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Biomass & Bio-waste Supply Chain Sustainability for Bio-energy and Bio-fuel Production

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Abstract

The terrestrial biomass feedstock can be generally categorized into two groups. The first group includes corn grain, sugarcane, soy bean, oil seed, etc. The second group of terrestrial biomass feed stocks, the cellulosic biomass, can avoid adverse impacts on food supply, because they are non-starch, non-edible and non-food feedstocks. Cellulosic biomass feed stocks can be obtained from a number of sources, such as agricultural residues, forest residues and energy crops. Currently, most bio-fuels are made from these feed stocks, due to the maturity in technologies and lower unit production cost. However, the use of these feed stocks for bio-fuel production might have implications both in terms of world food prices and production. Agricultural residues are typically plant parts left in the field after harvest (e.g., corn stover), as well as the secondary residues like manure and food processing wastes. Bio-fuel policies play an important role in the development of the energy sector specifically in the developing countries. The profitability of bio energy and bio-fuel production is significantly influenced by policies affecting multiple sectors such as agriculture, research, industry and trade. Identifying relevant policies and quantifying their specific impacts is difficult given the variety of policy instruments (taxes, subsidies, price support, etc) and the way they are applied. While reviewing the literature and the implementation projects, it has been observed that one of the main challenges is to develop an efficient and robust supply chain management system for sustainable bio-energy and bio-fuel production. There are many research activities found on bio-energy and bio-fuel production but the number of implementation as a business case is scant in the developing countries including India. Present study has reviewed the biomass and bio waste supply chain for bio energy and bio fuel production and investigated the cause of the major challenges and issues in India. It also proposed some feasible solutions for the developing countries. It may be concluded that the main challenge lie on the feedstock supply, farmers' choice for traditional use of biomass, economy of scale, efficiency, export of output energy and the major issue being the government policy. The study will definitely help in implementation of bio-energy production projects and the researchers for further improvement.

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Introduction

The combustion of petroleum based fossils fuel has become a concern with respect to the global climate change due to increasing rates of carbon emission. Fluctuations and uncertainty in supply and cost of fossil fuels made it unreliable burning source. There is convincing evidence that oil prices may trend higher over the next two decades and this would have a substantial negative macroeconomic impact for India, China and other developing economies. A 50% increase in oil prices between 2010‑2030 would significantly reduce economic growth, real consumption and household income. Expansion of biodiesel is one policy response the countries can use to counteract the economic impacts of oil price hikes. Biodiesel intervention can significantly counteract these negative impacts whereas ethanol intervention has a minimum offsetting impact. Combining supply‑side energy solutions, like biodiesel development, together with modest energy efficiency improvements and productivity improvements in agriculture will provide impressive results[1]. These factors associated with many others made all the countries in the globe to think of alternatives to fossil fuels. Bio-energy as sustainable renewable energy option attracts many hopes associated with many challenges. Bio-energy helps in promoting rural and regional development promoting rural diversification by creating jobs and income usually in underdeveloped rural areas[2], it promotes regional improvement[3] and importantly, it helps in reducing CO2-emissions preserving non-renewable resources to enhance energy security[4]. The bio-energy and bio-fuels have been taking the gap at a faster rate by providing the supply of green energy replacing the energy from fossil fuels. US and the Brazil are the leaders of producing starch based first generation fuel from food crop sugars using conventional technologies. Energy efficiency of bio-fuels varies strongly according to plant species and feedstock, local climate, and production technique. Bio-ethanol from Brazilian sugar cane yields 8 units bio-energy output from one unit fossil fuel input into the production process based on life cycle assessment. Biodiesel produced from rapeseed in the EU has a ratio of 1:2.5, while bio-ethanol from US corn merely holds an efficiency of 1:1.5[5,6].

In India, 23% of rice straw residue produced is surplus and is either left in the field as uncollected or to a large extent open-field burnt. About 48% of this residue produced is subjected to open-field burning[7] in Thailand, and in the Philippines it is 95%. The GHG emissions contribution through open-field burning of rice straw in India, Thailand, and the Philippines are 0.05%, 0.18%, and 0.56%, and the mitigated GHG emissions when generated electricity is used would be 0.75%, 1.81%, and 4.31%, respectively, when compared to the total country GHG emissions. It is estimated that 97.19, 21.86, and 10.68 Mt of rice straw residue are produced in India, Thailand, and the Philippines, respectively. China contributes to about 30 % of the world's total rice production whereas India contributes to nearly 21%[8,9]. The other two major rice-producing countries in Asia are Thailand and the Philippines contributing 4% and 2% of the world's rice production respectively. Rice straw is one of the main field based residues produced along with this commodity and its applications vary widely in the region[10,11].

The total installed costs of biomass power generation technologies vary significantly by technology and country. The total installed costs of stoker boilers was between USD 1 880 and USD 4 260/kW in 2010, while those of circulating fluidised bed boilers were between USD 2 170 and USD 4 500/kW. Anaerobic digester power systems had capital costs between USD 2 570 and USD 6 100/kW. In India and China there are several types of technology developed at low cost. The quality and the sustainability of that technology should be assessed before the decisions are made. Indigenous developed technology should always be preferred for small sized plants for achieving business model. Gasification technologies, including fixed bed and fluidised bed solutions, had total installed capital costs of between USD 2 140 and USD 5 700/kW. Co-firing biomass at low-levels in existing thermal plants typically requires additional investments of USD 400 to USD 600/kW. Using landfill gas for power generation has capital costs of between USD 1920 and USD 2 440/kW[12]. The cost of CHP plants is significantly higher than for the electricity-only configuration. Operations and maintenance (O&M) costs can make a significant contribution to the levelised cost of electricity (LCOE) and typically account for between 9% and 20% of the LCOE for biomass power plants. It can be lower than this in the case co-firing and greater for plants with extensive fuel preparation, handling and conversion needs. Fixed O&M costs range from 2% of installed costs per year to 7% for most biomass technologies, with variable O&M costs of around USD 0.005/kWh. Secure, long-term supplies of low-cost, sustainably sourced feed stocks are critical to the economics of biomass power plants[13]. Feedstock costs can be zero for wastes which would otherwise have disposal costs or that are produced onsite at an industrial installation (e.g. black liquor at pulp and paper mills or bagasse at sugar mills). Feedstock costs may be modest where agricultural residues can be collected and transported over short distances. However, feedstock costs can be high where significant transport distances are involved due to the low energy density of biomass (e.g. the trade in wood chips and pellets).

It has been observed in recent years that the production of bio-diesel, biogas and ethanol are the most attractive components among the energy produced from biomass and bio wastes. The adverse sustainability balance of certain forms of bio-energy from a whole lifecycle perspective has also been observed in recent years in the field implementation which have become a popular subject of interest for the researchers and on the public stage. If the agricultural climate conditions are advantageous, the environmental life-cycle balance of bio-diesel and ethanol is much more favorable than those of fossil fuels[14], if the correct feedstock is used, whereas, the balance of environmental impacts of current liquid fuels from biomass is ambiguous in a review of studies comparing bio-ethanol systems to conventional fuels on a life-cycle basis[15]. Biomass availability in India is estimated at upwards of 915 million metric tons (MMT) which covers both agricultural (657 MMT/year) and 'forestry & wasteland' residues (260 MMT/year). The combined power potential from both resources is estimated at 33,292 MWe (agro: 18,730 MWe and forest and wasteland: 14,562 MWe)[16,17]. The selection of correct feedstock is very important for the bio-energy production, e.g., making biodiesel from soybean can be worse than fossil fuel. The efficiency and the sustainability of bio-energy production from the biomass has a bearing on its supply chain. Researchers, implementers and the governments are concern with the supply chain uncertainty of the biomass and bio wastes for the production of bio-fuels and bio energy. What are the causes of this supply chain uncertainty? What are the possible solutions? This paper has reviewed present situation focusing on India and developed the frame work for sustainable supply chain for bio-energy production.

2.0 Biomass material, Bio-wastes, the conversion pathways and the outputs

Bio-energy is renewable energy made available from materials derived from biological sources. Biomass is defined as living or recently dead organisms and any by-products of those organisms, plant or animal. Biomass is any organic material which has stored sunlight in the form of chemical energy. The term is generally understood to exclude coal, oil, and other fossilized remnants of organisms, as well as soils. In this strict sense, biomass encompasses all living things. In the context of biomass energy, however, the term refers to those crops, residues, and other biological materials that can be used as a substitute for fossil fuels in the production of energy and other products. Living biomass takes in carbon as it grows and releases this carbon when used for energy, resulting in a carbon-neutral cycle that does not increase the atmospheric concentration of greenhouse gases. As a fuel, it may include wood, wood waste, straw, manure, sugarcane, and many other by products from a variety of agricultural processes. Bagasse, rice husk, rice straw, cotton stalk, coconut shells, soy husk, de-oiled cakes, coffee waste, jute wastes, peanut shells, and sawdust are used a raw material for power generation. The crop residues from non-fodder crops, e.g., cotton, oilseeds, chilies and bamboo residues may also be considered as good alternatives for biomass power production. Bio-wastes (e.g. agricultural wastes, municipal solid wastes, sludge, waste water and food wastes) are currently seen as low-valued materials, are beginning to be recognized as resources for the production of a variety of eco-friendly and sustainable products, with second-generation liquid bio-fuels being the leading ones. Agricultural wastes, for instance, contain high levels of cellulose, hemicelluloses, starch, proteins, as well as lipids. As such, they constitute inexpensive candidates for the biotechnological production of liquid bio-fuels (e.g. bioethanol, biodiesel, dimethyl ether and dimethyl furan) without competing directly with the ever-growing need for world food supply. As bio-wastes are generated in large scales, in the range of billions of kilograms per year, thus largely available and rather inexpensive, these materials are seriously considered to be potential sources for the production of bio-fuels. Much more consideration is also given to replacement products that stem from microbial metabolism[18].

2.1 Biomass Feed stocks

Every region has its own locally generated biomass feed stocks from agriculture, forest, and urban sources. A wide variety of biomass feed stocks are available and biomass can be produced anywhere that plants or animals can live. Furthermore, most feed stocks can be made into liquid fuels, heat, electric power, and/or biobased products[19]. This makes biomass a flexible and widespread resource that can be adapted locally to meet local needs and objectives. Some of the most common (and/or most promising) biomass feed stocks are, a) **Grains and starch crops** – sugar cane, corn, wheat, sugar beets, industrial sweet potatoes, etc., b) **Agricultural residues** – Corn stover, wheat straw, rice straw, orchard prunings, etc., c) **Food waste** – waste produce, food processing waste, etc., d) **Forestry materials** – Logging residues, forest thinning, etc., e) **Animal by products** – Tallow, fish oil, manure, etc., f) **Energy crops** – Switchgrass, miscanthus, hybrid poplar, willow, algae, etc. And g) **Urban and suburban wastes** – municipal solid wastes (MSW), lawn wastes, wastewater treatment sludge, urban wood wastes, disaster debris, trap grease, yellow grease, waste cooking oil, etc.

Table 1. Biomass Feedstock used for Bio-energy production

Types of Bio-energy	Feed stocks used All	Widely Used
Biodiesel	Oil/Seed Oil feedstock-Rapeseed, soybean, field pennycress, jatropha, Madhucaindica, mustard, flax, sunflower, corn, cotton seed, peanut, palm, coconut, hemp oils; Waste vegetable oil (WVO) Animal fats- Tallow, lard, yellow grease, chicken fat, by-products of Omega-3 fatty acid production from fish oil; Algae; Oil from halophytes like salicorniabigelovii.	Rapeseed and soybean
Bioethanol	Corn, wheat, cassava, barley, potatoes, sugar cane, sorghum, sugar beet, whey, barley, bagasse, lignocellulosic and cellulosic biomass, switchgrass, giant miscanthus, etc.	Corn, Sugar Cane
Biogas	All biomass including industrial and agricultural wastes, lignocellulosic waste, crops and crop residues, microalgae, etc.	
Bio-hydrogen	Cellulosic and lignocellulosic biomass (crop residues, short rotation woody crops), animal wastes, municipal solid wastes, agricultural wastes, sawdust, aquatic plants, herbaceous species like switch grass, waste paper, corn, etc.	

It has been observed that single product can be obtained from different feedstock with varied effectiveness. Biomass fuel has a wide source where, the resources are scattered. Biofuel policies play an important role in the development of the energy sector. The profitability of biofuel production is significantly influenced by policies affecting multiple sectors such as agriculture, research, industry and trade. Identifying relevant policies and quantifying their specific impacts is difficult given the variety of policy instruments (taxes, subsidies, price support, etc) and the way they are applied[20,21]. Figure 1. shows Brief description of the identified biomass and the Modern concept of Conversion routes to bio-fuel products.

2.2 Biomass Energy

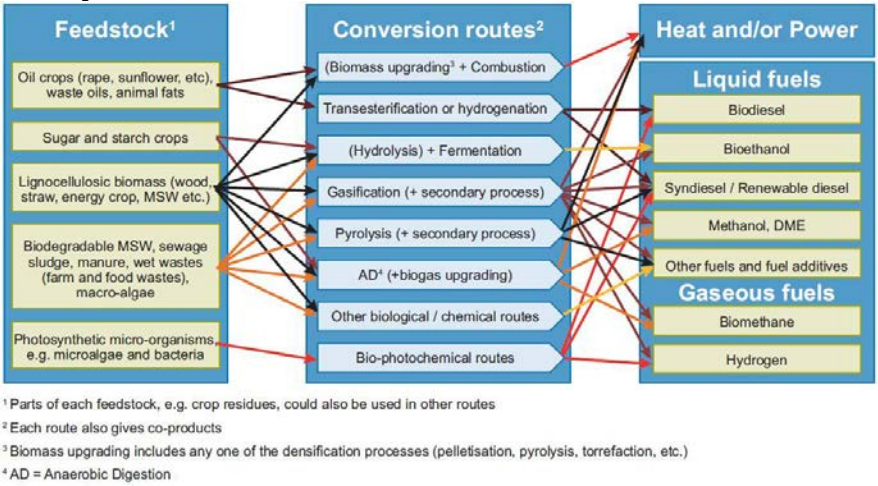
The energy stored in biomass can be released to produce renewable electricity or heat. Biopower is generated through combustion or gasification of dry biomass or biogas (methane) captured through controlled anaerobic digestion. Co-firing of biomass and fossil fuels (usually coal) is a low-cost means of reducing greenhouse gas emissions, improving cost-effectiveness, and reducing air pollutants in existing power plants. Thermal energy (heating and cooling) is often produced at the scale of the individual building, through direct combustion of wood pellets, wood chips, and other sources of dry biomass. Combined heat and power (CHP) operations often represent the most efficient use of biomass (utilizing around 80 percent of potential energy). These facilities capture the waste heat and/or steam from biopower production and pipe it to nearby buildings to provide heat or to chillers for cooling.

2.3 Bio-fuels

A number of transportation fuels can be produced from biomass, helping to alleviate demand for petroleum products and improve the greenhouse gas emissions profile of the transportation sector. Ethanol from corn and sugarcane, and biodiesel from soy, rapeseed, and oil palm dominate the current market for bio-fuels, but a number of companies are moving forward aggressively to develop and market a number of advanced second-generation bio-fuels made from non-food bio waste feed stocks, such as municipal waste, algae, perennial grasses, and wood chips. These fuels include cellulosic ethanol, bio-butanol, methanol and a number of synthetic gasoline/diesel equivalents. Until we are able to produce a significant amount of electric vehicles that run on renewably-produced electricity, bio-fuels remain the only widely available source of clean, renewable transportation energy.

3.0 World Trend in bio-fuels and bio-energy production

There is an increasing trend in the popularity of bio-fuels and bio energy production worldwide. Ethanol Production in the world has increased to nearly double from 13,123 Million Gallons in 2007 to 24,570 24,570 in 2014. World Fuel Ethanol Production by Country or Region has been given in Million Gallons in Table 2. The World's Fuel: Ethanol Production in thousand barrel per day country wise has also been displayed in the table 3. The rate at which the USA and the Europe have increased their production are far ahead of other countries and region. India started the bio fuel movement long back.



Source: UK Bio-energy Strategy

Figure 1: Modern concept of Conversion Pathways from biomass to bio-fuel products.

In the year 2000, it produced 2.9 thousand barrel per day whereas China contributed to zero. From the year 2005, China accelerated the movement by producing 20.79 thousand barrel per day with a value of 43.23598 in the year 2012. India could not keep pace and produced only 5.25587 thousand barrel per day in the year 2012.

Table 2. World Fuel Ethanol Production by Country or Region (Million Gallons)

Country/ Region	2007	2008	2009	2010	2011	2012	2013	2014
USA	6,521	9,309	10,938	13,298	13,948	13,300	13,300	14,300
Brazil	5,019	6,472	6,578	6,922	5,573	5,577	6,267	6,190
Europe	570	734	1,040	1,209	1,168	1,179	1,371	1,445
China	486	502	542	542	555	555	696	635
Canada	211	238	291	357	462	449	523	510
Rest of World	315	389	914	985	698	752	1,272	1,490
WORLD	13,123	17,644	20,303	23,311	22,404	21,812	23,429	24,570

4.0 Constraints & solutions in biomass and bio-waste supply chain for bio fuels and bio-energy production

Supply chain management plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption considering supply side management, demand side management and the operations management. After the analysis of the present situation, major areas of constraints, sub - constraints and possible solution for biomass and bio-waste supply chain for bio-fuels and bio-energy production have been presented in table 4. When evaluating bio-energy production, a system perspective has to be taken encompassing the components biomass resources, supply systems, conversion technologies, and energy services. In terms of activities, harvesting, refining and transporting of biomass are key issues, which must be facilitated by supply chain and operations management as well as the adoption of most adequate technologies[22,23,24]. Figure 2 shows a typical graphical representation of a waste biomass supply chain and Figure 3 proposes a sustainable model of biomass production based on Tripple Bottom line approach.

Table 3. World's Fuel : Ethanol Production in thousand barrel per day country wise

Country	2000	2005	2010	2011	2012
North America	109.24	259.09	891.744	938.9192	908.258
Canada	3.7	4.4	24	30	32.7
United States	105.54	254.69	867.444	908.6192	875.558
Central & South America	185.0267	284.6781	502.9115	415.903	428.94
Brazil	183.8867	276.4051	486.0114	392	402.5
Paraguay	0.04	0.6	2.2	2.2	2.3
Europe	2	14.76	71.601	72.801	68.462
France	2	2.5	18	17.4	17
Germany	0	2.8	13	13.3	13.37
Hungary	0	0.1	3.2	3	1.52
Poland	0	2	3.5	2.9	3.6
Spain	0	5	8	8	7.9
Sweden	0	1.4	3.5	3.4	2.7
United Kingdom	0	0	5	5	4.3
Asia & Oceania	2.9	26	52.68438	61.85163	63.5578
Australia	0	0.4	4.7389	5.49712	5.25869
China	0	20.7	36.67046	38.85897	43.23598
India	2.9	3.7	0.86162	6.28981	5.25587
Japan	0	0	0.86162	0.43081	0.43081
Thailand	0	1.2	7.77179	8.37493	8.11644
Other countries					
World	**299.3667**	**585.0281**	**1521.011**	**1490.515**	**1470.09**

Source: EIA's International Energy Statistics: Bio-fuels Production.
(http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=79&pid=80&aid=1&cid=regions&syid=2000&eyid=2012&unit=TBPD

Table 4. Supply Chain constraints and the solution.

Major constraints	Sub-Constructs	Proposed solution for sustainability
Behavioural & Social	Biomass Burning[25,26], Biomass used as the feed to cattle, Poor Awareness of the farmers and the stakeholders, Bio-fuel and bio-energy policy[27], Food Security,	Intensive training of stakeholders, Strengthening R&D, Community participation, Implantable government policy by & regular monitoring, Alternative livestock feed.
Economical	Transportation cost, Government support, Demand side network[28], Administratively determined price	Effective decision support system (DSS), Robust supply Chain, Implantable government policy, Tax and subsidy structure, Tariff structure.
Environmental	Land use pattern change, Food and Water security	Implantable government policy with regular monitoring.
Operational	Continuous feedstock supply[29], Pre-treatment[30], Technology adoption, Scale of operation and operational efficiency, Demand side network	Robust supply Chain, Effective R&D, Technology incubation centres for providing best technology as sustainable business model, Proper distribution channel

5.0. Salient features of India's Bio fuel Policy

India's bio-fuel policy will strengthen India's energy security by encouraging use of renewable energy resources to supplement motor transport fuels. An indicative 20% target for blending of bio-fuel for both biodiesel and bioethanol is proposed by end of 12th Five-Year Plan (fiscal 2012/13 through fiscal 2016/17). Minimum Support Price (MSP) mechanism for inedible oilseeds to provide fair price to oilseed growers but subject to periodic revision. The Cabinet Decisions that Ethanol produced from other non-food feedstock's besides molasses like cellulosic and lingo- cellulosic materials and including petrochemical route, may be allowed to be procured subject to meeting the relevant Bureau of Indian Standards (BIS) standards. On January 16, 2015, the Indian Union Cabinet decided to suitably amend the national bio-fuel policy for facilitating consumers of diesel in procuring bio-diesel directly from private bio-diesel manufacturers, their authorized dealers and joint ventures (JVs) of OMCs authorized by the Ministry of Petroleum and Natural Gas (Mo PNG), GoI.

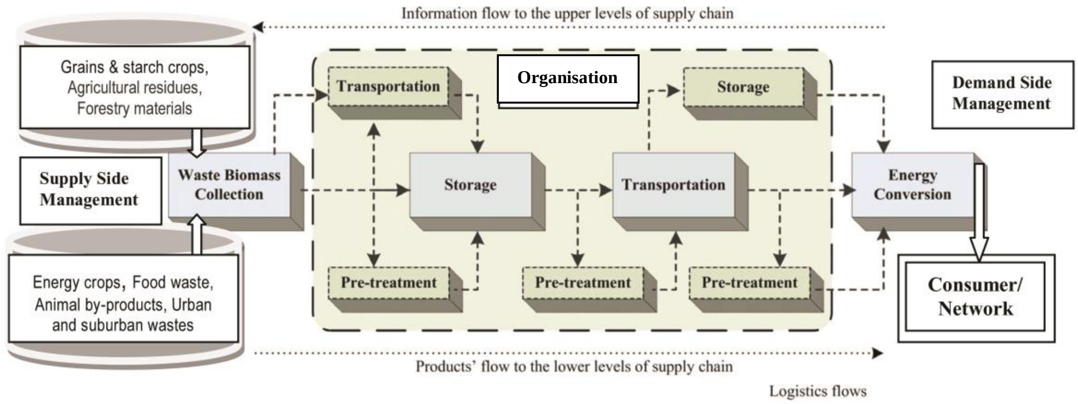


Figure. 2. Typical graphical representation of a waste biomass supply chain

The price of biodiesel will now be market determined. If necessary, GoI proposes to consid er creating a National Bio-fuel Fund for providing financial incentives, including subsidies and gra nts, for new and second generation feed stocks, advanced technologies and conversion process es, and production units based on new and second generation feedstock.

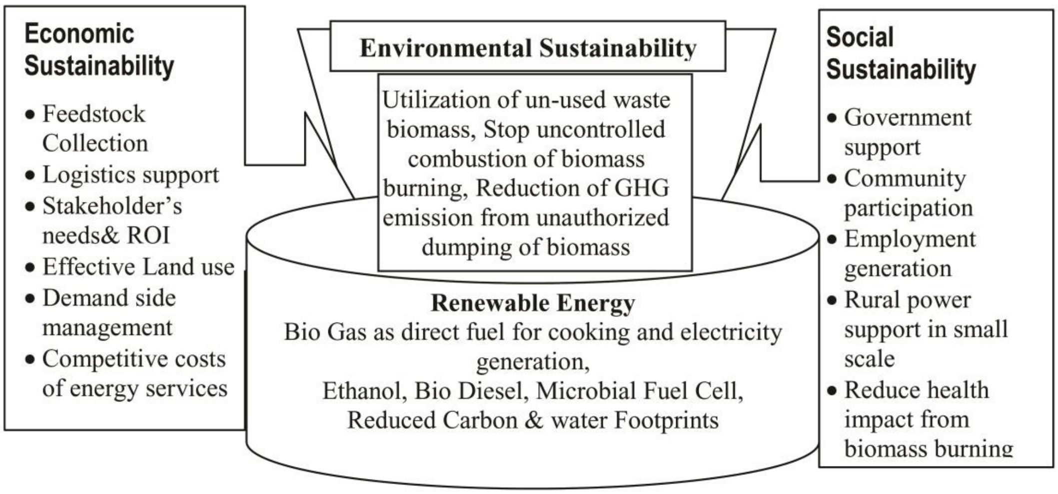


Figure 3. Sustainable Model of Biomass production based on Tripple Bottom line approach

Thrust for innovation, (multi-institutional, indigenous and time bound) research and development on bio-fuel feedstock (*utilization of indigenous biomass feedstock included*) production including second generation bio-fuels. Bring bio-fuels under the ambit of "Declared Goods" by the GoI so as to ensure their unrestricted interstate and intrastate movement. Except for a concessional excise duty of 16 percent on bioethanol, no other central taxes and duties are proposed to be levied on biodiesel and bioethanol. Bio-fuel technologies and projects would be allowed 100 percent foreign equity through automatic approval to attract foreign direct investment (FDI), provided the bio-fuel is for domestic use only, and not for export. Plantations of inedible oil bearing plants would not be open for FDI participation. Setting up of National Bio-fuel Steering Committee (NBSC) under Prime Minister to provi de policy guidelines. The National Bio-fuel Policy proposes to set up a National Bio-fuel Coordination Committee (NBCC) he aded by the Prime Minister. Various state governments will work closely with respective research institutio ns, forestry department, universities etc. for development and promotion of bio-fuel program in respective states. Several states have drafted policies and set up institutions for promoting bio-fuel.

6.0 Conclusion

The Indian bio-fuel industry, both private and public sector, claim to be successful in developing and customizing technology for converting ligno-cellulosic materials in form of wood biomass, agricultural (corn cob, bagasse, stalk of forage crops) waste and forest waste. Trials are underway to process municipal solid waste, micro-algae and photosynthetic organisms into advanced bio-fuels. However, given the technological challenges, commercial production and economic viability remains to be demonstrated. Providing economically, environmentally and socially sustainable bio-energy requires an optimization of the structure and functioning of the supply chain/network, adjusted to the specific conditions of the respective production system (climate and topology, feedstock, technologies, final application). A sustainable and robust supply chain leading to a business model is the only solution for effective results addressing the constraints of the stakeholdrer's rationally. India also pursue strategic international partnerships to carry out its bio-fuel and bio-energy policies and promote domestic bio-fuels / bio-energy industries. Priority areas for such collaboration will include technology transfer, joint research and technology development, field studies, pilot scale plants and demonstration projects. Government of India has been taking initiatives for making the bio-fuel and bio-energy more popular. In recent future the initiative will definitely see implementable business cases in both rural and urban India. The proposed National Biogas mission for setting up 10 million biogas plants during next 5 years up to 2020-21 may bring light to the dream of utilising biomass and bio-wastes making a robust supply chain for a business model. Moreover, Swacchh Bharat Avijan can make many waste management initiatives happen in the country.

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8.0 References

1. Final Report of TA 7250 IND, Submitted to the Department of Economic Affairs Ministry of Finance, New Delhi, India, 24 January 2011, India: Study on Cross-Sectoral Implications of Bio-fuel Production and Use, Report, Project Number: 42525. 2011.

2. Elghali L, Clift R, Sinclair P, Panoutsou C, Bauen A. Developing a sustainability framework for the assessment of bioenergy systems. Energy Policy. 2007;**35(12)**:6075-83.

3. René Wismeijer, Ir. Kees W. Kwant, Drs. Ella A. Lammers, Senter Novem, and Project Group. A Framework for Sustainable Biomass. Schriftenreihezu Nachhaltigkeit und CSR, vol.1, 2007.

4. Nguyen TL, Gheewala SH, Sagisaka M. Greenhouse gas savings potential of sugar cane bio-energy systems. Journal of Cleaner Production. 2010;**18(5):**412-8.

5. GTZ (German Technical Cooperation) (Ed.), KraftstoffeausnachwachsendenRohstoffen e GlobalePotenziale und Implikationenfüreinenachhaltige Landwirtschaft und Energieversorgungim 21.Jahrhundert [Fuels from renewable resources e Global potentials and implications for sustainable agriculture and energy supply in the 21st century], Berlin. (2006).

6. Kerckow B. Competition between agricultural and renewable energy production. Quarterly Journal of International Agriculture. 2007;**46(4):**333-47.

7. Engling G, He J, Betha R, Balasubramanian R. Assessing the regional impact of indonesian biomass burning emissions based on organic molecular tracers and chemical mass balance modeling. Atmospheric Chemistry and Physics. 2014;**14(15)**:8043-54.

8. Gadde B, Bonnet S, Menke C, Garivait S. Air pollutant emissions from rice straw open field burning in India, Thailand and the Philippines. Environmental Pollution. 2009;**157(5)**:1554-8.

9. Reijnders L, Huijbregts MA. Palm oil and the emission of carbon-based greenhouse gases. Journal of cleaner production. 2008;**16(4):**477-82.

10. Akagi SK, Yokelson RJ, Wiedinmyer C, Alvarado MJ, Reid JS, Karl T, Crounse JD, Wennberg PO. Emission factors for open and domestic biomass burning for use in atmospheric models. Atmospheric Chemistry and Physics. 2011;**11(9):**4039-72.

11. Binod P, Sindhu R, Singhania RR, Vikram S, Devi L, Nagalakshmi S, Kurien N, Sukumaran RK, Pandey A. Bioethanol production from rice straw: an overview. Bioresource technology. 2010;**101(13):**4767-74.

12. IRENA Working Paper, Renewable energy technologies: cost analysis series, The International Renewable Energy Agency (IRENA) is an intergovernmental organisation dedicated to renewable energy. Volume 1: Power Sector Issue 1/5.

13. Reinhard J, Zah R. Global environmental consequences of increased biodiesel consumption in Switzerland: consequential life cycle assessment. Journal of Cleaner Production. 2009;**17**:S46-56.

14. Puppan D. Environmental evaluation of biofuels. Periodica Polytechnica Social and Management Sciences. 2002;**10(1):**95-116..

15. Von Blottnitz H, Curran MA. A review of assessments conducted on bio-ethanol as a transportation fuel from a net energy, greenhouse gas, and environmental life cycle perspective. Journal of cleaner production. 2007 ;**15(7):**607-19.

16. Biomass Knowledge Portal, viainfotech.biz/Biomass/theme5/document/news.../launch-write-up.pdf viewed on 09.09.2015.

17. Van Belle JF, Temmerman M, Schenkel Y. Three level procurement of forest residues for power plant. Biomass and Bioenergy. 2003;**24(4):**401-9.

18. Daoutidis P, Marvin WA, Rangarajan S, Torres AI. Engineering biomass conversion processes: a systems perspective. AIChE Journal. 2013;**59(1):**3-18.

19. Mabee WE, Fraser ED, McFarlane PN, Saddler JN. Canadian biomass reserves for biorefining. Applied biochemistry and biotechnology. 2006;**129(1-3):**22-40.

20. BIO-FUELS: prospects, risks and opportunities, FAO 2008, T*he State of Food And Agriculture* 2008.

21. Andreae MO, Merlet P. Emission of trace gases and aerosols from biomass burning. Global biogeochemical cycles. 2001;**15(4):**955-66.

22. McCormick K, Kåberger T. Key barriers for bioenergy in Europe: economic conditions, know-how and institutional capacity, and supply chain co-ordination. Biomass and Bioenergy. 2007 ;**31(7):**443-52.

23. Gerbens-Leenes W, Hoekstra AY, van der Meer TH. The water footprint of bioenergy. Proceedings of the National Academy of Sciences. 2009;**106(25):**10219-23.

24. Madlener R, Bachhiesl M. Socio-economic drivers of large urban biomass cogeneration: Sustainable energy supply for Austria's capital Vienna. Energy Policy. 2007;**35(2**):1075-87.

25. Zhu C, Kawamura K, Kunwar B. Effect of biomass burning over the western North Pacific Rim: wintertime maxima of anhydrosugars in ambient aerosols from Okinawa. Atmospheric Chemistry and Physics. 2015;**15(4):**1959-73.

26. Yevich R, Logan JA. An assessment of biofuel use and burning of agricultural waste in the developing world. Global biogeochemical cycles. 2003;**17(4).**

27. Perry M, Rosillo-Calle F. Recent trends and future opportunities in UK bioenergy: Maximising biomass penetration in a centralised energy system. Biomass and Bioenergy. 2008;**32(8):**688-701.

28. Gold S, Seuring S. Supply chain and logistics issues of bio-energy production. Journal of Cleaner Production. 2011;**19(1):**32-42.

29. Sims RE, Venturi P. All-year-round harvesting of short rotation coppice eucalyptus compared with the delivered costs of biomass from more conventional short season, harvesting systems. Biomass and Bioenergy. 2004;**26(1):**27-37.

30. Kumar P, Barrett DM, Delwiche MJ, Stroeve P. Methods for pretreatment of lignocellulosic biomass for efficient hydrolysis and biofuel production. Industrial & Engineering Chemistry Research. 2009;**48(8**):3713-29.