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Assessment of global as well as India's bioenergy potential along with current technologies and research trends in bioenergy

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Abstract - After the 1973 energy crisis the global energy scenario is change rapidly. Due to dissimilar availability of conventional energy sources across the region, continuous rise of its demand, rapidly increasing prices, environmental degradation. These all lead to quick transition of global energy system to renewable energy sources. Which are efficient, environmental friendly and sustainable for the current and future economic, social and societal need [1].

In this review paper an overview of one of the most important renewable energy i.e. Bioenergy is provided. It is the energy from biomass sources like energy crops, residues, byproduct and waste from agriculture, forestry, etc. From the many past years global energy scenarios rely on the biomass for the variety of possible uses. As we get energy from it in all forms solid, liquid, gaseous fuel. As biomass recourses are abundant and relatively inexpensive so improving the understanding of bioenergy potential is crucible. The world bioenergy potential along with India bioenergy potential for different region, land, years for different bioenergy sources are briefly mention here. Research is currently in process to develop suitable technologies for bioenergy production. At last current technologies use for bioenergy production and recent global research topics in bioenergy is discuss in this paper.

Keywords – Renewable energy, bioenergy potential, bioelectricity, biomass, biofuels, energy crops, bioenergy technology

1. INTRODUCTION

The Energy requirement of the world is increasing very rapidly. It is now widely recognize that the conventional energy resources may not be adequate and worthy to keep pace with continuously increasing demand of electrical energy of the world. So long term world energy scenario depends heavily on non-conventional energy sources to decarbonizes and branch out our energy system. In addition to electricity generation from renewable sources like sun, wind, bioenergy play a significant role to mitigate a climate change problems and manage our energy demand [3].

Bioenergy is commonly defined as the renewable energy from the natural biological sources like plants, animals and their byproducts. These sources of bioenergy are called as biomass. In past years and now also immense part of bioenergy is used for coking purpose. This leads to more carbon emission and environmental degradation. But from the past few years several countries were utilize advance technology to convert biomass into fuels and use it for electricity generation.

Worldwide production of bioenergy is increasing rapidly due to rising rates of fossil fuels and growing environmental problems. There are many scenario forecast a higher potential for bioenergy in future. A thorough and detailed evaluation of the available bioenergy potential is therefore needed to deciding the contribution of bioenergy sources into the world energy system. In this article a overview of the world bioenergy potential especially Indian bioenergy scenario as well as current technology and research status of bioenergy is provided.

2. WORLD BIOENERGY SCENARIO

The World energy system shifting toward renewable energy resources. Because of conventional energy sources downside like climate change, pollution, etc. Inclusion of renewable resources in total energy production is increase year by years. During 2000-14 renewable electricity sector grow annual at rate of 4.5%. In this bioenergy had a growth of 8.2% achieving total generation of 493 TWh in 2014. It share 9% of total electricity generation globally from renewable energy in 2014 [4].

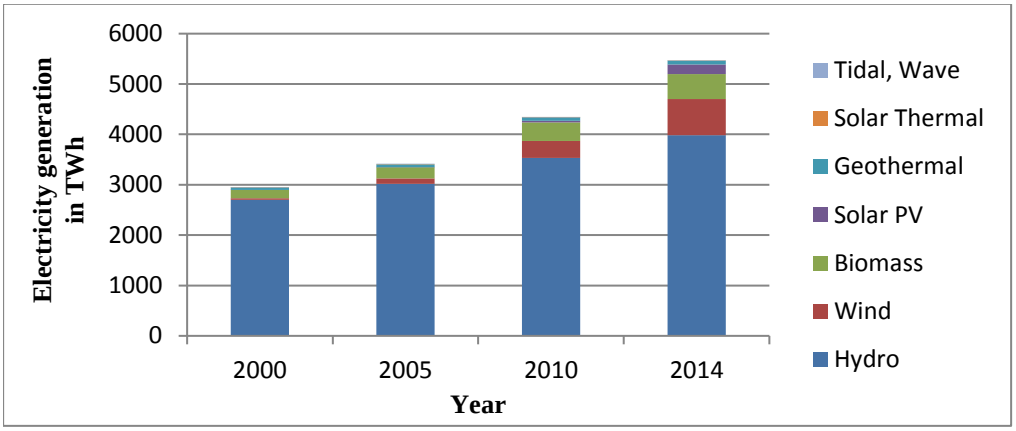

Fig.1 Electricity generation from renewable resources in continents

The total bioelectricity generation is categories into different types. Most of the bioelectricity is from solid biomass sources. These include wood chips, wood pellets, agricultural residues, forest residues, etc.

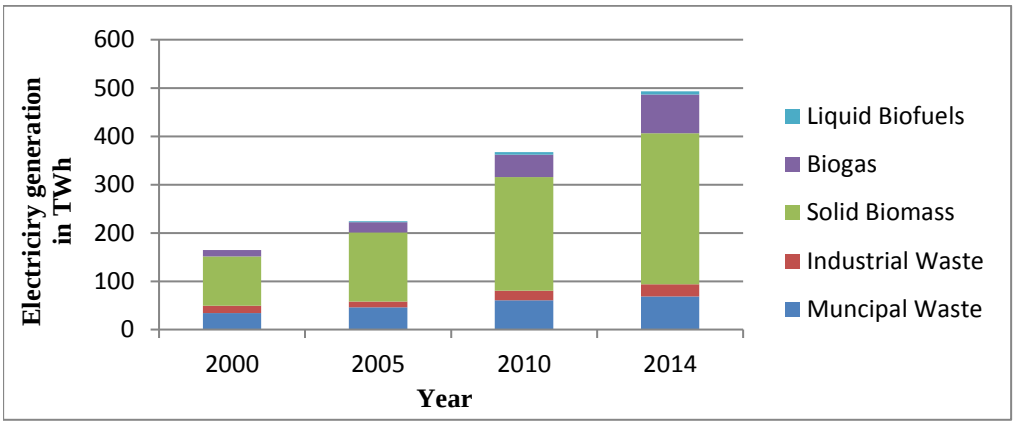

Fig.2 Global electricity generation from biomass

Most of the bioelectricity generation is in the Europe. 40% of the global bioelectricity generation totaling 196 TWh occurs in Europe. Asia has higher energy generation from industrial waste while municipal waste to electricity generation is prominent in Europe. Solid biomass generation is highest in Americas i.e. 118 TWh. USA, China, Brazil, Japan, India are the leading bioenergy producing countries.

Table 1- Electricity generation from biomass in continents in 2014 (TWh)

Sr. No.	Continents	Municipal Waste	Industrial Waste	Solid Biomass	Biogas	Liquid Biofuels	Total
1	Africa	0.00	0.00	1.80	0.03	0.00	1.83
2	Americas	16.9	2.90	118	15.4	0.21	153
3	Asia	11.7	15.2	106	3.51	1.26	138
4	Europe	40.2	6.74	85.6	59.3	4.85	196
5	Oceania	0.00	0.00	2.27	1.88	0.00	4.15
	World	**68.7**	**24.8**	**313**	**80.1**	**6.31**	**493**

Earlier the residues of plants, crops are used for the bioenergy production. Now as the technology developed and awareness about bioenergy is increase. Percentage of plants only used for bioenergy is rising. In many countries the byproduct or residues are burned, dumped into landfill due to lack of bioenergy policy. Now they are starting to use it for bioenergy production. Plantation of new forests and management of existing forests is help to increase the feedstock for bioenergy. Due to all these reasons the potential of biomass is rises year by year.

Table 2- Global potential of biomass in 2012 and 2035 (EJ)

Sr. No.	Main Sector	Sub Sector	2012	2035
1	Agriculture	Dedicated crops – Main product	3.5	30
		By products and residues including manure	2.1	34
		Total agriculture	**5.6**	**64**
2	Forestry	-	48.9	78
3	Organic waste	-	1.7	8
	Total	-	**56.2**	**150**

2.1 BIOENERGY SUPPLY

Total supply of biomass in 2014 was 59.2 EJ i.e. 10.3% of all energy supply globally. Biomass supply grew at annual rate of 2.3% [9]. The feedstock for bioenergy is come from forestry, agriculture and municipal solid waste.

I) Forestry

Forestry sector generates more than 87% of the biomass feedstock for bioenergy. It is the largest contributor to biomass supply globally due to its large area. Close to 40% of the in America continent is covered by the forest area. Europe follows second at 25% largely due to high concentration in Russia. Asia continent has highest share of planted forest. Russia, Brazil, Canada, USA, China these are the leading countries having high forest area.

Table 3- forest area in continents in 2014 (Mha)

Sr. No.	Continents	Forest Area	Primary Forests	Other naturally Regenerated Forests	Planted Forest
1	Africa	627	136	475	16.1
2	Americas	1595	721	816	57.5
3	Asia	593	117	348	127
4	Europe	1015	278	652	85.2
5	Oceania	173	27	141	4.35
	World	**4002**	**1279**	**2433**	**290**

II) Agriculture

Agriculture is significant contributor to the biomass supply in terms of energy crops for biofuels production and heat and electricity along with use of residues. Agriculture sector contribute 10% with animal and agricultural byproducts to the total global feedstock production. More than half agricultural area in Europe is under arable land. While the share is less than 12% for oceanic region [10]. Permanent pastures and meadows cover more than 50% of agricultural area for the rest of region excluding Europe. China, USA, Australia, Brazil, Russia, India these are the countries having high agricultural area. Sugarcane, maize, rice, wheat, soya beans are mostly used as biomass.

Table 4- Agriculture area in continents in 2014 (Mha)

Sr. No.	Continents	Agriculture Area	Arable Land	Permanent Crops	Permanent Pastures and Meadows
1	Africa	1132	234	34.0	861
2	Americas	1230	376	27.6	826
3	Asia	1650	482	86.2	1082
4	Europe	468	277	15.3	176
5	Oceania	420	48	1.55	370
	World	**4897**	**1417**	**165**	**3316**

III) Waste

Municipal solid waste and landfill cover remaining 3% of the biomass feedstock source. Waste obtained from municipalities and industries contributes to the increasing supply of biomass globally. This sector is classified into municipal waste and industrial waste. Municipal waste consist of products obtain from households, industries, hospitals, etc. On the other hand, Industrial waste is

waste consisting of solid and liquid products combusted directly in specialized plants. In 2014 2.21 EJ of waste was converted to energy globally. The waste sector has increased at an annual rate of 4% during 2000-14 [7].

2.2 BIOENERGY AS BIOGAS

Biogas is gaseous fuel produce from biomass using the process of anaerobic digestion of organic matter. Biogas consists of mainly methane and carbon dioxide. Commonly used feedstock for biogas includes manure and sewage, agricultural residues and organic part of household waste. The biogas either uses directly in transportation sector or bounded to generate heat and electricity. Global biogas generation has increased rapidly since 2000. During 2000-14 average growth of production was 11.2%. In 2014 the total biogas production was 1.27 EJ [9].

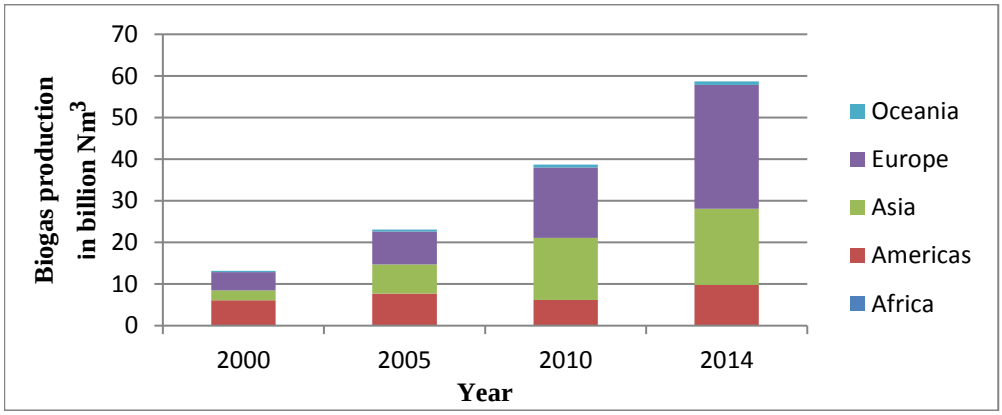

Fig. 3 Global biogas production

Almost half of the biogas production occurs in Europe 32% in Asia and 17% in Americas. Less than 2% of production occurs in Africa and Oceania countries. China, USA, India, Thailand are the leading countries in biogas production.

2.3 BIOENERGY AS BIOFUEL

The biofuels industry has seen tremendous growth in the past 14 years. Liquid biofuel for transport are the leading source of renewable energy in that sector. Biofuels are used predominantly for road transport.

In 2014 total biofuels production reached 126 million liters globally [9]. The annual growth rate of 15% since 2000 is lot higher than the average growth of all biomass supply at 2.3%. Most of biofuels are produced from bioethanol get from fermentation of sugar based crops and other from biodiesel via transesterification of vegetable oils and animal fats. Liquid biofuel production cover 2.9% of the land area used for production of major biofuels crops. Wheat, maize, sugar beet, sugarcane are mostly used for the bioethanol production. Palm oil, vegetable oil is mostly used for biodiesel production.

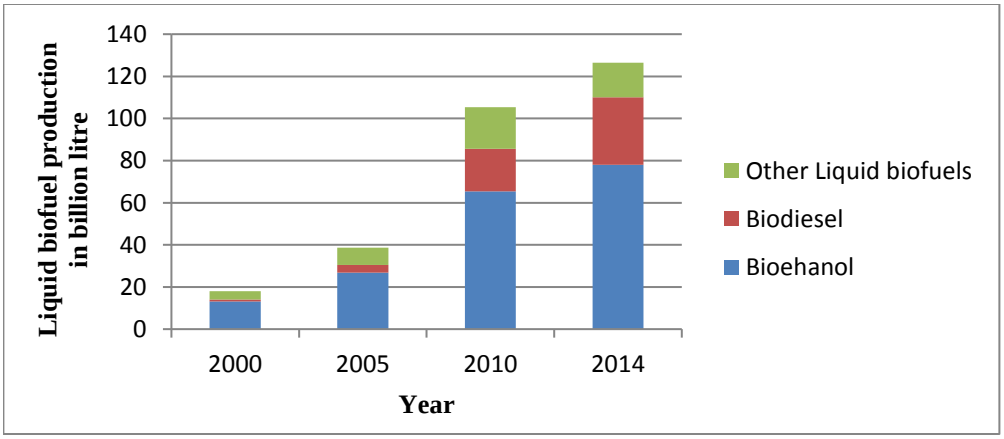

Fig.4 Liquid biofuel production globally

One continent dominates the liquid biofuels production sector. About 95.1 billion liters of biofuels are produced in Americas Predominant in USA and Brazil.

Table 5- Liquid biofuels in continents in 2014 (billion liters)

Sr. No.	Continents	Biofuels	Bioethanol	Biodiesel	Other liquid biofuels
1	Africa	0.06	0.06	0.00	0.00
2	Americas	95.1	68.5	11.0	15.6
3	Asia	11.4	4.53	6.54	0.29
4	Europe	19.4	4.57	14.3	0.53
5	Oceania	0.40	0.28	0.12	0.00
	World	**126**	**78.0**	**32.0**	**16.4**

3. BIOENERGY POTENTIAL OF INDIA

Over the years renewable energy sector in India has emerged as a significant player in the power generation. India is one of the countries with largest production of energy from renewable sources. In the electricity sector renewable energy account for 20% of the total installed capacity as of 30 June 2018. Among all the renewable energy sources bioenergy is play a vital role. Contribution of bioenergy in total installed grid interactive renewable power capacity as of 31 March 2018 is about 12.7% [2].

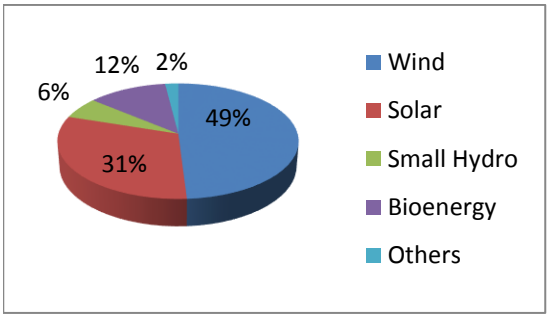

Fig.5 Percentage distribution of renewable Installed capacity in India

Table 6- Renewable installed capacity in India (as of 31 March 218)

Types	Capacity (in MW)
Grid connected Power	
Wind	34,046.00
Solar	21,651.48
Small Hydro Power Projects	4,485.81
Bioenergy	8,700.80
Others	138.30
Total – Grid connected Power	**69,022.39**

India is an ideal environment for biomass production given its on account of its tropical location, abundant sunshine and rains. The countries vast agricultural potential provides huge agro residue which can be used to meet energy needs both in heat and power applications. India produces about 400 to 500 million tones of biomass per year [6]. Punjab, Maharashtra, Madhya Pradesh, Uttar Pradesh, Gujarat are the leading states in biomass production. Biomass contributes 32% of all the primary energy use in the country at present. It is estimated that the potential for bioenergy in India include 16,000 MW from biomass and a further 3,500 MW from bagasse cogeneration [2].

Table 7- Bioenergy potential and performance in India

Sr. No.	Source/system	Estimated potential (MW)	Achieved as on 31 Dec 2016 (MW)
A	**Grid Interactive renewable power**		
1	Bio power (agro residue and plantations)	16881	7907.34
2	Bagasse cogeneration	5000	1938.30
B	**Captive/combined heat and power/distributed renewable power**		
1	Biomass/cogeneration (non bagasse)		232.17
2	Biomass gasifier		122.14
3	Family type biogas plants	120 lakh	49.40 lakh

3.1 BIOENERGY AS COOKING FUEL

Traditional solid fuel is still widely used for cooking. According to National survey (2007 – 08) 77.6% of Indian's rural household used firewood chips for cooking. As per the study by International energy agency (IEA) 585 million Indian's were depend on biomass for cooking and this predicted to increase up to 632 million by 2030 [5]. Dependence on bioenergy is expected to continue in India due to increase in rural population and lack of access to commercial fuels in rural areas particularly for cooking.

3.2 BIOENERGY AS BIOGAS

Biogas typically refers to a mixture of different gases produce by breakdown of organic matter in absent of oxygen. It primarily contains methane and CO_2. biogas can be used for clean cooking fuel. It also power gas lamps. In India the estimate for the production of biogas is about 20,757 lakh cubic meters in 2014 – 15. This is equivalent to 6.6 crore domestic LPG cylinder same as 5% of the total LPG consumption in the country [11].

Table 8- State wise estimated potential and cumulative achievements for family type biogas plant

Sr. No.	State/Union Territories	Estimated Potential (nos. of biogas plants)	Cumulative achievement As on 31 March 2017
1	Andhra Pradesh	1065000	549235
2	Arunachal Pradesh	7500	3555
3	Assam	307000	130375
4	Bihar	733000	129844
5	Chhattisgarh	400000	54825
6	Goa	8000	4230
7	Gujarat	554000	433317
8	Haryana	300000	62085
9	Himachal Pradesh	125000	47650
10	Jammu & Kashmir	128000	3163
11	Jharkhand	100000	7579
12	Karnataka	680000	491764
13	Kerala	150000	149568
14	Madhya Pradesh	1491000	365689
15	Maharashtra	897000	899472
16	Manipur	38000	2128
17	Meghalaya	24000	10196
18	Mizoram	5000	5412
19	Nagaland	6700	7953
20	Orissa	605000	270880
21	Punjab	411000	177445
22	Rajasthan	915000	71231
23	Sikkim	7300	9044
24	Tamil Nadu	615000	222870
25	Telangana	-	22571
26	Tripura	28000	3620
27	Uttar Pradesh	1938000	440713
28	Uttarakhand	83000	21558
29	West Bengal	695000	366974
30	A & N Islands	2200	137
31	Chandigarh	1400	97
32	Dadar and Nagar Haveli	2000	169
33	Delhi	12900	681
34	Pondicherry	4300	578
35	KVIC and Others	-	-
	Total	**1,23,39300**	**49,66,628**

3.3 BIOENERGY AS BIOMASS CROP YIELD

India's total land area is 328.7 Mha out of which 42.5 Mha is not available for cultivation [6]. The existed land usage in India is mentioned in table 9 below.

Table 9- Potential land areas in India with biomass potential

Sr. No.	Land Details	Areas (kha)	Percentage of India's total land area
1	Forest	69.8	22.9%
2	Net sown area	141.9	46.5%
3	Uncultivated land excluding fallow land	26.9	8.8%

4	Fallow land	24.2	7.9%
5	Not available for cultivation	42.5	13.9%
	Total	**328.7**	**100%**

The classification of biomass yield through the three main sources of forestry, agriculture and wasteland is provided below.

Table 10- Potential of biomass yield by source

Sr. No.	Types of resources	Area (kha)	Biomass generation (kt/yr)	Biomass surplus (kt/yr)
1	Agro-residue	16423	95512	43162
2	Forestland	64570	89119	59162
3	Wasteland	54253	66355	44369
	Total	**135246**	**250986**	**147210**

3.4 BIOENERGY AS BIOFUEL

The National biofuel policy of India adopted in December 2009 aims to facilitating development of indigenous biomass feedstock for production of biofuels [2]. The new biofuel policy will incentivize plantation of non-edible oilseeds like jatropha over 11.2 million hectors of land resulting in 13.38 million tons of biofuel. To fulfill its policy target of blending 20% of biofuels in transportation fuel by 2020.

A bioethanol program calls for E5 blends throughout most of the country targeting to raise this requirement to E10 and E20. In 2003 the National government set a 5% mandatory blending for gasoline. In 2005 country became the fourth largest producer of ethanol at 1.6 billion liters and the country has about 125 ethanol producers with a total capacity of 1.25 billion liters of ethanol [11].

4. CURRENT TECHNOLOGIES AND RESEARCH TRENDS IN BIOENERGY

Earlier bioenergy is only used as cooking fuel but from the past 15-20 years have see a strong resurgence along with gradual development of more modern and efficient bioenergy production systems. There many difference types of biomass residue, waste and energy crops available worldwide. To be able to utilize the different types of available biomass in a cost effective and efficient manner range of technologies are developed to convert it into various solid, liquid, gaseous biofuels. Current technologies for bioenergy production and its research status are mention in this segment.

4.1 COMBUSTION

Biomass combustion is the most common biomass conversion technology applied on household and industries since ancient time. It varies from small stoves to multi-megawatt combined heat and power (CHP) system. Over the last decades, however modern biomass combustion technologies have emerged like fully automated pellet boilers, co-firing and efficient combined and power production for a large variety of biomass recourses.

4.2 GASIFICATION

Gasification involves subjecting solid biomass to hot steam and air to produce a gaseous biofuel called producer gas. Biomass gasification is an endothermic thermal conversion technology in which limited sully of oxygen, air, and steam combination survives as oxidation agent. The product gas consists of carbon monoxide, carbon dioxide, hydrogen, varicose contaminant such as char particles, ash, tar, etc.

4.3 PYROLYSIS

Pyrolysis is the basic thermo-chemical process for converting solid biomass to a more useful liquid fuel commonly called a biofuel or pyrolysis fuel. This can be used for power, heat, transport, fuels and chemical production.

4.4 FERMENTATION

This process can be used on certain sugar producing energy crops to produce ethanol, alcohol. Yeast is added to the biomass and the mixture then ferment under specific condition. Then the resulting brew distilled to produce bio-ethanol. This can be used in specialized combustion engines or it can be mixed with petrol to produce a gasohol.

4.5 ANAEROBIC DIGESTION

Anaerobic digestion is the production of a methane rich biogas from wet biomass source like manure, kitchen and garden waste, waste water, etc. The biogas can be used for heat and power generation using as engines or upgraded for use in Natural gas grid. Commercially digestion technologies used are covered lagoon, completed mixed, plug flow, upflow anaerobic sludge blanket reactor (UASB).

4.6 CARBONIZATION AND TORREFACTION

Charcoal production from wood is a most common carbonization technology, but also agro residue like cotton stalks can be carbonized and further upgraded to household fuels. Torrefaction is a partial carbonization process at temperature of 200 to 400ºC making the biomass crispy. Torrified biomass is suitable for co-firing in coal fired power plants.

4.7 TRANSESTERIFICATION

The transesterification of vegetable oils, animal fats or waste cooking oils is the process use for production of biodiesel. In transesterification process a glyceride react with an alcohol in the presence of a catalyst forming fatty acid alkyl ester and alcohol. Now to get high quality of biodiesel, high product yield and various advantages multistage cavitations process is used for biodiesel production.

Research is ongoing to develop new technologies and processes to expand the bioenergy sector. Many research institutes throughout the world are working in bioenergy field. They broadly focusing on the area like

- Sustainable and cost effective supply and use of biomass recourses especially from forest.
- Research and Industry relevant characterization of biomass and biomaterial properties.
- Efficient biomass conversion into materials, bioenergy and other consumer products.
- Acclimation of high activity anaerobic sludge in organic waste water and is microbiological research.
- Township biogas septic tanks.
- Conventional fermentation process for regular biogas production of rural domestic hydraulic digesters.
- Dry fermentation in rural areas.
- Environmental control and waste treatment technology on scaled piggery farm.
- Application of biogas treatment and technical system for poultry and livestock waste.
- The use of land for energy production Vs food production.
- Finding more suitable biofuels crops improving the oil yields of these crops.
- Consequences of ethanol production on domestic food markets.
- Producing cellulosic ethanol.
- Enhancing the overall per acre oil yield of Jatropha through advancements in genetics, soil science and horticultural practices.
- Biofuels extraction from the single celled fungi.
- Technology of using the gut micro biomes of wood feeding insects for the conversion of lingnocellulotic material into biofuel.
- Recycling and reusability of lignocellulosic byproducts in biorefinery processes.
- Waste biorefineries: Future, green products and waste treatment.
- Biological Methanation or (bio/syn) gas upgrading.
- Advancement in biomass feedstock preprocessing.
- Current advances in micro algal biofuel.

5. CONCLUSION

In this paper we analyze the global as well as India bioenergy potential by comparing different previous research. The available research on bioenergy potential allows an evaluation of existing resources base scenario and gives information about possible future development. Existing research show that bioenergy has capacity to contribute major part of global primary energy supply in future.

In past decades no. of countries exploiting biomass opportunities for the provision of energy has increased rapidly. The

various researches provide the estimation of bioenergy potential but the exact potential estimation is unclear and it extensively varying. We found that the main four source of bioenergy are agricultural, Forest, waste and others. Out of these four sources forest can became a major source of bioenergy. Land availability is the important parameter in the bioenergy potential assessment. For all potential purpose it is vital to clearly define land use policies to ensure restriction of bioenergy cultivation to area that are not in competition with other uses like agriculture, biodiversity, etc. Liquid fuel made from biomass attracting growing interest worldwide. The bioenergy sources are available all around the globe at very low cost as compare to others energy resources. So it can be an effective option for provision of energy services. Therefore more research for making new technologies is needed.

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