamboo processing wastes; and all are considered as abundantly available feed stocks. Examples which have been used in India include cashew apple pulp, coffee pulp [30] and banana peels [31].

Cellulosic substrates require pre-treatments to increase ethanol yield and reduce fermentation times. This can be physical reduction in size, chemical treatment, biological treatment and ultrasound. Chemical treatment can involve the use of mild alkalis, acids or organic solvents [32]. Biological treatment can use fungi [33]. Ultrasound techniques are promising increasing yields by 10% [34].

Cogeneration in Sugar Mills: There are more than 640 sugar mills in India. In the year 2013-2014 509 of them were in operation and produced 22.97 million tons of sugar from about 345.6 million tons of sugarcane [35]. This is more than 17% of world production of cane sugar. The Indian sugar industry, in about two decades, has become modernized to use co-generation in co-firing or fluidized bed boilers and contributes significantly to inject surplus power to national grid after meeting their own needs - conservative estimate is 5000 MW of surplus power to national grid when all sugar industries adopt this modernization. For example, if steam generation temperature/pressure is raised from 400°C/ 33 bar to 485°C/ 66 bar, more than 80 KWh of additional electricity can be produced for each ton of cane crushed [36].

Thermal Waste to Energy (WtE): Technologies include incineration, gasification and pyrolysis. This is a large scale technology often requiring 1000 tonnes of municipal solid waste (MSW) per day. The overall power potential from MSW in India is estimated to be 3,650 MW by 2012 [37] Power potential from MSW from 59 cities was found out to be 1,292 MW. Generation of energy from MSW can displace 14.5 million tonnes per year of low grade coal every year. For example, Delhi has the highest potential for power generation from MSW (186.8 MW), followed by Mumbai (186.6 MW), Chennai (149 MW), and Hyderabad (91 MW). The rise of GDP in India is anticipated to increase the potential for WtE to around 5,200MW [37].

There are a number of other technologies particularly in relation to pressurized water reactions that have not been discussed owing to their immature status.

ENVIRONMENTAL ISSUES/ IMPACT:

India has made rapid strides in terms of economic development and modernization. This has had a positive impact on a vast majority of the population and millions of poor elevated into the middle class. This rapid

economic expansion and modernization has in turn contributed to increased number of vehicles on the Indian roads. This has led to about 6.64% increase in Gasoline consumption and 4.1% increase in diesel consumption [38]. Fossil fuel resources are limited therefore as the demand grows the price of fossil fuels will increase. Over the last decade the price of a barrel has increased at least fourfold driven primarily by the worldwide increase in demand. (Although this has fallen recently). The increased burning of fossil fuels increases the air pollution and also contributes to global warming. In order to mitigate the effect of fossil fuels, the Indian government promoted the production of biofuels.

One of the plant species that is being studied extensively for biofuels production is *Jatropha curcas*. The environmental impacts of *Jatropha* using 9 different agronomic trials that were grown in the state of Andhra Pradesh were investigated [39]. The biofuels produced from the *Jatropha* seeds can be a viable alternative to fossil fuel thereby reducing the GHG emissions. Cultivating *Jatropha* on arid and unusable lands prevents desertification of the land. Research also showed that *Jatropha* cultivation can be used for carbon sequestration. However, the water requirements were still unclear and could be low to high depending on the specific variety that is being used. *Jatropha* cultivation on large scale could also lead to Eutrophication. The authors conclude that while *Jatropha* cultivation reduced the greenhouse gas emissions and helped in carbon sequestration it could potentially increase other environmental impacts like acidification, ecotoxicity, eutrophication, and water depletion. Extra attention is needed to reduce the other impacts on the environment.

LCA (Life Cycle Assessment) is a good tool to study the environmental risks and impacts to compare the *Jatropha* biofuel system with fossil fuels [40]. The case in study is a low input, small scale *Jatropha* biofuel system in rural Allahabad, India. In the case that was studied, wasteland was being reclaimed and the biofuel was used in the local transportation sector. An EIA was also simulated for a biogas installation for the digestion of *Jatropha* seed cake.

Five main impact categories were considered namely, Non Renewable Energy Required (NRER), global warming potential (GWP), eutrophication potential, acidification potential and land use impact. The case study showed a large reduction in the NRER and a moderate reduction in the GWP. However, due to the fertilizer used in the seedling stage, there is an increase in the eutrophication and acidification potential. The energy efficiency is increased by adding biogas production to the biofuel *Jatropha* biofuel production system.

The potential for using *Jatropha* for sustainable environmental development has identified several of its benefits [41]. *Jatropha*'s bioaccumulation potential

allows it to be used for the phytoremediation of polluted soil while producing biodiesel [41]. Biofuels are carbon neutral making them a good renewable energy source. When compared to fossil fuels, biofuels reduce CO₂ emissions along with the reduction in SO₂, ozone forming chemicals; trace gases that cause air pollution and toxic heavy metals. *Jatropha* plantations also help in the mitigation of soil erosion due to taproot stabilization. It can also be used for reforestation in arid areas, management to marginal land, help in water and soil conservation, prevent wind erosion and for stabilization of sand dunes. The authors state that one of the advantages of using *Jatropha* is the fact that its cultivation helps in re-vegetation of degraded land and there is no competition for arable land that used for food crops. Another advantage of using *Jatropha* plant is that once the seed is processed and the oil is extracted the remaining seed meal can be used to produce biogas or the remaining seed cake can be used as manure.

CONCLUSIONS

This paper has highlighted that despite the policies, resources and technologies the role of biofuels in the current fuel mix is small compared to the demand.

There are a number of challenges in developing biofuels in India (and other parts of the world). The main market constraints specific to biofuels can be summarized by eight main market barriers, as following:

Economic barriers: The production of biofuels are still expensive, beneficial externalities are not costed.

Technical barriers: The fuel quality is not yet constant and conservation technologies for certain biofuels are still immature (e.g. for synthetic biofuels.)

Trade barriers: For some biofuels still no quality standards exist.

Infrastructure barriers: Depending on the type of biofuel, new or modified infrastructures are needed. Especially the use of bio-hydrogen and bio-methane.

Ethical barriers: Biomass feedstock sources may compete with food supply.

Knowledge barriers: The general public, but also decision makers and politicians are lacking knowledge on biofuels.

Political barriers: Governments ongoing subsidy to kerosene promoting inefficient and sometimes illegal use of this fossil fuel though with the application of available technologies the target population could have been equally or more benefitted with the use of biofuels but for political will and policy.

Conflict of interest: Conflict between "promoters" of first and second generation Bio-fuels may weaken the overall development of biofuels.

Without action to raise the production of biofuels this situation will continue and India will rely heavily on fossil fuels for the foreseeable future with the consequences of continued or increasing air pollution and greenhouse gas emissions.

REFERENCES

- [1] India Online, "India's Population 2014," 2014. [Online Available: <http://www.indiaonlinepages.com/population/india-current-population.html>].
- [2] A. Kumar, K. Kumar, N. Kaushik, S. Sharma and S. Mishra, "Renewable energy in India: Current status and future potentials," *Renewable and Sustainable Energy Reviews*, pp. 2434-2442, October 2010.
- [3] Central Statistics. Office. Govt.. of. India, "Energy statistics," New Delhi, 2014.
- [4] IEA, 2012, Understanding energy challenges in India – policies, issues and players. International Energy Agency, Paris, France.
- [5] Bandyopadhyay, K.R. 2015. Policy Brief on Biofuels promotion in India for transport: Exploring the grey areas, The Energy Research Institute, New Delhi.
- [6] IEA, 2014, World energy outlook, International Energy Agency, Paris, France.
- [7] Gunatilake, H., 2011. *India: Study on Cross-Sectoral Implications of Biofuel Production and Use*, Asian development Bank, Manila
- [8] Planning Commission, 2003. Report of the Committee on Biofuel Development, Planning Commission, New Delhi
- [9] GAIN (Global Agricultural Information Network). 2014. India – Biofuels Annual. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_New%20Delhi_India_7-1-2014.pdf
- [10] Altenburg T., Dietz H., Hahl M., Nikolidakis N., Rosendahl C. and Seelige K. 2009. Biodiesel in India - Value chain organisation and policy options for rural development German Development Institute, Bonn, Germany.
- [11] <https://data.gov.in/keywords/biogas-plants>
- [12] <http://mnre.gov.in/schemes/decentralized-systems/schems-2/>
- [13] Radu T, Wheatley AD, Blanchard RE. 2013. Anaerobic co-digestion of maize and sewage sludge: providing energy for rural communities in India. 13th World Congress on Anaerobic Digestion: Recovering (bio) Resources for the World, Santiago de Compostela, Spain, 25 Jun 2013 - 28 Jun 2013. 1-1. 25 Jun 2013.
- [14] Blanchard, R. E., & Pollard, A. M. 2014. A Hybrid Biogas System for Kolkata. In *1st International Conference on Non-Conventional Energy* (pp. 1-6). JIS College of Engineering, Kalyani, India.
- [15] Radu, T., Blanchard, R. E., Wheatley, A., Yadav, D., Bora, D., Purkayastha, R., Ghatak M, Barbora L, Mahanta P, Collins F, and Diamond, D. 2014. Providing energy for rural Indian communities. Anaerobic digestion at Loughborough University. In *UK AD & Biogas 2014* (pp. 1). Birmingham.
- [16] Yadav, D., Bora, D., Purkayastha, R., Ghatak, M., Barbora, L., Mahanta, P., Radu, T., Blanchard, R. E. and Wheatley, A. D. 2014. Small Scale Anaerobic Digestion: A Case Study. In *37th WEDC International Conference: Sustainable Water and Sanitation Services for All in a Fast Changing World* (pp. 1). Hanoi, Vietnam.
- [17] Yadav, D., Bora, D., Purkayastha, R., Ghatak, M., Barbora, L., Mahanta, P., Radu, T., Blanchard, R.E. & Wheatley, A.D. 2015. An investigation into the potential for improving anaerobic digestion process using thermal enhancement. Bioenergy: an engine for economic growth in the global South workshop. Wellcome Trust, London 28/01/2015.
- [18] Encinar JM, Gonzalez JF, Rodriguez-Reinares A. 2005. Biodiesel from used frying oil. Variables affecting the yields and characteristics of the biodiesel. *IndEngChem Res* ;44:5491–9.
- [19] Zhang Y, Dube MA, McLean DD, Kates M. 2003. Biodiesel production from waste cooking oil: 2. Economic assessment and sensitivity analysis. *Bioresour Technol* , 90:229–40
- [20] Cetinkaya M, Karaosmanoglu F. 2004. Optimisation of base-catalysed transesterification reaction of used cooking oil. *Energy Fuels*, 18: 1888–95.
- [21] Utlu Z. 2007. Evaluation of biodiesel obtained from waste cooking oil. *Energy Sources, Part A*, 29:1295–304
- [22] Leyvison Rafael V. da Conceição, Carlos E.F. da Costa, Geraldo N. da Rocha Filho, José R. Zamian. 2011. Obtaining and characterization of biodiesel from jupati (*Raphiataedigera* Mart.) oil *Fuel*, 90 2945–2949.
- [23] Nas B, Berkay 2007. A. Energy potential of biodiesel generated from waste cooking oil: an environmental approach. *Energy Sources* 2:63–71.
- [24] Utlu Z, Kocak MS. 2008. The effect of biodiesel fuel obtained from waste cooking oil on direct injection diesel engine performance and exhaust emissions. *Renewable Energy*, 33:1936–41.

- [25] Bryant, C. 2009. India- an emerging market for cellulosic bio-ethanol. *Bio-fuel*, 78–9.
- [26] Timilsina GR, Shrestha A 2011. .How much hope should we have for biofuels? *Energy*, 36:2055–69
- [27] Khalil HPSA, Aprilia., NAS, Bhat., AH, Paridah., MT, Rudi., DA. 2013. *Jatropha* biomass as renewable materials, for biocomposites and its application. *Renewable Energy Sus Rev*, 22:667–85.
- [28] Sukumaran., RK, Surender., VJ, Sindhu., R, Binod., P, Janu., KU, Sajna. ,KL. 2010. Lignocellulosic ethanol in India: prospects, challenges and feed stock availability. *Bioresour Technol*, 101:4826–33.
- [29] Pandey A, Biswas S, Sukumaran RK, Kaushik N. Study on the availability of Indian biomass resources for exploitation: a report based on nationwide survey. Technology Information, Forecasting and Assessment Council (TIFAC) Publisher; 104.
- [30] Shenoy, D, Pai., A, Vikas., RK, Neeraja, HS, Deeksha JS, Naya KC. 2011. A study on bioethanol production from cashew apple pulp and coffee pulp waste. *Biomass Bioenergy*, 35:4107–11.
- [31] Bhatia., L, Paliwal., S. 2010. Banana peel waste as substrate for ethanol production. *Int J Biotechnol and BioengRes* 1(2):213–8.
- [32] Kumar., R, Singh., S, Singh., OV. 2008. Bioconversion of lignocellulosic biomass: biochemical and molecular perspectives. *J Ind Microbiol Biotechnol*, 35:377–91.
- [33] Sarkar N, Ghosh., SK, Bannerjee., S, Aikat., K. 2012. Bioethanol production from agricultural wastes: an overview. *Renew Energy*, 37:19–27.
- [34] Yachmenev., V, Condon., B, Klasson., T, Lambert., A. 2009. Acceleration of the enzymatic hydrolysis of cornstover and sugarcane bagasse celluloses by low intensity uniform ultrasound. *J Biobased Mater Bioenergy* 3:25–31
- [35] http://www.indiansugar.com/PDFS/world_sugar_production-07-13.pdf
- [36] <http://mnre.gov.in/schemes/grid-connected/biomass-powercogen/>
- [37] National Solid Waste Association of India. 2010. Urban Municipal Waste Management Newsletter 18 (1).
- [38] Basavaraj G., P Parthasarathy Rao, Ch Ravinder Reddy, A Ashok Kumar, P Srinivasa Rao and BVS Reddy, A Review of the National Biofuel Policy in India: A critique of the Need to Promote Alternative Feedstocks, Working Paper Series no. 34, RP – Markets, Institutions and Policies 2012, International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India
- [39] Gmunder Simon, Reena Singh, Stephan Pfister, Alok Adhelooya and Rainer Zah, 2012. Environmental Impacts of *Jatropha curcas* Biodiesel in India, *Journal of Biomedicine and Biotechnology*, Article ID 623070.
- [40] Achten W. M.J., Joana Almeida , Vincent Fobelets, Evelien Bolle, Erik Mathijs, Virendra P. Singh, Dina N. Tewari, Louis V. Verchot, Bart Muys. 2010. Life cycle assessment of *Jatropha* biodiesel as transportation fuel in rural India , *Applied Energy* 8, 3652–3660.
- [41] Pandey Vimal Chandra, Kripal Singh, Jay Shankar Singh, Akhilesh Kumar, Bajrang Singh, Rana P. Singh. 2012. *Jatropha curcas*: A potential biofuel plant for sustainable environmental development, *Renewable and Sustainable Energy Reviews* 16, 2870–2883.