SUSTAINABLE BIOENERGY & BIOFUELS

INDIA REPORT

2019

MISSION INNOVATION

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आयुष्मान भारत
PM-JAY
जय विज्ञान
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MESSAGE

Renewable energy sources offer a viable option to address the energy security concerns of our country. With depleting fossil fuels and impending signs of global warming, India now must rely on renewable resources to part meet its rising energy demand, especially in transport sector.

2. Honorable Prime Minister Sh. Narendra Modi in 2016 gave a call that oil imports should be reduced by at least 10 per cent by 2022. He also said that biofuels can power India's growth in 21st century and can help reduce import dependency on crude oil and can contribute to a cleaner environment.

3. India is member of all eight innovation challenges under Mission Innovation and has allotted considerable research grants to innovate new technologies under this clean energy initiative and different Ministries/Departments of Government of India are participating in these Innovation challenges to accelerate clean energy development.

4. Government of India is committed to increasing production of biofuels to enhance the farmers' income and to improve the environment. Ministry of Science and Technology through Department of Biotechnology (DBT) has funded a large number of R&D projects for development of advanced biofuels from agricultural residues, Municipal Solid Waste (MSW) and other wastes. Some of these programmes have already reached maturity and are in commercial use. Several R&D efforts are being made to develop bioenergy technologies which are sustainable and cost-competitive.

5. Reports, such as the instant one, which elaborate present status of various R&D Projects on development of Sustainable Bioenergy and Biofuels, Government policies thereon and future outlook, will serve important purpose of reference.

6. I am happy to release India report on Sustainable Bioenergy & Biofuels.

Harsh

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MISSION INNOVATION

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Foreword

Energy plays a vital role in the economic development of a country and its sustained and affordable availability contributes to accelerated economic development. However, most of the conventional energy sources, e.g. coaldoes add to the environmental load. Government of India is committed to reduce the carbon footprints in the energy sector and meet its commitments of Paris accord. Biomass contributes to about third of primary energy in India but predominantly it is used in rural households which is associated with inefficient burning and environmental hazards of indoor pollution.

India has recognized the benefits of using biofuels for transportation use as these help in reductions of crude import, provide support to agriculture sector and make positive impact on the environment. Government of India has notified a new Biofuel Policy in 2018, which provides a step-wise plan to increase the availability of biofuels so as to achieve 20 percent blending of biofuels in petroleum transportation fuels. This challenge should act as an opportunity for biofuel sector to come up with new technologies and feedstocks.

Sustainable Biofuels has been designated as one of the eight Innovation Challenges in which new technologies are necessary so as to meet the National mandate. DBT has been supporting all the Innovation Challenges and has allotted several projects under different Innovation areas in collaboration with MI countries.

Honorable Prime Minister of India while addressing world Biofuel day in 2018 said that biofuels can generate additional income for farmers and boost rural employment. He further observed that the transformative potential of biofuels can be realized only through the participation of students, teachers, scientists, entrepreneurs and the people. He urged everyone present to help take the benefits of biofuel to the rural areas.

The present report on the Indian biofuel sector details the current scenario, future plans and government policies to promote biofuels. The report covers conventional biofuels like ethanol & bio-diesel and also endeavours of research community for promoting advanced biofuels.

I do believe that this report will be of interest to all the stakeholders in the biofuel sector.

Renu Swarup

(Renu Swarup)

MISSION INNOVATION

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CONTEXT:

Energy has been universally recognized as one of the most important inputs for economic growth and human development. There is a strong two-way relationship between economic development and energy consumption. On one hand, growth of an economy depends upon the availability of cost-effective and environmentally benign energy sources, and on the other hand, the level of economic development has been observed to be dependent upon the energy demand. India is one of the fastest-growing economies in the world with a very impressive economic growth rate. Energy plays a vital role in the economic development goals set up by the Indian government for providing sustainable and affordable energy to its people. Energy is a prime factor to maintain or surpass this growth rate and the country's consumption is projected to double by 2030. As measured by the per capita primary consumption which is linked to the Human Development Index (**HDI**) set by the United Nations, India still lags behind. **[1-3].** India's share of global energy consumption in 2018 is only 5.8 % given the fact are we are second most populated country. India's primary energy consumption rose by 7.9 % in 2018, highest since 2007. Coal consumption also grew by 8.9 % in 2018. On the positive side, India has 5th Global position for overall installed renewable energy capacity, 4th position for wind power and 5th position for solar power (MNRE REPORT 2018; YEAR-END REVIEW).

According to a survey of IEA, transport biofuel consumption globally, needs to triple by 2030 (to 280 Mtoe) to be on track with the Sustainable Development Scenario (SDS). This equates to 10% of global transport fuel demand, compared with the current level of around 3%. Global biofuel production is not increasing quickly enough to meet SDS demand. Output grew 7% year-on-year in 2018 to reach 88 Mtoe (152 billion litres), but average production growth of only 3% per year is anticipated over the next five years. This falls short of the sustained annual growth of 10% through to 2030 required to keep pace with the SDS.

Coal and crude petroleum, two main energy sources, are non-renewable and adds to the greenhouse gas emissions and their rising costs impact the nation's foreign exchange reserves. Replacing these non-renewables with a renewable alternative via solar, wind or biomass will be a paradigm shift in India's energy security along with the reduction in carbon emissions eventually impacting India's energy mix.

India holds the seventh large share of land and second-largest share of the human population on the earth. Resource augmentation and growth in energy supply has not kept pace with increasing demand and, therefore, India continues to face serious energy shortages. This has led to an increased reliance on imports to meet energy demand. With depleting fossil fuels and impending signs of global warming, India now must rely on renewable resources.

Recognition of renewable energy as the keystone of sustainable development has led to the rapid adoption of technologies by the developed and developing economies of the world. India is large country of world in terms of geographical area and more than half of its land is fertile, against a global average of 11%, making India an agro-based economy. Approximately a third of the total primary energy consumed in the country comes from biomass and caters to the needs of two-third of the population [1]. Despite increasing dependence on commercial fuels, a sizeable quantum of energy requirements, especially in the rural household sector, is met by non-commercial energy sources, which include fuelwood, crop residue, and animal waste, including human and draught animal power. However, other forms of commercial energy of a much higher quality and efficiency are steadily replacing the traditional energy resources being consumed in the rural sector.

Renewable energy sources offer a viable option to address the energy security concerns of a country. Today, India has one of the highest potentials for the effective use of renewable energy. A target of installing 175 GW of renewable energy capacity by the year 2022 has been set, which includes 100 GW from solar, 60 GW from wind, 10 GW from bio-power and 5 GW from small hydro-power (Press Information Bureau, Government of India, Ministry of New and Renewable Energy, 19-July-2018)

As per estimates of the Indian Ministry of New and Renewable Energy (MNRE), every year around 450-500 MMT of biomass including the agro residue and the forestry waste is generated in India **[3,4]**. In another nationwide survey conducted on behalf of Technology Information Forecasting and Assessment Council (TIFAC) **[5]**, it was concluded that almost 80% of the agro-residues comprises of rice straw, rice husk, sugarcane tops and bagasse. The survey further revealed that Indian states of Uttar Pradesh, Punjab, Tamil Nadu, Haryana, West Bengal and Maharashtra possess the highest availability of biomass per unit area; hence, they are potent locations for developing biomass-based industries **[5]**. Globally the biofuel production has been increasing rapidly over the last decade, but the expanding biofuel industry has recently raised important concerns, the sustainability of many first-generation biofuels which are produced primarily from food crops such as grains, sugar cane and vegetable oils has been questioned over concerns such as effect on environmental, sustainability, food vs fuel concerns and climate change **[6]**. There is a growing consensus that if significant emission reduction in the transport sector is to be achieved, biofuel technologies must become more efficient in terms of the net life cycle greenhouse gas [GHG] emission reductions while at the same time be socially and environmentally sustainable. It is understood that most of the first-generation biofuels (except sugar cane molasses-based ethanol) will likely to have a limited role in the future transport fuel mix as the food-based feedstocks will always be limited.

Increasing criticism about the first-generation biofuels has focused attention on the potential of second-generation biofuels, from agricultural residues etc which do not compete with food/fodder crops for available land, can have a positive effect on development and can improve economic conditions of farmers in emerging and developing countries **[6a]**. However, the long-term sustainability of second-generation biofuels will depend on whether the producers comply with the criteria like minimum life cycle GHG reductions (including the land-use change and social standards).

By 2050, a new generation of sustainable biofuels could provide over a quarter of the world's total transport fuel, according to a recent report by the International Energy Agency **[IEA]** and biomass-based fuels offer the best viable low-carbon alternative to high energy density liquid fuels, including diesel and jet fuel **[6]**. To achieve that scenario, researchers are developing fuels from wastes, agricultural residues and non-fuel crops that are environmentally and socially sustainable.

This report details the current Indian/Global scenario on bioenergy; biofuel policies of Government of India, new initiatives in R&D of advanced Biofuels and future projections. The data has been taken from authentic sources and is supported by references, wherever necessary.

1. INDIAN SCENARIO ON RENEWABLE ENERGY

Biomass contributes over a third of primary energy in India. Biomass is predominantly used in rural households for cooking and water heating, as well as used by traditional industries. Biomass delivers the most energy for domestic use (rural - 90% and urban - 40%) in India **[7].** Wood fuels contribute 56 per cent of total biomass energy and consumption of wood/biomass has grown annually at 2 per cent rate over the past two decades **[8,9a].**

Three main problems associated with the traditional biomass are - inefficient combustion technologies, environmental hazards from indoor pollution and unsustainable harvesting practices. The aim of modern biomass programmes is to overcome these problems and to produce energy-dense liquid and gaseous biofuels with low carbon footprints.

1.1 Biomass to Power

India produces about 450-500 million ton of biomass per year **[5]** and as such biomass provides ~32% of all the primary energy use in the country at present.

EAI and other reports estimate that the potential in the short term for power from biomass in India varies from about 18,000 MW, when the scope of biomass is as traditionally defined, to a high of about 50,000 MW if one were to expand the scope of the definition of biomass **[9a,9b,9c].**

The Indian renewable energy sector is the fourth most attractive renewable energy market in the world. As of October 2018, India ranked 5th in installed renewable energy capacity **[Figure 1].** Installed renewable power generation capacity has increased at a fast pace over the past few years, posting a CAGR of 19.78 per cent between FY14–18 **[9d].**

The focus of the Government of India has shifted to clean energy after it ratified the Paris Agreement, where several nations committed to drastically reduce their carbon dioxide emissions. India agreed to reduce its Intended Nationally Determined Contribution (INDC) of the emissions intensity of its GDP by 33 to 35 per cent by 2030 from 2005 level **[10]** (Press Information Bureau, Ministry of Environment, Forests and Climate Change; 2nd Oct 2015)

With the increased support of Government and its improved economics, the renewable energy sector has become attractive from an investors perspective. As India looks to meet its energy demand on its own, which is expected to reach 15,820 TWh by 2040, renewable energy in the total energy mix is set to play an important role.

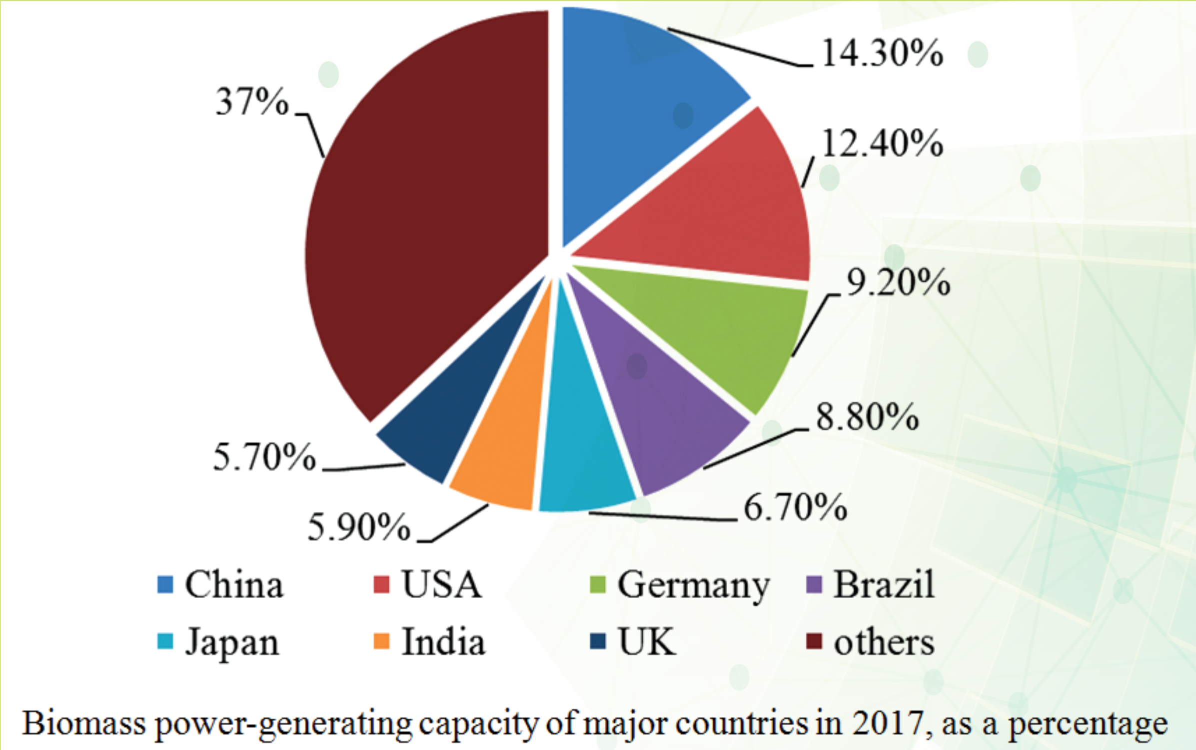


***Figure 1:* Biomass Power generating a capacity of major countries in 2017, as a percentage [9d]**

The Government of India is committed to the increased use of clean energy sources and is already undertaking various large-scale sustainable power projects and promoting green energy extensively. In addition, renewable energy has the potential to create many employment opportunities at all levels, especially in rural areas **[11].** The Ministry of New and Renewable Energy [MNRE] has set an ambitious target to set up renewable energy capacities to the tune of 175 GW by 2022 of which about 100 GW is planned for solar, 60GW for wind and other for hydro, 10GW for Bioenergy among others **[3,9c].** As of June 2018, Government of India is aiming to achieve 225 GW of renewable energy capacity by 2022, much ahead of its target of 175 GW as per the Paris Agreement. As per the data from the Economic Survey, India's renewable energy sector is expected to attract investments of up to US$ 80 billion by the year 2022 **[9,11].** It is expected that by the year 2040, around 49 per cent of the total electricity will be generated by renewable energy. Use of renewables will save India Rs 54,000 crore [US$ 8.43 billion] annually **[9c,12].**

According to data collected by **IRENA** on estimated direct and indirect jobs created in the bioenergy sector in 2016, in India 35K jobs in liquid Biofuel; 58K jobs in solid biomass and 85K jobs in biogas sector were created. The number of estimated jobs in the renewable sector is 1.2 million by 2030**[13]**. According to 2017 IRENA working paper on prospects of renewable energy in India**,** most biomass in the year 2010 was used for heat and other direct uses **[13]**. Biomass used for power generation was only 4 % of the total biomass **[Figure 2]** and only 1% of biomass was used for producing transport fuels. The total energy generated from biomass was 6.9 EJ.

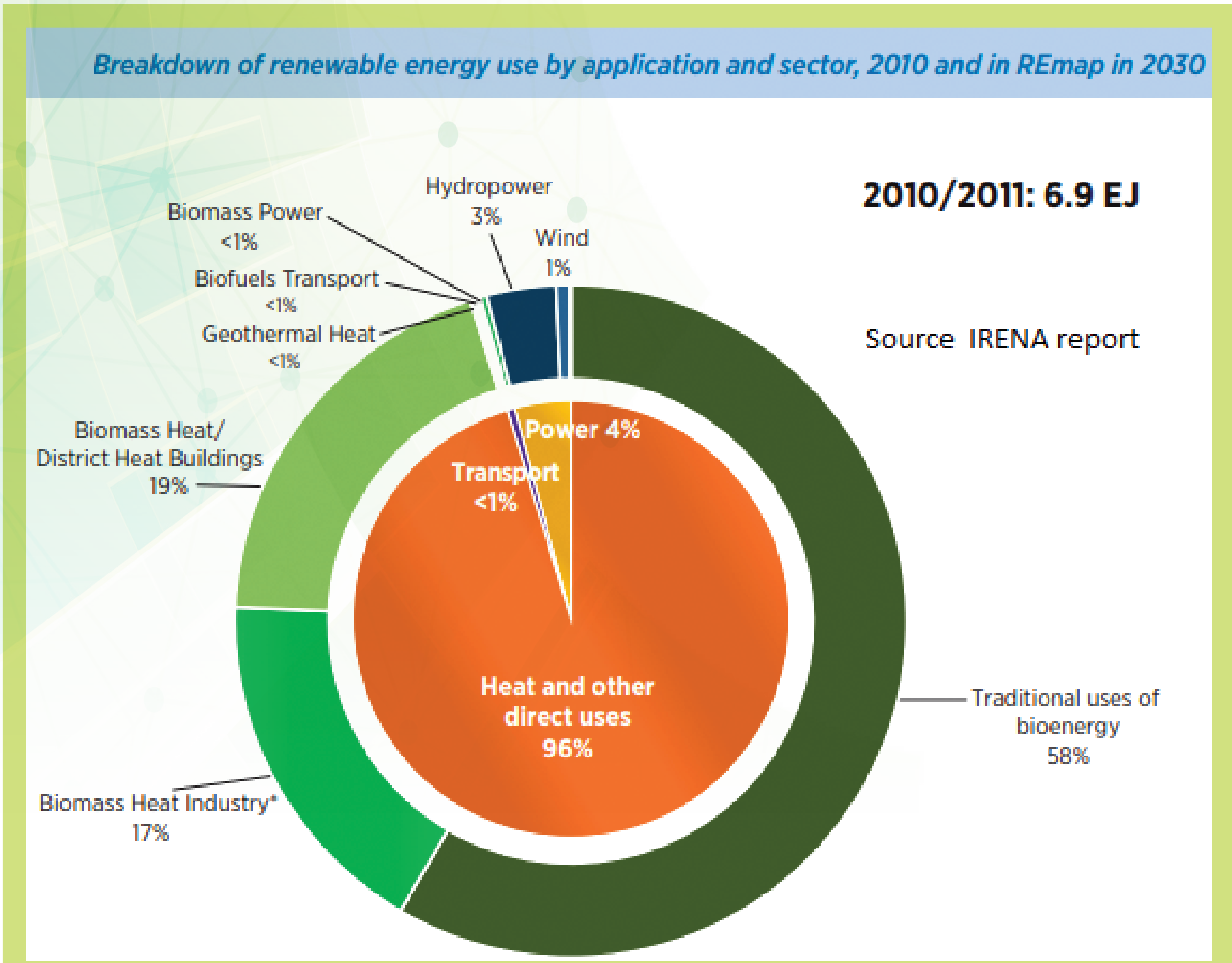


Figure 2: **Breakdown of Renewable Energy use by application and sector 2010 and REmap in 2030[13]**

However, as per predictions for the year 2030 total energy generation from biomass is estimated at 9.3 EJ which shows an increase of 35 % from 2010. As shown in **Figure 3,** the sector-wise use of biomass is expected to change drastically. Biofuels from biomass will increase by 5 times and use of biomass for power generation will increase by 9 times and direct use of biomass for heat will reduce to nearly half. The data for the year 2017 points to achieving targeted predictions even before 2030.

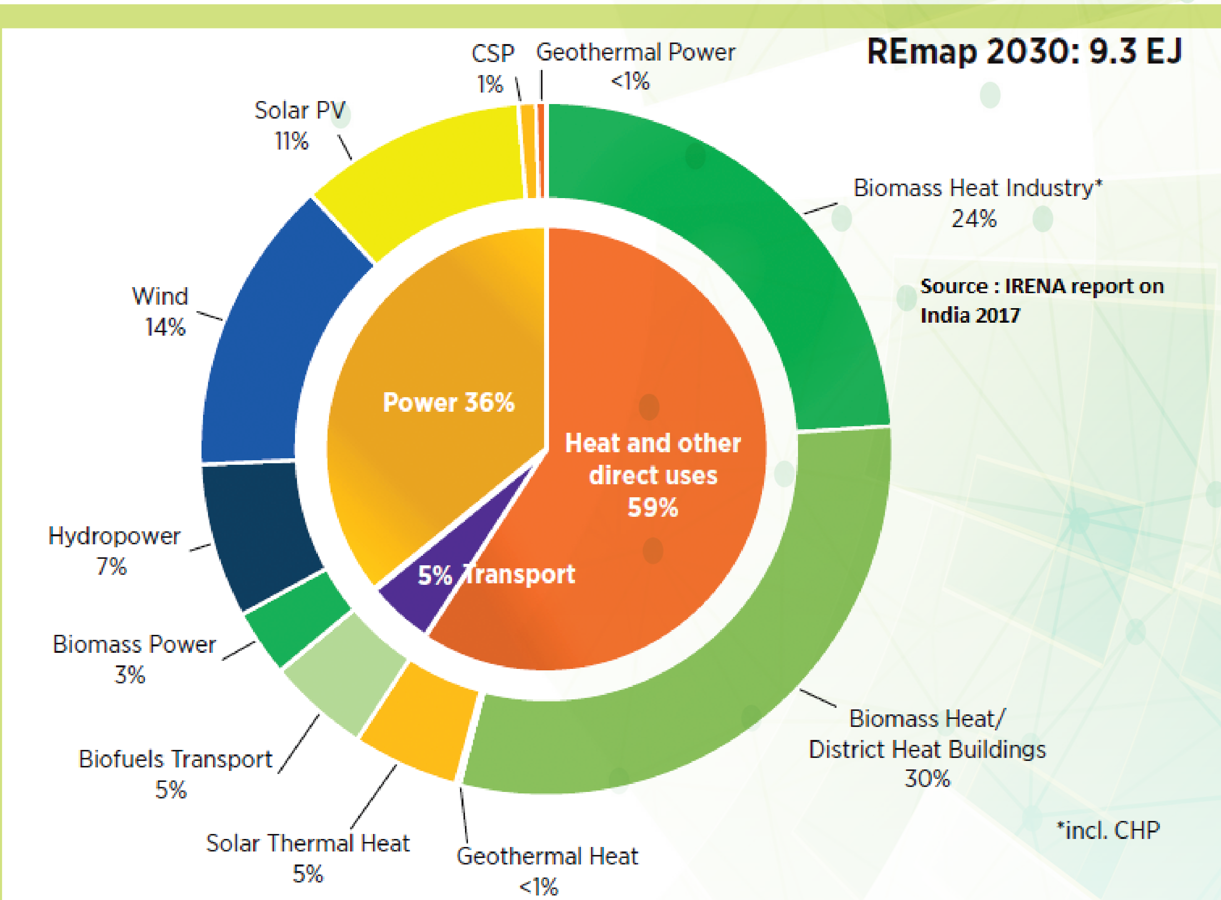


Figure 3: **Breakdown of Renewable Energy Map 2030 [13]**

For co-generation in industry, in 2010/2011, the total installed cogeneration capacity in India's sugar mills was about 1.9 GW (electric-capacity), generating about 6 TWh/yr. India produces approximately 80 Mt wet bagasse with a lower heating value of approximately 7-8 MJ/kg] each year, about 70 Mt of which is used for captive power generation **[14,15].** According to Vision 2030 prepared by National Institute for Transformation of India **(NITI Aayog)**, for the sugar industry, total sugar cane production will grow to 520 Mt/yr by 2030 and would generate a total volume of 120 Mt wet bagasse per year. Based on today's level of wet bagasse use for power cogeneration (70 Mt out of 80 Mt), this provides the potential to install 5.1 GW in power capacity **[16].**

1.2 Biomass to Energy Conversion Pathways

There are many pathways by which biomass feedstock can be converted into useful renewable energy. A broad range of wastes, residues and crops grown for energy purposes can be used directly as fuels for heating or for electricity production, or they can be converted into gaseous or liquid fuels for transport or as replacements for Petro based fuels **[Figure 4]**. Many bio-energy technologies and conversion processes are now well-established and are commercial **[18, 18a]**. A further set of conversion processes – in particular, to produce advanced liquid fuels – is maturing rapidly. In 2016, local and global environmental concerns, rising energy demand and energy security continued to drive increased production and use of bioenergy.

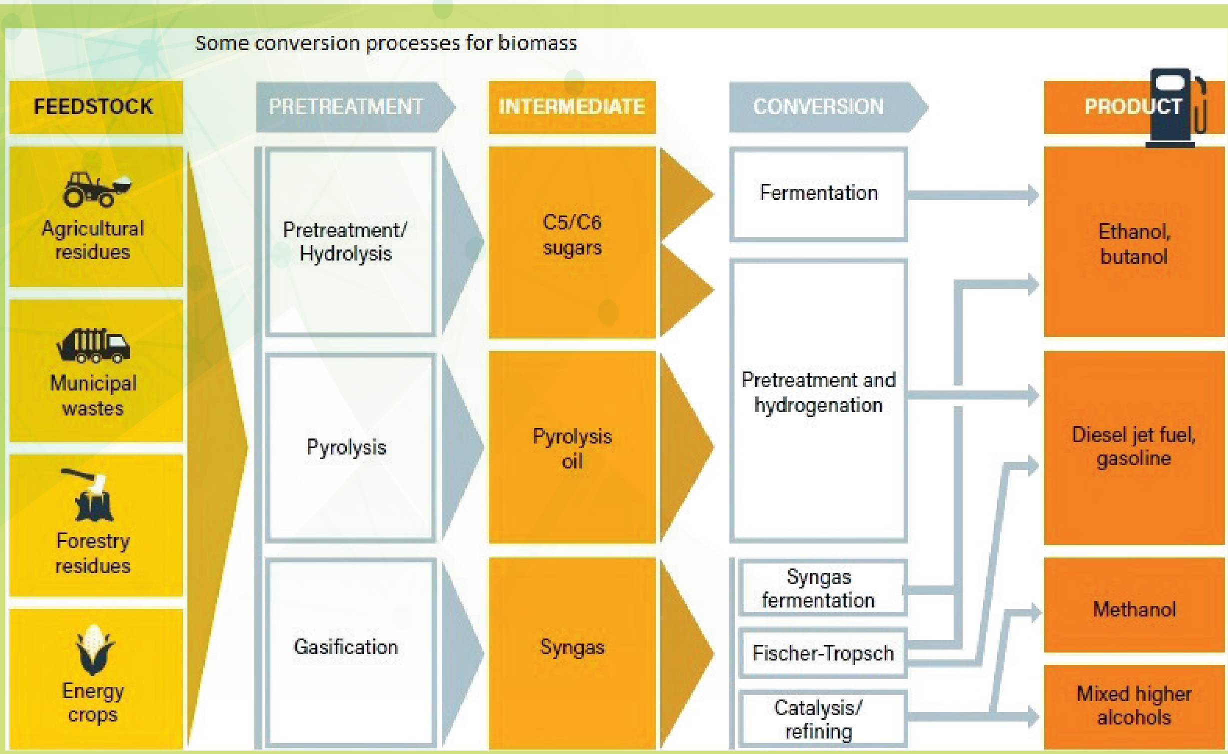


***Figure 4:* Conversion processes for biomass [18a]**

Indian R&D institutes are active in almost all areas listed in **Figure 4**. The following sections of this report shall give a brief about Indian efforts in the conversion of agricultural residue to ethanol, biogas, biofuels by biochemical methods and via pyrolysis/gasification.

The continuing discussion about the sustainability of some forms of bioenergy has led to regulatory and policy uncertainty in some markets and has made the investment climate difficult in bioenergy. Corn-based ethanol in the US and sugarcane-based ethanol in Brazil are already facing the debate on food vs fuel.

India declared its biofuel policy right in beginning whereby the major feedstock for biofuel production must predominantly be non-food and non-fodder.

1.3 Bio-Ethanol Production

Global demand for environmental, energy security and benefits to agriculture sectors have elicited global attention towards liquid biofuels, such as bioethanol and biodiesel. Around the world, several governments have introduced various policy measures, mandatory fuel blending programmes, incentives for flex-fuel vehicles and agricultural subsidies for the farmers to promote the use of biofuels.

Major Ethanol Feedstocks Around The World

Country	Fuel ethanol production in 2016 (Billion litres)		Major feedstock
USA	56.0	58%	Maize
Brazil	26.8	28%	Sugarcane, sugarcane molasses
EU	5.2	5%	Beet, beet molasses, wheat, maize
China	3.1	3%	Maize, wheat, sugarcane, beet molasses
Canada	1.6	2%	Maize
Thailand	1.3	1%	Sugarcane molasses, cassava
Argentina	0.8	1%	Maize, molasses
India	0.8	1%	Sugarcane molasses
Rest of the world	1.5	2%	Sugarcane molasses

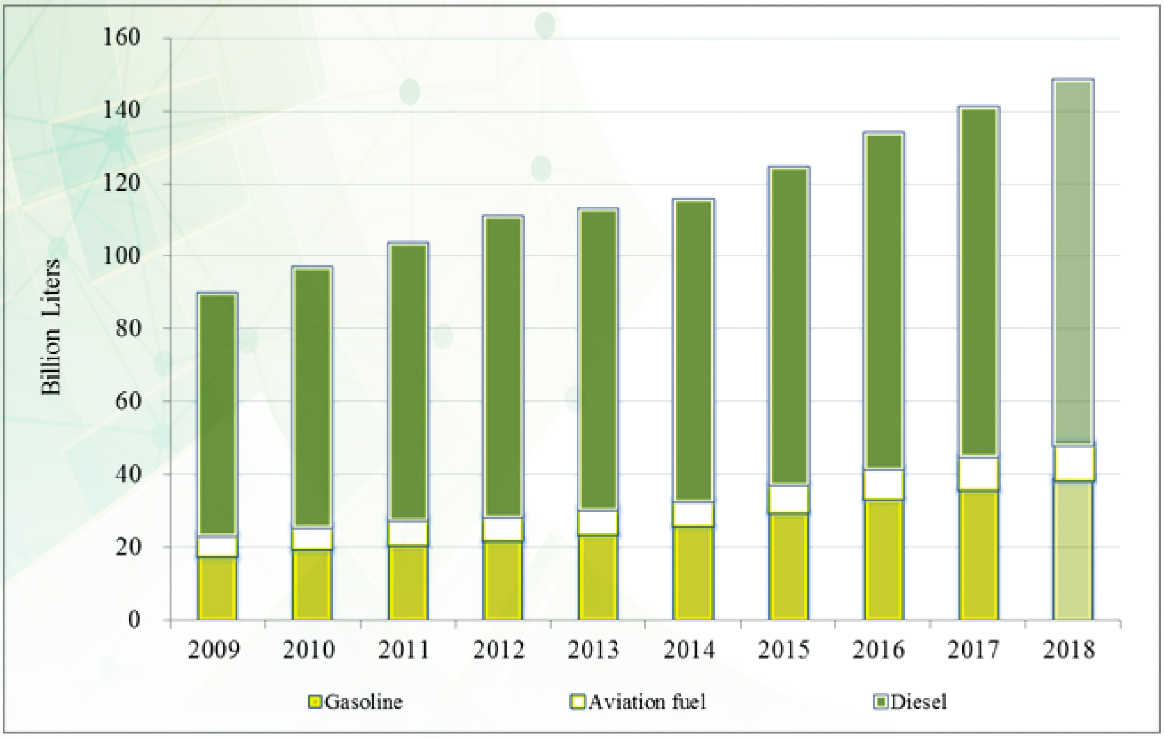
Figure 5: **Global ethanol production in 2016 [9]**

Global production of ethanol is shown above in **Figure 5**. It may be mentioned that India's ethanol production had been based on sugar molasses, a by-product of the sugar industry, and not directly from sugarcane or grains/corn.

As can be seen, major ethanol producers like the US, Brazil and China used food crops like maize, wheat and sugarcane, which are not feed stock of choice for India. Presently, India being a major sugarcane producing country produces almost all of its ethanol for fuel blending and other uses from sugarcane molasses. India has around

330 distilleries which can produce over 4.5 billion litres of the rectified spirit [alcohol] per year. Of this total, about 162 distilleries have the capacity to distil over 2.2 billion litres of conventional ethanol which can be used for the blending of gasoline **[17,18,19a&21].**

India has a very large consumption of petroleum products which also growing very fast. Growth of petroleum products for transport fuels is shown in **Figure 6**. The consumption of main transport liquid fuels viz. gasoline, diesel and aviation fuel has grown by ~ 70 % during 2009-2018. Therefore, any biofuel policy must consider the consumption growth of transport fuels **Figure 6 [17].**



Source: Petroleum Planning and Analysis Cell, government of India (GOI)
*: Estimated for 2018

India: Consumption of Liquid Fuels, In Calendar Year

Figure 6: **Growth of liquid transport fuel consumption in India [17]**

1.4 Biofuel: Policy Interventions

First Generation (1G) Ethanol Blended Petrol (EBP), Programme

Government of India, with effect from January 2003 resolved to supply ethanol-blended petrol in nine States and four Union Territories for sale of 5% ethanol-blended gasoline. Ethanol Blended Petrol (EBP) programme is aimed at achieving multiple outcomes such as reducing import dependency, conserving foreign exchange, reducing carbon emissions and provide a boost to the agriculture sector.

The Ministry of Petroleum & Natural Gas (MoP&NG) vide its notification dated 20th September 2006 {**http:// egazette.nic.in/WriteReadData/2006/E 450 2011010.pdf)** directed the Public Sector Oil Marketing Companies (OMCs) to sell 5% ethanol-blended gasoline subject to commercial availability as per Bureau of Indian Standards specifications in the notified 20 States and 4 UTs of the country with effect from 1st November 2006.

The erstwhile National Policy on Biofuels - 2009, allowed ethanol to be procured from non-food feedstock like molasses, celluloses and lignocelluloses material. Government, in its decision dated 3rd July 2013, inter -alia decided that ethanol be procured only from domestic sources and sugarcane or sugarcane juice may not be used for the production of ethanol and it is produced only from molasses. Thus, the EBP programme was being implemented in 21 States and 4 UTs till 31.03.2019, wherein Public Sector OMCs procured ethanol from suppliers, blended at 10% ethanol in gasoline for selling.

However, sufficient supplies were not forthcoming. To increase indigenous production of ethanol, the Government since 2014 took multiple interventions including, re-introduction of administered price mechanism, opening of alternate route for ethanol production, amendment to Industries (Development & Regulation) Act, 1951 which legislates exclusive control of denatured ethanol by the Central Government, reduction in Goods & Service Tax (GST) on ethanol meant for EBP Programme from 18% to 5%, Notification of National Policy on Biofuels - 2018 which indicates a target of 20% ethanol blending in gasoline by 2030, DFPDs interest subvention scheme namely - **"Scheme for financial assistance to sugar mills for enhancement and augmentation of the ethanol production capacity"** on 19th July, 2018. Under the aforesaid scheme, interest subvention at the rate of 6% per annum or 50% of the rate of interest charged, whichever is lower, on the loan sanctioned; for a period of 5 years; shall be borne by the Central Government.

The aforesaid actions helped in increasing ethanol procurement by PSU OMCs from 380 million litres during ethanol supply year (ESY) 2013-14 (December 2013 to November 2014) to 1505 million litres during 2017-18 (December 2017 to November 2018). (Data provided by MoPNG)

For the first time during ESY 2018-19, different ex-mill price of ethanol, based on the raw material used was fixed by the Government. In addition, OMCs fixed the ex-mill price of ethanol derived from damaged food grains. Further, ethanol from surplus food grain and fruit and vegetable waste has also been allowed for 2018-19.

The response to the above actions has been encouraging and against the tender requirement of 3290 million lit for ESY 2018-19, PSU OMCs have signed contracts for 2447 million lit. Further, Government has given in-principle approval to 245 proposals involving maximum loan amount of around Rs.125 billion (US$ 1.79 billion) for grant of interest subvention which is estimated to add approximately 4 billion litres of ethanol distillation capacity.

With effect from 01.04.2019, EBP Programme has been extended to the whole of India except islands of Andaman Nicobar and Lakshadweep. (**http://egazette.nic.in/WriteReadData/2019/197698.pdf**)

Second Generation (2G) Ethanol Blended Gasoline Programme (EBP)

The Government has approved Pradhan Mantri JI-VAN Yojana **[20]** for providing financial support to integrated bio-ethanol projects using lignocellulosic biomass and other renewable feedstock with a total financial outlay of Rs.1969.50 crore(US$ 281 million) for the period from 2018-19 to 2023-24. Out of scheme fund, Rs.1800 crore (US$ 257 million) has been allocated for supporting 12 commercial projects, Rs.150 crore (US$ 21 million) has been allocated for supporting 10 demonstration projects. The scheme focuses to incentivize 2G ethanol sector and support this nascent industry by creating a suitable ecosystem for setting up commercial projects and increasing Research & Development in this area. These plants are estimated to garner total investment of Rs 10,000 Crores (US$ 1.43 billion).

National Policy on Biofuels -2018 [20]

The Government has notified new National Policy on Biofuel 2018 on 8th June 2018. The Policy categorizes biofuels as "Basic Biofuels" viz. First Generation (1G) bioethanol & biodiesel and "Advanced Biofuels" - Second Generation (2G) ethanol, Municipal Solid Waste (MSW) to drop-in fuels, Third Generation (3G) biofuels, bio-CNG, algal fuels etc. to enable an extension of appropriate financial and fiscal incentives under each category.

The Policy expands the scope of raw material for ethanol production by allowing the use of sugarcane juice, sugar-containing materials like sugar beet, sweet sorghum, starch containing materials like corn, cassava, damaged food grains like wheat, broken rice, rotten potatoes, unfit for human consumption for ethanol production.

Since farmers may be at risk of not getting the appropriate price for their produce during the surplus production phase, taking this into account the policy allows the use of surplus food grains for production of ethanol for blending with gasoline with the approval of National Biofuel Coordination Committee.

The policy encourages setting up of supply chain mechanisms for biodiesel production from non-edible oilseeds, used cooking oil, short gestation crops. Roles and responsibilities of all the concerned Ministries/Departments with respect to biofuels have been captured in the policy document to synergize efforts. The Policy also recognized the significant opportunity that biofuels offer to India's agricultural and industrial sectors.

Ethanol demand for blending into gasoline is given in **Figure 7**. As is evident the bioethanol demand will increase, due to an increase in gasoline consumption, by 1.5 times from the base year of 2016-17 to 2021-22 **[17,19]**.

Projected Blending Ethanol Demands

Year	Petroleum Demand	E5 Demand	E10 Demand	E15 Demand	E20 Demand
2016-17	30,649	1,532	3,065	4,597	6,130
2017-18	33,280	1,664	3,328	4,992	6,656
2018-19	36,075	1,804	3,608	5,411	7,215
2019-20	39,042	1,952	3,904	5,856	7,808
2020-21	42,191	2,110	4,219	6,329	8,438
2021-22	45,659	2,283	4,566	6,849	9,132

All values are in million litres

Figure 7: **Bioethanol blending demands in gasoline [17]**

An indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel is proposed by 2030 **(Figure 7) and** this goal of Biofuel policy, to be administered by the Ministry of Petroleum and Natural gas, Govt of India**(20),** is to be achieved by:

(a) Reinforcing ongoing ethanol/biodiesel supplies through increasing domestic production

(b) Setting up Second Generation [2G] biorefineries

(c) Development of new feedstock for biofuels

(d) Development of new technologies for conversion to biofuels.

(e) Creating a suitable environment for biofuels and its integration with the main fuels

Technology development with a focus on:

- Drop-in fuels produced from MSW, industrial wastes, biomass etc.
- Advanced biofuels including bio-CNG, bio-methanol, DME, algal, bio-hydrogen, bio-jet fuel etc.

The major thrust of this policy is to ensure the availability of biofuels from the indigenous feedstock.

Research, development and demonstration **[RD&D]** will be supported to cover all aspects from feedstock production and biofuels processing for various end-use applications. Thrust will also be given to the development of advanced biofuels and other new feedstocks **[20].**

The policy will allow the production of ethanol from B grade molasses as well as directly from sugarcane juice in case of excess production of sugarcane. The policy will also allow production of ethanol from damaged food grains like wheat, broken rice etc. which are unfit for human consumption. Farmers will be encouraged to grow a variety of different biomass as well as oilseeds on their marginal lands, as intercrop and as the second crop wherever only one crop is raised by them under rainfed conditions.

1.5 Financing Mechanisms for Advanced Biofuels

Government of India has announced a new biofuel policy 2018, **[20]** which includes funding support to production of advanced biofuels. The government will consider extending financial incentives including viability gap funding, subsidies and grant for biofuels. The government will classify Second Generation(2G) Ethanol, Drop-in fuels, Bio-CNG, Algae-based 3G Biofuels, Bio-methanol, DME, Bio-hydrogen etc" as "Advanced Biofuels".

The Government of India has already planned 12 large cellulosic ethanol plants at various locations to be set up by public sector oil marketing companies. The biofuel policy has provision to support investments in advanced biofuel commercial production by means of viability gap funding (VGF) of up to 20 % of the project cost. Further the project developers can approach state agencies for additional 20 % VGF for the projects. **(20; Section d &e)**

Suitable supply chain mechanisms, feedstock collection centres and fair price mechanisms for the engaged community will be developed in coordination with local bodies, States and concerned stakeholders.

Ample quantity of wastes such as MSW, industrial waste, plastic waste etc. is available across the country with established collection mechanism. This will serve as a feedstock for generating biofuels such as bio-CNG, drop-in fuels, bio-methanol, DME, bio-hydrogen etc.

The government has supported the sugar industry's demand for more financial assistance to enhance the ethanol capacity and for the first time India hopes to double gasoline blending with ethanol to 8 per cent in the 2018-19 sugar season. Public OMC's have blended 150.5 Crore litres(1.505 billion) ethanol during ethanol supply year (ESY) 2017-18 resulted in average blending percentage of 4.22%. Further, Public OMC's has contracted 244.7 Crore litre(2.447 billion) ethanol for blending in petrol and is expected to achieve 6% blending percentage for the ESY 2018-19.

To augment capacity through up-gradation of existing distilleries attached to sugar mills by installing incineration boilers and setting up new distilleries in sugar mills; Government of India has notified ''Scheme for Extending Financial Assistance to Sugar Mills for Enhancement and Augmentation of Ethanol Production Capacity" on 19.07.20 18 wherein Government will bear the interest subvention of maximum Rs.1332 crore (US$ 190 million) over a period of five years including moratorium period of one year on estimated bank loan amounting to Rs.4440 crore (US$ 634 million) to be sanctioned to the sugar mills by the banks over a period of three years. Subsequently, the Government has approved 114 projects under this scheme with an estimated production capacity of 200 Crore litres(2.0 billion).

Government has further allocated additional funds on the DFPD's aforesaid interest subvention scheme thereby approving Rs.2790 crore (US$ 398 million) towards interest subvention for extending indicative loan amount of Rs.12900 crore (US$ 1.84 billion) by banks to sugar mills. Additionally, Rs.565 crore (US$ 81million) towards interest subvention has been approved for extending indicative loan amount of Rs.5500 crore (US$ 786 million) by banks to molasses-based standalone distilleries. This is estimated to add 440 crore litre(4.4 billion) and 100 crores (1.0 billion) litre of ethanol distillation capacity respectively. Government has approved 245 proposals involving maximum loan amount of Rs.12493 crore cumulatively (US$ 1.78 billion) for grant of interest subvention which is estimated to add approximately 400 crores (4 billion) litre of ethanol distillation capacity. (Data provided by MoPNG)

With the current initiatives of Government of India on ethanol in terms of policy, strategy and implementation coupled with widening the feedstock, including cellulosic ethanol, India is expected to meet its target of 20 % blending of gasoline with ethanol as stipulated in new Biofuel policy of 2018.

2. STATUS OF BIODIESEL FUEL IN INDIA

The production of biodiesel fuels was 800 million litres for the world as a whole in 2000, and this had increased nearly 30-times to 22.5 billion litres by 2012.Most biodiesel was produced in the US using soyabean oil and UCO, whereas the EU produced biodiesel from vegetable oils, sunflower etc. and UCO.

In 2009 India enacted its National Policy on Biofuels, where it raised the objectives of replacing gasoline with alternatives such as fuel with 20% bioethanol intermixed **[B20]** and fuel with 10% biodiesel intermixed **[B10]**.

Biodiesel producers in India utilized multiple feed-stocks such as Used Cooking oils [UCO], animal fats, tallow's and 'other oils' [palm stearin, sludge, acidic soils, and tree oils etc.], tree-borne oils to produce biodiesel, thereby utilizing only 30 per cent of the installed capacity. While the use of animal fats and tallow's has remained constant, remaining feedstock use has shown steady growth, namely UCO and other oils **[22].**

According to the Union Ministry of Petroleum and Natural Gas (MoP&NG),bio-diesel procured by public sector Oil Manufacturing Companies [OMCs] is given in the table below **[Table 1] [17]**. Letter of Intent for 16 crores (1.6 billion) litres are being placed by OMCs for 2019-20 and 1.01 Crore (10.1 million) litres has been procured by OMCs during April- May'2019.

Table 1: **Biodiesel procurement by Public sector OMC's (MoPNG)**

Year	Procurement in Crorelit (million litres)
2015-16	1.19 (11.9)
2016-17	3 . 59(35.9)
2 017-18	4.36(43.6)
2018-19	8.21(82.1)

The chronological progress **[17]** of the biodiesel programme in India is summarized below:

- August 2015: Direct procurement of biodiesel allowed for bulk consumers
- August 2015: Retailing of HSD blended with Biodiesel B5 started
- June 2015: Retailing of B100 allowed for blending
- More than 45 Million litres of B100 supplied
- Used edible oils to be converted to biodiesel

2.1 New Initiatives in Biodiesel

India has been making progress with developing production technologies, and the Indian Oil Corporation (IOCL) has developed the technology to manufacture bio-hydrogenated diesel **[BHD]** by mixing and processing non-food vegetable oil and petroleum-based feedstock in an oil refinery's diesel hydrotreater unit **[DHDT] [23]**. The diesel obtained from this shows a high cetane value and high oxidative stability, which makes it possible to achieve a roughly 50% reduction in production costs compared with biodiesel produced at normal biodiesel plants. This biodiesel called green diesel is indistinguishable from petrodiesel and hence there is no limit to its blending with diesel.

What is more, the Central Salt and Marine Chemical Research Institute **[CSMCRI]** and the National Environmental Engineering Research Institute **[NEERI]** has developed a technique for producing biodiesel fuel from microalgae, with driving tests being carried out using B20 fuel at CSMCRI **[24].**

2.2 Feedstock Development for Biodiesel

- ***Used Cooking Oils (UCO) as a feedstock for biodiesel***
- Used Cooking Oil (UCO) has been identified as a potential raw material for biodiesel production in National Policy on Biofuels-2018 which envisages laying down stringent norms for avoiding the entry of UCO in food stream and developing a suitable collection mechanism to augment its supply to Bio-diesel production. To tap this resource, OMCs have invited EOIs (Expression of Interest) for procurement of biodiesel produced from UCO at remunerative prices, it is proposed to ensure that Rs 51/ literlitre is paid for Biodiesel for the first year, Rs 52.7 for the second year and Rs 54.5 for the third year. Oil companies will also bear the cost of transportation and GST for the first year.
- ***Algae as a feedstock***
- Molecular studies of potential biodiesel producing strains of microalgae, developing low water demanding cultivation system of algae for Rajasthan, onsite high-density microalgae cultivation
- Photobioreactor design and harvest technology for algae production have been supported. In the project on Computational Fluid Dynamic (CFD) Modeling of Algal Photobioreactors for CO_2 sequestration and Conversion to

Value Added Products, a CFD model for 1000L pilot scale open raceway pond was successfully developed which predicts the hydrodynamics and aims at the elimination of static zones in microalgal culture. CFD model for bench-top indigenously designed closed air-lift photobioreactor was developed which predicts water velocity, gas velocity, gas hold-up, mass transfer coefficient and light transfer for microalgal cultures **[34].**

- The Research & Development projects on improvement in Seed Yield of Jatropha curcas through Breeding and Silvicultural Practices, Phenotypic screening of oleaginous microalgae, Molecular studies of potential biodiesel producing strains of microalgae, developing low water demanding cultivation system of algae for Rajasthan, Onsite High-Density Microalgae Cultivation, Photobioreactor Design and Harvest Technology for Algae Production have been supported. In the project on Computational Fluid Dynamic (CFD) Modeling of Algal Photobioreactors for CO_2 sequestration and Conversion to Value Added Products, a CFD model for 1000L pilot scale open raceway pond was successfully developed which predicts the hydrodynamics and aims at the elimination of static zones in microalgal culture. CFD model for bench-top indigenously designed closed air-lift photobioreactor was developed which predicts water velocity, gas velocity, gas hold-up, mass transfer coefficient and light transfer for microalgal cultures. A semi-engineered 1000L open raceway pond with automation system for CO_2 sequestration and production of value-added products was developed for Spirulina as model microalgae **[34]**.

3. BIOGAS DEVELOPMENTS IN INDIA

Biogas is a carbon-neutral, sustainable and renewable source of energy that can be produced and consumed without much adverse effect on the environment. Biogas has the potential to cater to the needs for cooking, basic fuel, electricity and can be upgraded to biomethane which then used as a transportation fuel as compressed bio-gas (CBG). The spent slurry obtained after production of biogas from carbon-rich materials like agricultural residues, MSW and household waste is used as an organic fertilizer instead of chemical fertilizers and thus contributes in reduction of greenhouse gas emission in both energy and agriculture sector. These organic fertilizers from biogas plants have a huge demand in the Indian agriculture sector. Thus, biogas has the potential in the context of sustainable development that addresses the social-economic and environmental problems.

In India, it has been estimated that the total potential of biogas production from different organic wastes is about 40,734Mm3 /year **[25].** The country has the potential of installation of about 12 million household type biogas plants. About 4.75 million biogas plants have already been installed to the year 2014, which is about 40% of total potential [MNRE data] **[3].** It is estimated that India can produce power of about 17000 MW using biogas which is about 10 % of country's energy requirement **[12].** Biogas production technology also helps to solve the waste management problem as it disposes different organic wastes in an environment-friendly manner. In India, at present most popular and technically mature biogas plants are mostly for the digestion of animal waste. But as the technology advances new feedstocks viz. kitchen waste, municipal solid waste, agricultural waste, processing industries waste etc. has been successfully being used for biogas generation.

India is the country with the world's largest livestock population of about 512.1 million **[26]** and hence the availability of enormous animal waste**.** The organic waste generated by these livestock animals is the most suitable feedstock for biogas production which can generate biogas about 15083 Mm^3 annually.

Municipal solid waste **(MSW)** generation and its disposal have become a global issue as it is adversely affecting the environment as well as public health all over the world and it is more serious in developing countries because of rapid urbanization and population growth. In India, more than 1,27,000 tons per day of MSW is being generated because of various household, industrial and commercial activities **[27].**

Crop residue of agriculture is the prime source of available biomass in India and large quantities of crop residues is generated, a sizable part of which is burnt in fields. Crop residues represent a large unexploited energy potential that could be harnessed by the production of methane (CH_4)-rich biogas through anaerobic digestion (AD). At present, the country produces 450-500 MMT of crop residues per annum, of which 234MMT is reported as surplus **[5,28]**. The various cellulolytic crop residues like straws from wheat, rice and sorghum, maize & sugarcane stalk can be a good feedstock for anaerobic digestion with a suitable pretreatment. It has been estimated that India's potential for biogas production from crop residue and agricultural waste is about 45.8 Mm^3/day **[29].**

Ministry of New and Renewable Energy [MNRE], Government of India has fixed an annual target of launching 65,180 biogas plants in the current year under the **National Biogas and Manure Management Programme (NBMMP) [3]**, in order to promote clean cooking. The National Biogas and Manure Management Programme (NBMMP) aims at setting up of family type biogas plants for providing biogas as clean cooking fuel and a source of lighting. Under the NBMMP, about 49.6 lakh (4.96 Million) household size biogas plants have been installed since the inception of the National Biogas Programme in the country. The slurry, produced from biogas plants as a by-product, is an organic bio-manure for enhancing crop yield and maintaining soil health **[3,31].**

3.1 Biogas in India— Some Recent Examples (31):

- 4.7 M Household biogas plants based on cattle manure mainly for producing cooking fuel
- Mid-sized biogas plants based on cattle manure and other similar wastes for heat, electricity or motive power
- Biogas from urban and industrial wastes and effluents
- Co-digestion of farm / agricultural residues with urban and industrial wastes
- 2.4 MW project based on the mix of poultry droppings, cattle manure along with some agro-industrial wastes after MW scale projects based on only cattle dung
- About ten projects on production and up-gradation of biogas to Compressed Natural Gas Quality fuel. Capacity ranges from 0.4 to 8 TPD bio-CNG.
- Bio-CNG and Power from biogas at distilleries and STPs
- Biogas up-gradation to Natural Gas Quality, Bio-CNG, for use as transport fuel

 # Data from 'Overview of Biogas in India. A review by Anil Dhussa, MNRE [31]

Figure 8: **Biogas Project at a Dairy Complex in Ludhiana [31] Capacity: 1.0 MW power from biogas produced from about 250 tons/day of cattle manure**

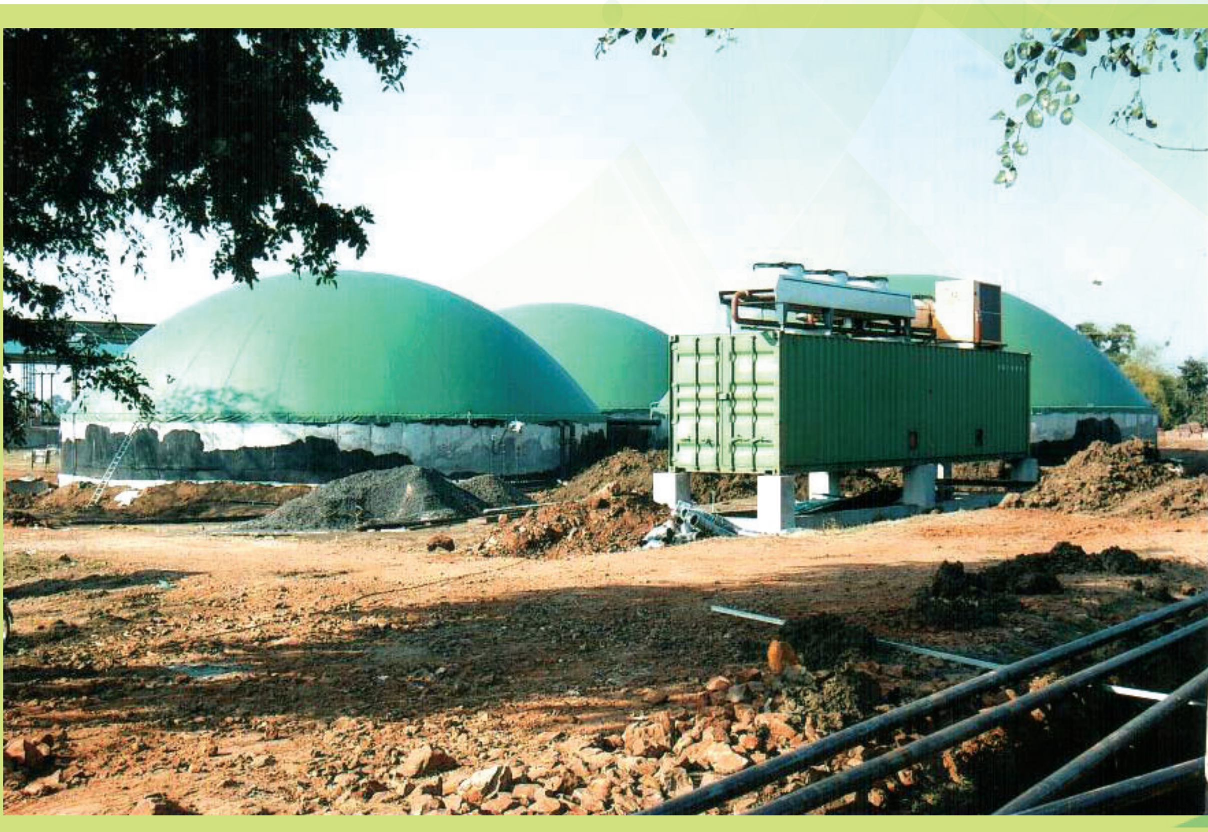


Figure 9: **1.2 MW power project based on cattle manure in Dairy Colony in Jabalpur [31]**

3.2 Commercial Projects on Compressed Biogas

India plans to start 5,000 compressed biogas plants over the next four years to curb oil imports and improve farm incomes. Setting up compressed biogas plants across the country will require an investment of nearly Rs 1.75 lakh crore [the US $ 25 Billion,] as per Ministry of Petroleum and Natural Gas **[30].** As many as 5,000 CBG plants are envisaged to be set up in the private sector that will generate 75,000 direct employments. State-owned fuel marketing companies will purchase all the bio-gas from these plants at market-driven prices.

Many medium-scale and large-scale biogas and biomethane plants have been set up using effluent of distilleries, breweries and other industries. In addition, biogas & biomethane plants based on the sludge of sewage treatment plant, MSW, crop residues, kitchen waste etc. have also been set up. Till recently, biogas plants were used to produce electricity and steam (CHP), especially in distilleries. However, there is an increasing trend to set up bio-CNG plants in India **[32]**

Figure 10: **A Commercial Bio-CNG plant {#Photographs taken from 'Overview of Biogas in India [31]}**

There is a large-scale program to use crop residues such as rice straw for producing bio-CNG in which Indian oil corporation (IOCL) proposes to set up 2000 plants in India. An MOU for setting up of 42 plants by 2018 in the state of Punjab has been signed between IOCL and the State Government. It is also proposed to initiate a project to set up 400 plants consuming 10 million tons per year of biomass over the next 3 to 4 years. These plants are projected to produce about 1,400 million kg per annum CNG and 6,000 million kg per annum manure. The plants, to be based on a new concept and technology, will be set up at a total investment of Rs 50 billion (US$ 750 Million) **[30].**

Biomass and waste sources like agricultural residue, cattle dung, poultry manure, other organic residues & waste materials etc. produce Biogas through the process of anaerobic decomposition. The Biogas is then purified and compressed to form Compressed Bio Gas (CBG or Bio-methane) **[Figure 11]** which has Methane (CH_4) content of more than 90%. CBG has calorific value and other properties very similar to Natural Gas (CNG) and hence can be utilized as a green, renewable automotive fuel. The Sustainable Alternative Towards Affordable Transportation **(SATAT)** Scheme was launched in India on 1.10.2018. The scheme envisages production and marketing of CBG from 5000 plants by March 2023. As per SATAT scheme, the CBG Plants shall be set up by independent entrepreneurs. The entrepreneur shall be responsible for planning, preparation, engineering and execution of the CBG Plant. An Expression of Interest (EOI) was released by Oil & Gas Companies namely Indian Oil, BPCL, HPCL, GAIL and IGL to procure Compressed Bio Gas (CBG) from suppliers at a delivered price of Rs. 46/kg of CBG excluding GST and sell to automotive and commercial customers **[23a]**. The estimated 5000 plants are expected to produce 15 million tons of CBG.

Indian Oil has developed an innovative two-stage anaerobic digestion technology to significantly increase Bio-gas production. Indian Oil **[Figure 12] [Table 2]** has also developed an enviro-tolerant inoculant, which produces higher biogas with high methane and reduced CO_2 content. The combined process has resulted in Biogas yield of 1.5-2 times over conventional process having methane content of 75-80% in raw Biogas **[23a].**

Figure 11: **Compressed Bio-methane Filling Section of Plant in Warna, Maharashtra [31]**

Figure 12: **IOT Biogas Pvt. Ltd. (a subsidiary/JV of Indian Oil) a Biogas Plant at Namakkal, Tamil Nadu. The inoculums developed by Indian Oil(R&D) has been used in the Plant.**

Table 2 **IOT Biogas Pvt. Ltd., a subsidiary of a JV of Indian Oil, which operates a Biogas Plant at Namakkal, Tamil Nadu**

Plant name	Type D/C	Status	Start-up year	Biomass type	Feedstock capacity	Product	By product
IOT Biogas, Namakkal, Tamil Nadu	Commercial	Operational since 2012	2012	Press mud, Chicken litter, cattle dung, etc.	Designed capacity 290 TPD mixed waste	Presently Biogas (24000 m^3/day) used to produce electricity. Purification & compression units being set up to produce CBG	Manure

Table 3: **List of Existing Compressed Biogas plants**

Name of Plant	Location	Feedstock	The production capacity of CBG (kg /day)
Noble Exchange Environment Solutions Pune	Pune Maharashtra	Organic Waste	14,000
Green Earth Biogas Pvt Ltd.	Surendra Nagar, Gujarat	Press Mud	5000
Bleach Energy	Anand, Gujarat	Press Mud, Cow Dung, Vegetable Waste	2130
Clarus Bioenergy	Sangli Maharashtra	Press Mud, Spent Wash	3000

Table 4: **Replacement values for different fuels by 1m3 of Biogas**

S. No.	Fuel	Replacement value	Estimated Equivalent with 15083 Mm3 of biogas/annum (in millions)
1	LPG	0.45 Kg	6787.35 Kg
2	Firewood	3.47 Kg	52338.01 Kg
3	Cattle dung cake	12.30 Kg	185520.9 Kg
4	Charcoal	1.4 Kg	21116.2 Kg
5	Diesel	0.52 liter	7843.16 liter
6	Electricity	6.5KWh	98039.5KWh
7	Kerosene	0.62 liter	9351.46 liter
8	Gasoline	0.8 liter	12066.4 liter

(http://vikaspedia.in/energy/energy-production/bio-energy/biogas)

As shown in **Table 4**, biogas as a source of energy has very good potential to replace common fuels and a good choice for producing electricity.

3.3 Main R&D Thrust Areas in Biogas Development and Commercialization [31]

- Development, demonstration and evaluation of existing and new designs of biogas plants for biogas generation utilizing different feedstock for cooking, power generation and transport applications.
- Development of efficient and cost-effective slurry handling system
- Standardization of multiple designs of biogas plants – all sizes, all feedstock based. Performance testing utilizing standardized gas flow meters for measurement of biogas generated.
- Technology development for the reduction in HRT
- Performance validation and cost economics before approval.
- New enzymes/ consortium of bacterial development of fast bio methanation processes
- Development in new materials of biogas plants for cost reduction.
- Standardization biogas slurry-based bio-fertilizer, value addition and marketing network development.
- Bio-manure up-gradation [incorporation of micronutrients into the slurry for land application].
- Development and standardization of scrubbers for biogas purification and gas flow meters.
- Cost-effective method of methane enrichment
- Development of efficient 100% biogas engine for power generation.
- Development of technology for effective collection and storage of feedstock.
- Development of technology for pretreatment of biomass
- Development of technologies for facilitating the sale of CBG including booster compressor, cascade and CBG dispensing units

3.4 Policy Initiatives by India in Biogas

- Development of centralized biogas generation plants with distribution through piping.
- Development of a business model for biogas fertilizer plants should be taken up. The strategy should be developed for large scale biogas plants, i.e., sewage treatment plants, sugar industry effluent, Cow sheds, etc.
- Mechanism and regulation to be developed to segregate the municipal
- Solids waste and Polluter–Pays principle should be made mandatory to stop the burning of crop and industry derived biomass source.
- City dairies are to be mandated to treat their waste and produce biogas.
- Technology development and demonstration and standardization of Bio CNG/ Bio Gas scale-up projects. Only those projects which have reduced HRT ~ 1-2 days, and which can give BIO-CNG at ~ 25-30 Rs/Kg must be scaled up
- Command area for biomass waste collection and utilization in urban and rural areas needs to be promoted.
- Promoting Bio–CNG marketing mechanism with standardization and control systems.
- Facilitating the financing of CBG plants through inclusion in priority sector lending with interest subvention.
- Facilitating pollution clearance of CBG Plants through inclusion in the white category.
- Facilitating the sale of bio-manure through the creation of special category "Fermented Manure/Slurry from Biogas Plants·· in fertilizer control order.

 # MNRE Report on Biogas [3, 31] & inputs received from MoP&NG

4. ALGAL BASED BIOFUELS

Algae have been in contention as one of the major sources of biodiesel in the near future. Cultivation of algae does not necessarily need prime agricultural land and can be grown under desert-like conditions using brackish and saline waters that are unfit for other uses **[33].** The water used for algal cultivation does not compete for agricultural important activities. Various studies in the design of raceway ponds with varying design parameters like water depth, stirrer design, the velocity of circulation, sparging of gas and gas compositions, and rate and type of algal harvesting have been carried out in India.

India has a very vast coastal area and thus marine algae becomes an important choice for producing biodiesel and other products. **Department of Biotechnology [DBT]**, Ministry of Science and Technology **[34]** and CSIR of India sponsored a very large number of projects on algal cultivation. DBT established algal banks for marine, cyanobacteria and freshwater algae. Some of the algal culture banks having high yielding varieties of algae are as under:

1. **Institute of Bioresearches and Sustainable Development** [IBSD], Imphal - Creation of freshwater cyanobacterial repository at IBSD by DBT 2010. More than 1200 unialgal cyanobacterial/micro-green algae have been purified and maintained in the freshwater Cyanobacterial and Microalgal with accession numbers.
2. **Institute of Minerals and Materials Technology** IMMT, Bhubaneswar
3. **Indian Institute of Chemical Technology**, Hyderabad
4. **Department of Agronomy, Institute of Agricultural Science**, Kolkata - Collection, characterization and screening of potential microalgae from West Bengal & Orissa Coast and Pilot-Scale Demonstration of Algal Oil Production – large project supported by DBT 2010
5. **University of Pune,** Pune - Collection, Identification, and Screening of Algal Biodiversity from Western Maharashtra for Quality and Quantity of Lipids funded by DBT

4.1 Indian Contribution Towards Algal Bio-Fuels Research

- Identification of a few micro algal species [marine] for bio-diesel production, cultivation protocols optimized.
- Harvesting procedure for these species standardized and under scale-up
- Extraction, conversion and testing of biodiesel completed at pilot scale
- Bio-oil production from marine microalgal biomass through hydrothermal liquefaction.
- CMCRI has successfully developed a low-cost technology of cultivation and harvesting using marine Chlorella in salt pan area. Cultivation area is planned to be expanded for scale-up purposes during phase 2.

4.2 Indian Institutes Involved in Algal Biofuels Research

- Central Salt and Marine Chemicals Research Institute [CSMCRI], Bhavnagar
- International Center for Genetic Engineering & Biotechnology, ICGEB – New Delhi"
- Calcutta University **[CU]**, Kolkata
- Indian Institute of Chemical Technology **[IICT]**, Hyderabad
- Indian Institute of Technology, Kharagpur **[IIT-KGP]**
- National Chemical Laboratory **[NCL]**, Pune
- National Institute of Oceanography **[NIO]**, Goa
- National Institute of Ocean Technology **[NIOT]**, Chennai
- National Institute of Interdisciplinary Science∞& Technology **[NIIST]**
- Institute of Chemical Technology ICT – Mumbai as DBT supported centre
- Bharathidasan University, Tiruchirappalli
- The Energy and Resource Institute **[TERI]**, New Delhi
- DBT-IOC Bioenergy Centre, Faridabad

4.3 Some Indian Industries Active in Algal Technology

- Reliance Industries – Algal biofuels
- Tata Power, Mumbai – CO_2 mitigation and biomass production
- National Thermal Power Corporation, [NTPC] Raceway ponds
- Indian Oil Corporation, Faridabad Algae from waste streams
- Abellon Clean Energy, Ahmedabad - Remediation and biomass production

 # Some of the Data from Development in biomass valorization. EU-India collaboration on Biomass and bio-waste; Oct 28-29; Utrecht, The Netherlands [35]

4.3.1 Ethanol from refinery off-gases using a fermentation process

To achieve the twin objective of carbon capture as well as to reduce Oil import and reduction of vehicular emission, the feasibility of manufacturing of Ethanol from refinery off-gases need to be explored.

Pre-feasibility study for production of ethanol by utilizing fermentation route is being carried out for PSU refineries wherein refinery-wise Ethanol potential, CAPEX and estimated cash cost of production (CCOP) shall be assessed.

IOCL is setting up ethanol production plant of 100 MT per day capacity at Panipat Refinery by using refinery off-gases as feedstock and bio-fermentation technology from M/s LanzaTech, the USA for the first time. M/s LanzaTech is the global leader in gas fermentation technology based on Syn gas feedstock having CO, CO_2 and H_2. They have demonstrated this technology at 100,000 gallons/year scale at Bao Steel, in Shanghai, China (commissioned in November 2012) and subsequently two other demonstration-scale plants have been commissioned. Lanzatech has also started commercial production at 48 KTPA at Shougong plant in China using steel mill off-gases.

5. ADVANCED BIOFUELS

5.1 Cellulosic ethanol

Crop residues represent a large unexploited energy potential that could be harnessed by the production of cellulosic ethanol through a combination of chemical and biotechnology tools. At present, the country produces 450-500 MMT of crop residues per annum, of which~ 234 MMT is surplus **[5 & 28].** The various cellulolytic crop residues like straws from wheat, rice and sorghum, maize stalk can be a good feedstock for the production of cellulosic ethanol.

Based on funding from **Department of Biotechnology [DBT],** Government of India, the Institute of Chemical Technology **[ICT]** has developed commercial technology which has been demonstrated at India Glycol Ltd **[IGL]**, Kashipur **[Figure 13]** on continuous processing pilot plant **[34a**]**.** The process is based on a novel two-step continuous enzyme process with rapid reaction rates and reduction in enzyme dosage and reaction time resulting in more than 90 % yield of sugars from biomass. The ethanol yield is > 300 L/Ton biomass. This technology has been selected for two commercial plants of 100 KL /day capacity **(Table 5).**

Figure 13: **View of the demonstration plant of DBT-ICT for 2G ethanol at India Glycol Ltd [IGL] Kashipur [34a]**

The DBT-ICT 2G-Ethanol/2G Sugar Technology is a feed-stock agnostic process that fractionates any biomass feedstock (hardwood chips, cotton stalk, soft bagasse, rice straw, etc) into separate streams of glucose (C6), xylose (C5) and lignin. The C6 and C5 sugars produced as intermediates can be co-fermented to produce ethanol. Major and distinct features of the technology are: (a) through and through continuous flow processing from biomass size reduction to fermentation; (b) low chemical, enzyme and water consumption through recycle & reuse; (c) Low overall processing time of 18 h from feed to alcohol; (d) zero liquid discharge; and (e) possibility of using C6 and C5 sugar intermediates for making other products. The compact plant design has unique features such as advanced reactor design and separation technologies with slurry-flow rapid rate operations. The technology can be easily used at scales from 100 to 500-ton biomass/day.

Table 5: **List of Current Demonstration scale & Commercial plants being built**

Plant name	Type D/C	Status	Start-up year	Biomass type	Feedstock capacity	Product	By product
2G-Ethanol plant at India Glycols Ltd	Demonstration	Operating	March 2016	Any feedstock	10 ton/day	Ethanol (750,000 L per annum)	Lignin
HPCL, Bhatinda plant, Punjab	Commercial	Under Construction	Expected 2020	Proposed for Rice straw, cotton stalk	450 ton/day	Ethanol (100 KL)	Silica, Food grade carbon dioxide, inorganic mineral fertilizer
BPCL, Bina, Madhya Pradesh	Commercial	In the process for finalizing BEDP	Expected 2021	Proposed plant for wheat straw and soya	450 ton/day	Ethanol (100KL perday)	Food grade carbon dioxide, inorganic mineral fertilizer

Praj Industries, Pune, a large company with global sales of first-generation bioethanol plants has developed its propriety technology for cellulosic ethanol **[36]**. The demonstration plant **[Figure 14]** is a continuous one with a capacity of 3 KLPD of Ethanol-based on 12 TPD of feedstock in Daund, in Pune district. The plant started commissioning in May 2017 and it became fully operational before the end of 2017. Based on successful trials and due diligence of this technology by IOCL & BPCL, it has entered into MOU to set up 3 cellulosic ethanol plants.

Figure14: **Views of the Praj Industries demonstration plant of 2G ethanol in Daund, in Pune district [36]**

Oil PSUs are in the process of setting up 12-second generation bio-refineries having an average ethanol manufacturing capacity of 100 KL/PD under the guidance of the Ministry of Petroleum and Natural Gas (**Table 6**). These plants shall use rice straw, cotton stock and other agricultural residues. Ethanol so produced will enable India to meet its target of 20 % blending in gasoline **[37]**. These plants are:

Bharat Petroleum Corporation Ltd. Proposes to set up a Lignocellulosic Second Generation (2G) Ethanol Bio-refinery at Bina, Sagar District (Madhya Pradesh) in India based on technology provided by DBT-ICT, Mumbai. The Biorefinery will have the capacity to produce 100-kilo litres of Ethanol per day. About 2 Lakh tones (0.2 Million tons) per annum of Soya Stalk/ Wheat Straw will be used as feedstock in the plant **[18]**.

BPCL proposes to set up total three Lignocellulosic Second Generation (2G) Ethanol Bio-refineries in the states of Odisha, Madhya Pradesh and Maharashtra in India using biomass like Rice straw, Wheat straw, Soya stalk etc.

Table 6: **List of 2G Bio-refineries being set up by Oil PSUs**

Sr. No.	State	Location	No. of Plants -100 KL	Company
1	Andhra Pradesh	Godavari	1	HPCL
2	Assam	Numaligarh	L (200 KLPD)	NRL
3	Bihar	Now Muzaffarpur	1 (1O KLPD)	HPCL
4	Gujarat	Dahej	1	IOCL
5	Haryana	Panipat	1	IOCL
6	Karnataka	Davanagere	L (60 KLPD)	MRPL
7	Madhya Pradesh	Bina	1	BPCL
8	Maharashtra	Bhandara	1	BPCL
9	Odisha	Bargarh	1	BPCL
10	Punjab	Bhatinda	1	HPCL
11	Uttar Pradesh	Gorakhpur	1	IOCL
12	Uttar Pradesh	Badaun	1	HPCL

DBT has sponsored a large number of projects for the production of enzymes used in cellulosic ethanol process. DBT- Indian Oil Bioenergy Centre has developed a viable technology for cellulolytic enzymes and the scaled-up material, at 5000-litre fermenter scales, has been validated in a semi-commercial plant **[34b]**. With this development, commercial plants of cellulosic ethanol will have an additional source of enzymes. ICGEB has also developed genetically engineered fungal strains to produce cellulolytic enzymes **[34c]**.

5.2 Some Identified areas of R&D in Commercialization of Cellulosic Ethanol

- A large number of Indian institutes supported by DBT, DST, Public Sector Units and by the private sector is actively involved in further reefing the cellulosic ethanol production process to reduce the cost of production and to improve process efficiency. Some of areas of interest and collaborations are:
- Sorghum Stover based Biorefinery for ethanol and chemicals
- Low-cost Enzyme development with increased efficiency to improve hydrolysis and bioethanol yields per ton of biomass
- 2nd Generation Biofuels &Value-added Chemicals from Lignocellulosic Biomass
- Xylitol production from biomass-derived sugars
- Characterization of feedstock such as Agri-waste lignocellulosic biomass-wheat straw, rice straw, cotton stalk, soya stalk, maize Stover etc. for 2G ethanol production
- Life Cycle Analysis **[LCA]**
- Market analysis of potential products from lignocellulosic refineries [e.g. 1,4-butanediol, 2,3-butanediol, Lactic acid, Succinic acid, Adipic acid etc.]
- Development & Demonstration of upcoming technologies for optimal usage of water and/nutrients and residues from 2G Ethanol plants in agricultural fields
- Valorization of lignin

5.3 Catalytic-thermochemical Liquefaction of MSW & Biomass for anaerobic Digestion [CTL]

DBT-ICT Bioenergy Centre at Mumbai, under a grant from DBT, has developed a biomass liquefaction technology to produce Biogas/Biomethane **[34,34b].** It is a hybrid patented technology based on Catalytic Thermo-Liquefaction **[CTL]** of biomass or MSW. The technology uses a new catalyst which operates at benign conditions of the low temperature of 150°C and 15 bar pressure and claims to give an oil yield of 90% and nearly 100% of carbon recovery efficient. The oil can be used directly as a fuel in shipping or in the boiler.

Another conventional way to use the CTL-oil is to upgrade this oil to petroleum products such as gasoline and diesel by catalytic dehydration/hydrotreatment followed by cracking and distillation.

DBT-ICT has also proposed a third novel process route to produce biogas from the CTL-oil followed by purification to obtain compressed biomethane **[bio-CNG]**. The anaerobic digestion in this process is very efficient and it is claimed that the total residence time for digestion is less than 24 hours and produces 90% methane yields and is a zero solid waste technology. It is proposed to set up two plants of bio-CNG based on MSW and one based on biomass of capacity 30 TPD each in 2019.

A catalytic thermochemical process developed by Reliance Industries Ltd. (RIL), converts biomass, bio-waste, plastic waste and any organic waste into energy-rich drop-in green liquid fuel and recovers fertilizer-rich water from wet waste **[18]**. Drop-in green crude from RCAT-HTL can be processed in the existing refining infrastructure, thereby avoiding the additional investment in new infrastructure. No change is required in the engine to use RCAT-HTL derived transportation fuel (aviation fuel, marine fuel, diesel or gasoline). This environmentally sustainable process overcomes the limitations of the existing technologies and offers a green solution to the global problem of waste disposal. RIL's RCAT HTL is at advanced Technology Readiness Level and is all set for scale-up to commercialization **[18]**.

Fast pyrolysis of biomass has reached TRL 8. In India, the thermochemical catalytic process has progressed significantly and is being pursued at TERI, IIT [Mumbai] among other institutes **[38]**. The pyrolysis oil has been successfully tested for use in blending with furnace oil.

Some of the R&D areas in Pyrolysis Oil development:

1. Cost-effective [low CAPEX and low cost] production of bio-oil at the distributed level
2. Upgradation of Bio-oil to drop-in fuels
3. Hydro pyrolysis of Lignocellulosic Biomass to value-added Hydrocarbons
4. Fuels such as marine bunker fuels from waste plastics and polymers
5. Hydrothermal Liquefaction of aquatic biomass including algae.

5.4 Bio Jet Fuel

The Indian aviation sector is growing at a CAGR of 5.5 %. Presently India consumes about 6 MMT of aviation fuel which is likely to double by the year 2030 **[39].** Under the

Ministry of Science and Technology, GOI, Indian Institute of Petroleum [IIP] developed indigenous technology for production of bio-jet fuel from non-edible oil [Jatropha]. Basic technology involves Hydro-treatment of vegetable oils to deoxygenate; Isomerization to impart low temperature followed by up-gradation by hydrotreatment **[40].**

The fuel was recognized by American Standard for Testing and Material and received a patent in 2011. By 2013, it was tested in a Pratt and Whitney engine in Canada. Since then in 2018, it has been tested in civil commercial flights and in military aircraft.

Since 70% of the cost of the biofuel constitutes the feed cost and therefore if the production of these crops can be scaled up, or cheaper oils are used, the bio-jet fuel produced can cost-competitive. In future, it is planned to produce bio-jet fuel from used cooking oils **[UCO].** A litre of used cooking oil can yield 850-950ml of biodiesel **[40]**. India's Food Safety and Standards Authority [FSSAI] has introduced regulations from July 1, 2018 that bar commercial eateries from reusing cooking oil, and instead encourages them to pass it on to biofuel developers and this quantity can be huge as annually, about 23 million tons of cooking oil is consumed in India **[41]**. The conventional jet fuel demand in India is 6-7 million tons, up to half of that can be technically substituted by bio-jet fuel, and about a third of this half can be obtained from used cooking oils [UCO].

5.5 Biofuel for Aviation – Sustainable Indigenous Development

Used cooking oils and non-edible oils valorization for bio-aviation fuels production have immense potential, with economic, societal and environmental benefits. CSIR - Indian Institute of Petroleum, Dehradun (CSIR-IIP), a research lab of the autonomous Council of Scientific and Industrial Research under the Ministry of Science and Technology, Government of India, has developed and demonstrated technology for production of renewable green aviation fuel from non-edible oils and waste oils.

The demonstration plant is based on a patented catalyst and process by CSIR-IIP produces bio-aviation fuel which is more energy-efficient, economical and environment-friendly (<10 ppm sulfur, reduced NOx and COx), meets ASTM D 7566 and ASTM D1655 (after blending with fossil-derived Aviation Turbine Fuel) as well as the IS 17081:2019 specification for Bio- ATF **[18].**

The infrastructure for a CSIR-IIP Bio-jet plant (**Figure 15**) is very similar to a conventional Hydrocracker unit. Till March 2019, CSIR-IIP has produced approximately 2600 litres of Bio-Aviation fuel. This has been supplied to Spicejet Ltd. for India's 1st Biofuel flight on August 27, 2018 (at 25% blend in one engine), and to Indian Air Force (IAF) for testing.

Figure 15: **Demonstration-scale plant established to produce bio-aviation and renewable diesel fuels at IIP**

Some of the R&D areas in Bio-jet fuel development are:

1. Process development for alcohol to bio jet fuel
2. Process development for microbial including algal oil to bio-jet fuel
3. Process development for castor Oil to bio jet fuel
4. Process development for lignin to bio-jet fuel

Synthetic biofuels via the gasification process still must reach large scale demonstration. However, IISC, Bangalore has developed a pilot-scale process to oxy-gasify agricultural residues into high quality, low tar Syngas **[42]**.

Biomass Gasification R&D areas

1. Techno-commercial process for hydrogen & Syngas Production from Biomass
2. Syngas clean up and tar utilization
3. Syngas to methanol

5.6 Biomass to Fungible fuels

The CRI/SHELL/ **IH2** plant technology (**Figure 16)** involves four primary processes, sizing and drying up to 10–30 wt.% moisture, hydrodeoxygenation, fixed–bed hydrotreater and finishing. The SHELL R&D Centre at Bangalore has successfully established a 5 TPD pilot of this technology. The minimum commercially viable scale of this technology is expected to be from 500 to 1000 TPD of biomass. A 500 TPD plant will produce about 200 TPD of renewable drop-in advanced Biofuel **[43].**

Figure 16: **CRI/SHELL demonstration plant of IH2 technology in Bangalore, India [43]**

6. HUMAN RESOURCE DEVELOPMENT

Bioenergy-Awards for Cutting Edge Research (B-ACER): The Department of Biotechnology, Govt. of India and the Indo-US Science and Technology Forum (IUSSTF) have partnered for a dynamic visitation program called The Bioenergy-Awards for Cutting Edge Research (B-ACER) focusing on the capacity building in the frontier area of Biofuel and Bioenergy. The B-ACER Program has successfully completed one year and currently, the second batch of 2017 B-ACER awarded Interns and Fellows have commenced their Internships/ Fellowships at respective U.S. Universities. So far 11 Interns and 9 Fellows have been benefited from this Program including training for 6 Internships and 2 Fellowships during 2017 **[34].**

6.1 Main Indian Government Ministries and agencies for Biofuel Development

- **Ministry of New and Renewable Energy [MNRE]:** Funding of projects in the renewable area like wind, solar, biomass gasification, biogas etc.
- **Ministry of Petroleum and Natural Gas [MoP&NG]:**

Work allocated to MoPNG pertaining to Biofuel development is as follows **[20]**:

a) Overall coordination concerning biofuels
b) National Policy on Biofuels
c) Marketing, distribution and retailing of biofuels and its blended product
d) Policy/scheme for supporting manufacturing of biofuels
e) Blending and blending prescriptions for biofuels including laying down the standards for such blending
f) Setting up the National Biofuel Development Board and strengthening the existing institutional mechanism
g) Research, Development and Demonstration on transport, stationery and other application of biofuels

- **Ministry of Agriculture:** New feedstock development, estimation of biomass availably in different regions Research on existing and new feedstock
- **Ministry of Science and Technology [DST, DBT and DSIR]:** Funding R&D programmes in Advanced Biofuels; biotechnology interventions; algae

production; valorization of by-products. DBT under Clean Energy Development through Mission Innovation programme has taken up a large number of projects for the production of advanced biofuels.

- **Ministry of Road Transport and Highway; [MoRTH]:** Specifications of transport biofuels and their application; field trials and emission monitoring
- **Ministry of Environment and Forest [MoEF]:** Notification of Biofuel specifications; handing protocols

Apart from these Ministry of Railways; Ministry of Power, Ministry of Rural Development; Ministry of Defense are also actively supporting bio-fuel and bio-energy programmes.

6.2 R&D Initiatives of the Department of Biotechnology [DBT] in Advanced biofuel Development

The Department of Biotechnology **[DBT]**, Government of India has made significant efforts in the Second-Generation advanced biofuels, with an overall aim to make available cost-effective biofuel technology by improving feedstock / developing new feedstock, improving biofuel production technologies, developing enzymes / microorganisms for improved yield of biofuels and developing value-added materials from by-products **[34]**.

The Energy Bioscience Division of the Department of Biotechnology has been promoting innovative research in Biofuel area through Centres of Excellence, extramural projects and fellowship schemes. Capabilities have been developed in systems and synthetic Biology with demonstrated laboratory work. Technologies/ products developed at DBT-Bioenergy Centers are taken forward for scale-up/ demonstration at pilot scale. The salient achievements are summarized below:

DBT-BIOENERGY RESEARCH CENTRES

Department of Biotechnology is supporting Five DBT-Bioenergy Centers with specific goals and targets in accordance with the National Biofuel Policy. Recently on September 2018, 5th Bioenergy Centre has been set up at The Energy and Resource Institute [TERI] with 3 other partner institutions [IITG, IARI and Transtech Green Power Private Limited] which would focus on integrated production of Advanced Biofuels and Bio-commodities. All the DBT research centres have specified mandates and work in a coordinated manner **[Figure 17]**

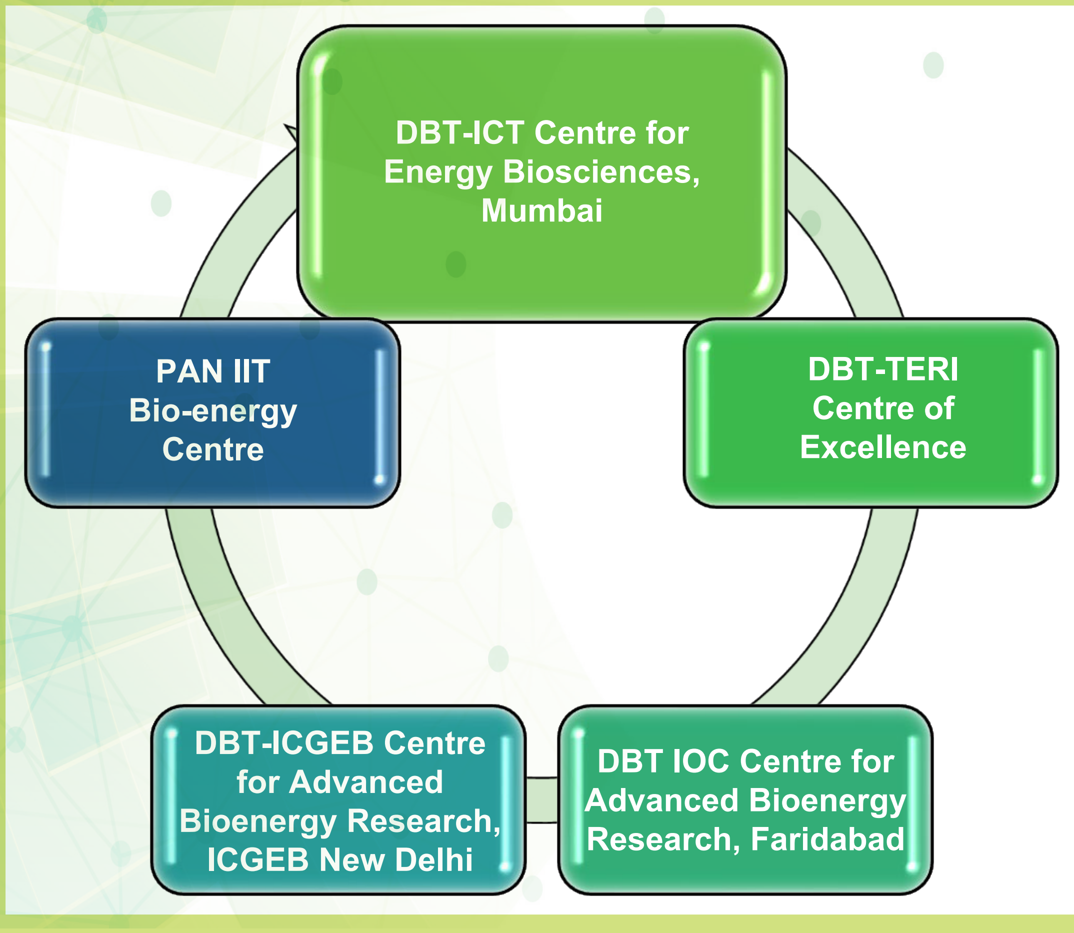


Figure 17 **Department of Biotechnology: Energy Biosciences Centres of Excellence [34].**

DBT-ICT CENTRE FOR ENERGY BIOSCIENCES, MUMBAI

This Centre for R&D and technology translation in biofuels and bio-refineries completed 10 years of its operation **[34a].** Besides making significant strides in the area of Waste-to-Value Technologies, the DBT-ICT Centre added two major milestones in its journey in the year 2017-18. The first of-its-kind robotic platform explorer™ G3 Workstation for High Throughput microbial & enzymes screening and molecular biology routines was installed at the Centre in partnership with Perkin-Elmer, India/ Germany/ USA, the facility has resulted in accelerating the development process in enzyme and microbial innovations alongside synthetic biology involving multiple microbial chassis for various target products.

The DBT-ICT Centre also successfully scaled up algal cultivation in its newly designed cost-effective photobioreactors. The DBT-ICT Centre has also been able to package the algae cultivation with an effective biorefinery process design that is able to derive multiple products from the on-shore marine produce.

The major focus during the year 2016-19 has been on the demonstration of technologies to convert waste to energy, biofuels and value-added products. A major project for Barapullah Sewage Treatment technology demonstration being commissioned using the Microalgae Photobioreactor technology developed at the DBT ICT Centre for a capacity of 1 million Liters/day. This Centre has also developed Carbon to Liquid technology **[CTL]** for the conversion of MSW to bio-oil and then to biogas by anaerobic digestion. Large pilots of 39 TPD capacities are being built.

This Centre has developed and commercialized its unique technology for 2G ethanol production.

DBT-IOC CENTRE FOR ADVANCED BIOENERGY, FARIDABAD

DBT-IOC Centre successfully developed and scaled up its enzyme technology at 5000 lit fermenters. The cost-effective enzyme has good hydrolytic efficiency and this material was tested at 1MT/ Day pilot plant of 2G ethanol. The enzyme showed comparable performance when compared to a commercial enzyme.

The Centre has installed the world's first pilot plant based on DBT-IOC & LanzaTech technology for conversion of CO and CO_2 to high-value Lipids [Omega 3 Fatty Acids]. Data is being generated in the pilot plant trials [100-litre scale] to optimize the cost/ economics.

The Centre has installed and commissioned India's first continuous steam explosion pilot plant & extractor system. This 300 kg/day pre-treatment pilot facility shall be used for developing process technology for 2G ethanol agnostic to feedstock [cotton, mustard stalk etc.]. Centre has filed 8 patents and published more than 25 papers.

DBT-ICGEB CENTRE FOR ADVANCED BIOENERGY: RESEARCH, ICGEB

DBT-ICGEB is the third Bioenergy Centre of DBT set up at International Centre for Genetic Engineering and Biotechnology **[ICGEB]**, New Delhi. The research focus of this Centre is to use molecular tools to engineer microbes, cellulolytic enzymes, algae for enhanced biofuel production **[34c].** The salient achievements of this Centre are:

Enzyme Development: The efficiency of cellulase enzymes, developed using engineered fungal strain also validated from the third party. This Centre utilizes its expertise in synthetic biology to engineer microbes and yeast for application in advanced biofuel production.

The Centre is quite advanced in genetic engineering of algal strains for efficient production of biofuels.

DBT PAN-LLT CENTRE FOR BIOENERGY [VIRTUAL CENTRE OF 5 IITS]

The DBT Pan-IIT Centre for Bioenergy, a virtual Centre of Excellence spread across five different Indian Institute of Technology [IIT][IIT, Bombay; IIT, Kharagpur; IIT, Guwahati; IIT, Roorkee and IIT Jodhpur] **[34d].**

The Centre has been involved in developing novel catalysts and enzymes for the conversion of algal oil to hydrocarbons and utilizing lignocellulosic biomass for production of biofuels.

This Centre has developed a trained human resource for continued research and development in advanced Biofuels.

TERI BIOENERGY RESEARCH CENTRE

The fifth bioenergy research Centre was established by DST at The Energy & Resource Institute (TERI) in 2018 at New Delhi. This Centre is supported by agricultural research Institute, IIT Guwahati and ONGC Energy Centre. This Centre shall develop Advanced Biofuels technologies and study their economic viability. TERI has already developed bio-hydrogen production at 10,000-liter scale. This Centre will also work on commercial scale micro-algal technologies, production of bio-hydrogen from low value organic streams, pyrolysis of biomass to produce fuel grade hydrocarbons etc. This Centre has also focused on development of bio commodities to value add the biofuels and the gasification technologies **[34e]**.

MUNICIPAL SOLID WASTE [MSW] TREATMENT TECHNOLOGY

The Department of Biotechnology has supported various Demonstration and R&D projects under the **Swachh Bharat Mission** across the country for developing and demonstrating the technologies for Sustainable utilization of MSW/ Biodegradable waste for a cleaner environment as well as the generation of biogas, bio-oil, bio-CNG and bio-methanol. A total of twelve Waste to Energy projects were initiated to develop/demonstrate a novel and viable technologies for sustainable utilization of Municipal solid waste for a cleaner environment. The three demonstration projects being commissioned with a focus on the modern and scientific conversion of MSW/ Biodegradable waste management include:

"High rate bio-methanation of organic fraction of MSW for the generation of biogas-based power and bio-manure" by IICT, Hyderabad in collaboration with HIMSWL to convert 10 tons/ day of organic solid waste into biogas and bio manure.

Government of India has given the responsibility to Department of Biotechnology [DBT], Ministry of Science & Technology to coordinate the Indian MI activities.

7. ACCELERATING CLEAN ENERGY INNOVATION THROUGH MISSION INNOVATION

Mission Innovation **[MI]** is a global initiative of 24 countries and the European Union to dramatically accelerate global clean energy innovation. This initiative will dramatically accelerate the availability of the advanced technologies that will define a future global energy mix that is clean, affordable, and reliable **[Figure 18].** India is an active member of the Mission Innovation initiative and **DBT** is coordinating National efforts in collaboration with DST and other line ministries **[44].**

Figure 18 **Mission Innovation: Accelerating Clean Energy Innovation: the objectives**

India has actively engaged in global calls [MI Challenges], to action aimed at accelerating Research, Development, and Demonstration [RD&D] for Clean Energy Development. India is an active participant in all the eight MI challenges and is a co-lead in three challenges [Smart Grids, Off-Grid access to Electricity and Sustainable Biofuels]. In 2018, India has been actively focusing and working, on key Mission Innovation tasks of Information sharing, Analysis and Joint Research, Business and Investor Engagement and being part of the MI Ministerial Planning Team. An International Conference on Sustainable Biofuels was organized with the active participation of Biofuture platform in 2018. The New Delhi declaration was released for sustainable Biofuels, highlighting intent of MI countries to work in collaboration mode in development and deployment of sustainable biofuels on commercial scale by sharing best practices.

The key activities under the Sustainable biofuels Initiatives in India include:

- **The Funding Opportunity Announcement [FOA] for US$ 5.5 Million** of public funding to support R&D projects focusing on Sustainable Biofuels, Innovation Challenge was advertised and is now under final review stage of the selection process. A total of 14 Sustainable Biofuels projects under the FOA call has been recommended for funding disbursement **[44].**
- **Analysis and Joint Research Support**: India being an active member of AJR sub-group, has actively participated in the design, schedule, conduct and scoring of ongoing assessment of the Innovation challenges as set by the Mission Innovation Secretariat. Based on the recommendations from the AJR Co-lead meeting held in October in Brussels, an action plan has been devised and has been submitted, focusing on more engagement, communication, enhanced leadership and wider collaboration amongst the SBIC members.
- **Supporting Public-Private Partnerships and Innovation in India**: Clean Energy International Incubation Centre **[CEIIC]**: The Department of Biotechnology **[DBT]** & BIRAC have joined hands with Tata Trusts, to set up the first "Clean Energy International Incubation Centre **[CEIIC]**" in Delhi under "Mission Innovation". The incubator will support a wide spectrum of clean energy innovations and the Centre is open to innovators and start-ups from MI countries ensuring synergy in fund flows and more concerted effort in supporting the growth of new and clean energy solution internationally.
- **Clean Energy Investments and Technology: Innovation in India**: IEA and the Ministry of Science and Technology, Govt. of India, have proposed a joint project focused on the assessment of Indian R&D investments in clean energy

development by Public and Private sector in India. The project is conceived to provide support to India's action: under the Mission Innovation initiative, in cooperation with key relevant national stakeholders and government entities.

DBT has participated in National Swachh Bharat Mission **[45]** through supporting research projects on the generation of energy from waste. A total 8 waste to energy projects has been initiated to develop/demonstrate a novel and viable technologies for sustainable utilization of Municipal Solid Waste (MSW) for the cleaner and pollution-free environment as well as generation of the energy.

India is also an active member of Biofuture Platform which is an action-oriented, country-led, multi-stakeholder mechanism for policy dialogue and collaboration among 20 leading countries to accelerate development and scale-up deployment of modern sustainable low carbon alternatives to fossil-based solutions in transport, chemicals, plastics and other sectors. Based on inputs provided by 20-member countries and partners a report on Creating Biofuture for low carbon bio economy has been developed and released on 10th December during High-Level meeting at COP 24 held in Katowice, Poland. More details about Biofuture Platform may be seen at website **http://biofutureplatform.org**.

8. CONCLUSION AND REMARKS

The Government of India attaches prime importance to the development of renewable and sustainable energy sources. The declaration of National Biofuel Policy in 2009 had set the pace and direction of future bioenergy and biofuel programme in India. With the learning's from the implementation of biofuel policy, the Government of India has announced New National Biofuel Policy in 2018. This document lists the strategies and policy interventions like assured market, competitive pricing and financial incentives for large scale commercialization of first-generation as well as advanced second-generation biofuels so as to achieve the indicated targets of blending 20 % biofuels in transport fuels. Steps have been taken to establish 12 large 2G ethanol plants based on available agricultural residues. The feedstock for production of liquid biofuels has been widened to include grains unfit for human consumption, agricultural residues which are not used for animal fodder, Municipal Solid wastes, algal and waste gas fermentation. These policy initiatives have already shown effects and the availability of ethanol for gasoline blending is expected to double in the current year.

India is committed to clean energy innovation with the objective to make it widely affordable, reliable and secure energy supplies. India is also committed to long term global climate goals as agreed in Paris agreement.

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