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# Biomass Gasification Status in India

IEA Bioenergy: Task 33

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Cover photo source : MNRE bi-monthly news letter, June, 2018
Bamboo biomass gasification plant installed by GP Green Systems at ITC, Mangaldoi, Assam


# Biomass Gasification Status in India

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## 1. Introduction

Transition of world energy landscape is currently underway, with a major shift from fossil fuels to renewable sources. India is a part of global renewable energy transition and currently it stands at 4th position in the world in terms of installed renewable energy (RE) capacity. India's installed renewable energy capacity has gained pace over the past few years, posting a CAGR of 17.33% between FY16-20. On 12th August 2021, the Union Ministry of New and Renewable Energy (MNRE) announced that India has achieved the milestone of installing 100 GW of renewable energy capacity. MNRE has further informed that around 50 GW of renewable energy is currently under installation and 27 GW is under tendering. India has ambition to install 450 GW of renewable energy capacity by 2030[1].

India is an agrarian economy with agriculture being the primary source of livelihood for about 58% of India's population. India generates vast quantities of biomass that can be used as feedstock for modern bio-energy generation. Large number of biomass gasification plants was set up in India during 1995-2010 for catering decentralized energy requirements utilizing the locally available biomass resources. Biomass gasification based energy has been used in India for rural electrification and captive energy requirements of micro, small and medium enterprises.

Biomass gasification technology has not been exploited for production of transportation fuels and chemicals in India. Currently small number of small and medium scale biomass gasification systems is being set up every year in India for off-grid rural electrification and captive energy requirements. However, large scale grid connected biomass gasification power plants are not being considered due to economic reasons.

This report covers India's energy scenario, bioenergy promotion and potential in India, technologies being pursued for bioenergy deployment in India, development and dissemination of biomass gasification technology in India, major organizations associated with development of biomass gasification technology in India and biomass gasification system technology providers and manufacturers in India. This report also covers some of the successful biomass gasification case studies, recent initiatives on deployment of biomass gasification for advanced biofuels generation and some of the other notable bioenergy related initiatives in India.

## 2. India's energy scenario

India is one of the fastest growing economies in the world. Indian economy is expected to grow steadily despite temporary setbacks due to the COVID pandemic. Currently India is sixth largest economy by nominal GDP, behind the United States, China, Japan, Germany and United Kingdom. In terms of purchasing power parity, India is the third largest economy, behind China and the United States. However, India continues to be a low income economy, with per capita income less than the half of the world average. With half of India's population under the age of 25, India's economy has the potential to grow very rapidly[2]. India is expected to be one of the top three economic powers in the world over the next 10-15 years, backed by its robust democracy and strong partnerships[3].

India is currently the world's third largest energy consuming country. Due to increased urbanization and industrialization, India's energy consumption has been more than doubled since 2000 and it has contributed to more than 10% of the increase in global energy demand during the same period. In absolute terms, India's primary energy consumption has increased

from 441 million ton oil equivalent (MTOE) in 2000 to around 930 MTOE in 2019[2].

Since 1990, India's primary energy demand has been largely met by using coal, oil and biomass. These three sources in aggregate contribute to about 80% of India's energy requirements. Use of coal in India's energy mix is nearly tripled between 2000 and 2019, accounting to about half of the primary energy demand growth. Contribution of coal in energy mix has increased from 33% in 2000 to 44% in 2019. Use of traditional biomass, primarily fuel wood but also includes animal waste and charcoal, was second largest energy source in India in 2000 after coal. But the share of traditional biomass in India's energy mix was reduced from nearly 25% in 2000 to around 12% in 2019. This is largely due to Government of India efforts to improve access to modern cooking fuels such as LPG to rural communities. Demand for oil in India has more than doubled since 2000 as the result of increasing vehicle ownership, commercial road transport use and promotion of LPG for cooking application. But the share of oil in India's energy mix remains stable at around 25% from 2000 to 2019. Share of different fuels in India's primary energy mix in 2019 is given in fig. 1[2].

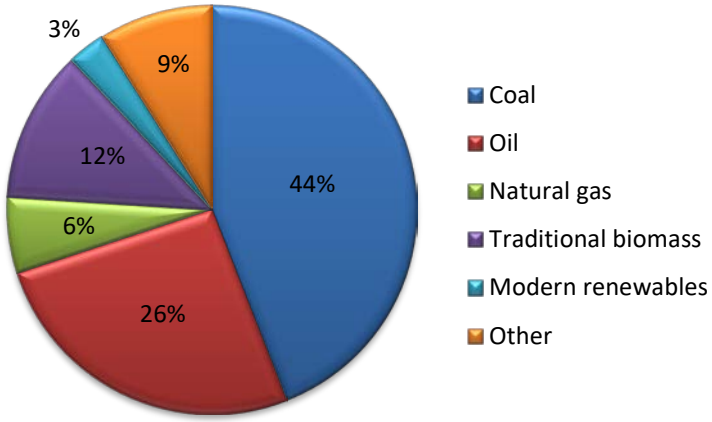


*Figure 1 : Share of different fuels in India's primary energy mix in 2019[2]*

Due to an expanding economy, there is huge potential for further growth in energy demand in India. India is expected to be main driver for global energy demand growth over the next two decades, accounting for nearly 25% of growth. By 2040, India's power system is expected to surpass European Union and becomes world's third-largest, and it will be second largest growth market for renewable energy after China[2]. As per the BP energy outlook 2020, India's primary energy demand is expected to be more than doubled between 2018 and 2050, with share of India's primary energy in global energy demand rising from 5.9% in 2018 to 12% in 2050[4].

## 2.1 Indian power sector

India's power sector is undergoing significant transformation that has redefined industry outlook. India's electricity consumption growing faster than the total energy demand and it has been nearly tripled over the last two decades. During the same period, installed power generation capacity has grown more than 3.5 times[2]. As on 31.07.2021, total installed capacity of power generation in India is around 385 GW with around 61% from thermal, 12% from large hydro(>25 MW), 1.8% from nuclear, and 25% from renewable energy sources(RES). RES includes small hydro (≤25 MW), bio-power, solar and wind energy. Though the installed capacity of RES during 2020-21 was around 25%, but the share of renewable energy in electricity generation during 2020-21 was only around 11%[5].

India's installed RES capacity as on 31.07.2021 is 98.9 GW. Break up of installed RES as on 31.07.2021 is shown in fig 2. Combined solar and wind energy contribute to around 84% of the installed RES. Biomass and waste energy account for nearly 11% of installed RES[5]. India's installed RES has increased at a fast pace over the past few years, posting a CAGR of 17.33% between FY16-FY20[6].

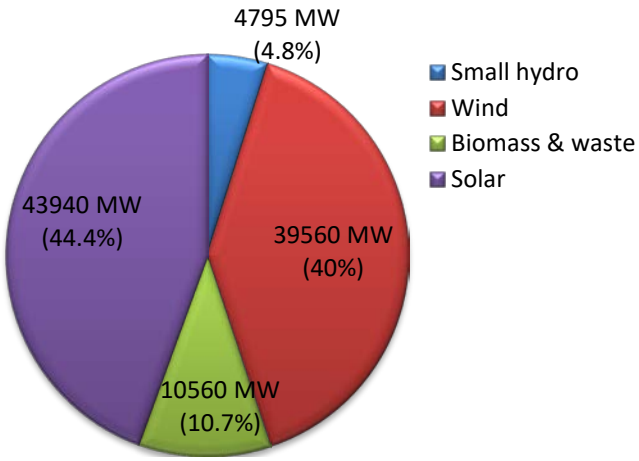


*Figure 2 : Breakup of installed renewable power generation capacity as on 31.07.2021*

As per the estimates, India has a solar power potential of ~750 GW, assuming 3% wasteland is made available; wind power potential of more than 300 GW at a hub height of 100 meter, bio-energy potential of 25 GW and small hydro potential of 20 GW. Further, there exist significant potential for solar energy for distributed applications such as hot water requirement for residential, commercial and industrial sector and biogas to cater cooking energy requirements in rural areas. Government of India has set an ambitious target of adding 175 GW of renewable power by 2022, which includes 100 GW from solar, 60 GW from wind, 10 GW from biomass and 5 GW from small hydro power[6]. India has plans to increase installed RE capacity to 450 GW by 2030[1].

## 2.2 India's carbon emissions

India's $CO_2$ emissions are the third highest in the world with 2.5 Giga Tons (GT) emissions in 2019[7]. But India's per capita $CO_2$ emissions are 60% lower than the global average. India's energy sector related $CO_2$ emissions are more than quadrupled since 1990, with the major sources of emissions growth being from power generation, industry and transport sectors. Emissions growth from the power generation over this period has been nearly twice to the total emissions from all sectors in 1990. After power generation, the next highest emitting sector is industry. India provides more than 6% of steel production globally, and iron and steel sector is the largest industrial subsector in terms of emissions. India generates around 8% of global cement production, and this is the second largest emitting industrial sub-sector. In the transport sector, road transport is the largest contributor with more than 45% of emissions comes from trucks. India has plans to reduce Carbon emissions intensity of GDP by 33-35% by 2030 from 2005 levels, as part of its commitments to the United Nations Framework Convention on Climate Change (UNFCCC) adopted by 195 countries in Paris in 2015[2].

## 2.3 India's quest for energy security

India is one of the fastest growing economies and the third largest consumer of primary energy in the world after the US and China. Domestic production of fossil fuels in India has not been able to keep pace with demand, which has resulted in rapid rise of imports over the past two decades. India currently imports around 40% of its primary energy. India's import dependency of coal, oil and natural gas in the year 2019 are around 32%, 85% and 55%, respectively[7].

Continuous reliance on imported fuels is expected to create vulnerabilities to price cycles and volatility as well as possible disruptions to supply chain. India has been focusing on improving energy security by reducing import dependence, with a target of decreasing fossil fuels use by 10% from current levels by the year 2022, and diversifying energy basket. India's five-pronged strategy to reduce oil imports includes promoting energy efficiency and conservation measures, giving thrust on demand substitution, promoting biofuels and other alternative fuels/ renewable energy sources, increasing domestic production of oil and gas, and refinery process improvements[8]. The growing concern about import dependence for fuel supplies in tandem with environmental pollution issues are driving the development of alternative fuels that have superior environment benefits and can be economically competitive with fossil fuels.

## 3. Bioenergy promotion in India

Among the portfolio of renewable energy alternatives that are available, Government of India (GoI) has realized the potential and role of biomass energy in the Indian context and hence has initiated a number of programmes through MNRE for promotion of efficient technologies for its use in various sectors of the economy to ensure derivation of maximum benefits. For efficient utilization of biomass, MNRE has implemented bagasse based cogeneration in sugar mills and biomass power generation under biomass power and cogeneration programme[9].

To encourage application of technologies for generation of advance biofuels, GoI has revised national biofuel policy in 2018 to utilize, develop and promote domestic feedstock and its utilization for production of biofuels thereby increasingly substitute fossil fuels while contributing to National Energy Security, Climate Change mitigation, apart from creating new employment opportunities in a sustainable way. This policy encompasses various biofuels which can be used as transportation fuel or in stationery applications that includes bio-ethanol, bio-diesel, bio-CNG, advanced bio-fuels and drop-in fuels[10].

## 4. Resources and bio-energy potential in India

India is an agrarian economy with agriculture being the primary source of livelihood for about 58% of India's population. India generates vast quantities of organic wastes that can be used as feedstock for modern bio-energy generation. Currently, only a small fraction of this sustainable feedstock has been utilized.

As per the joint report of TIFAC and IARI, total estimated annual dry crop residue generation in India is around 682.61 Million Tons (MT) from the selected eleven crops in three seasons. Around 59% of crop residue is generated in Khariff season and nearly 39% is generated in Rabi season. After different usages of crop residue by farmers, there is still significant surplus residue left, which can be used for biofuel production. It was estimated that annually around 178 MT surplus crop residue is available, which is approximately 26% of the overall identified crop residue generation. Maximum surplus crop residue was rice, which account for around 44 MT[11]. Estimated power generation potential using surplus biomass is around 25 GW. Burning of crop residues in Haryana, Punjab, Rajasthan and Uttar Pradesh states is one of the primary

causes of the air pollution crisis every year in northern India, with as much as half of the particulate pollutants in Delhi attributable to this burning.

As the world's second-largest producer of sugar cane, India also produces vast quantities of bagasse, an energy-rich by-product of sugarcane processing. Annual bagasse production in India is around 87 MT[12]. Nearly 14 GW power could be generated through bagasse based cogeneration in India[9].

Organic waste is another source of potential feedstock for bioenergy generation in India. It constitutes 40-50% of the 60 MT of Municipal Solid Waste (MSW) generated annually in urban areas of India. It is projected that annual MSW generation in India will reach to 100 MT by 2040. Out of total MSW, currently about 65-70 per cent of the waste gets collected and only 19-20 percent of this waste is processed and treated. Energy generation potential of industrial and urban waste in India is 5.7 GW[13].

Forest wastes which include residues from wood processing and logging activities is another potential feedstock for bioenergy generation in India. Industrial wastes such as rice husk, peels etc. could also be used for production of biofuels in India.

## 5. Technologies being pursued for deployment of bioenergy in India

Biomass based energy generation has been gradually increasing in India and variety of biomass residues such as agro-residue, shells, husks, de-oiled cakes, wood etc. are being used for biofuels generation. Technologies being pursued for deployment of bioenergy in India include combustion (Rankine Cycle), bagasse-based cogeneration, non-bagasse based cogeneration, gasification (Otto Cycle), and other advanced biofuels technologies such as cellulosic ethanol, trans-esterification and biomethanation. Around 11 GW of biomass power and cogeneration plants were set up in India, mainly for catering local heat and power, using biomass combustion and gasification technologies. Bagasse based co-generation plant which uses direct combustion accounts for nearly 8 GW of power generation in India[9].

Currently, there are two operating cellulosic ethanol plants in India - one pilot and one demonstration plant - with combined capacity of 1.75 million litres per year of ethanol. There are several other cellulosic ethanol plants under development. GoI has been focusing to increase the production of bio-diesel in India. Nameplate capacity of biodiesel production in India was around 670 million liters in 2019[14].

Cumulative total of 50.28 Lakh small size biogas plants and 389 medium size biogas plants for generation of electricity or use of biogas for various thermal and cooling applications were set up in India. Cumulative capacity of medium size biogas plants in India is around 9 MW[9]. Around 190 large scale biogas plants with cumulative capacity of 280 MW are operational in India. Further, around 90 biomethane/ compressed biogas plants were set up in India[15]. Sustainable Alternative towards Affordable Transportation (SATAT) scheme was launched by GoI envisages production of 15 million metric tons (MMT) of CBG by 2023, from 5000 Plants[16].

## 6. Development and dissemination of biomass gasifiers in India

Development and dissemination of biomass gasifiers in India was started in the early 1980s. During this period, a number of research organizations commenced efforts to examine different aspects of biomass gasifier use as well as to develop indigenous gasifiers and gasifier based

systems. Much of the initial work centered on small wood based gasifiers that would be useful for applications such as powering irrigation pump sets. This focus was motivated by thinking within the Department of Non-conventional Energy Sources (DNES, now MNRE) that it would be beneficial to utilize renewable energy sources to provide power for irrigation pumping[17].

The organizations that were forerunners in terms of the efforts to develop bioenergy through gasification based systems are given below[17].

- Indian Institute of Science (IISc) : With financial support from the Karnataka State Council for Science and Technology, a research group at IISc initiated research on biomass gasification based systems in 1981.
- Jyoti Solar Energy Research Institute (JSERI) : Researchers at JSERI developed a 5 hp biomass gasifier in 1980s that was suitable for coupling to a diesel engine that in turn could power irrigation pump sets. In 1984, JSERI changed its name to Sardar Patel Renewable Energy Research Institute (SPRERI).
- The Energy and Resources Institute (TERI) : Researchers at TERI were first trained on biomass gasifiers in 1982. TERI's Field Research Unit constructed a 5 hp gasifier by 1984. These efforts were funded by TERI's internal resources, with institute providing the hardware components and manpower.
- Indian Institute of Technology (IIT), Bombay : A group at the IIT Bombay realized the need for appropriate testing facilities to support the nascent biomass gasification efforts in the country, a testing laboratory was set up at IIT Bombay with funding from DNES.
- IIT Delhi : IIT Delhi worked on biomass characterization in the early 1980's.
- Other institutes such as Punjab Agricultural University, Ludhiana and Nimbkar Agricultural Research Institute, Phaltan were also commenced work on biomass gasification.

The DNES launched its first major national initiative under biomass gasifier programme in 1987. The initiative was intended to give an impetus to biomass gasification efforts in the country. Demonstration of large number of small scale gasifiers in rural areas was one of the key activities. Standard ratings of 5 hp (3.73 kW) and 10 hp (7.46 kW) were taken up for irrigation pumping while decentralized power generation covered the range of 3kW to 100 kW of electrical output. The program dealt with field trials and technology demonstration based on a generous subsidy mechanism to promote end users to experiment and get familiar with the technology while simultaneously providing constructive feedback for further development. The cost sharing covered the total cost of the gasifier sub-systems and part of the cost of the diesel engine pump set/gen set[18]. Users contributed between 20 to 50% of total capital cost of the system. Higher subsidy was provided for irrigation pump set applications[17].

The DNES indentified six manufacturers as potential suppliers under this program but only three of these eventually supplied gasifiers. These were: M/s Ankur Scientific Energy Technologies Pvt. Ltd., Gujarat with its own technology; M&M Engineers and Fabricators, Bangalore, Karnataka (using the design licensed by Indian Institute of Science), and Associated Engineers Works (AEW), Tanuku, Andhra Pradesh (using design licensed by SPRERI in Gujarat)[17].

The subsidy based scheme was quite successful in setting up around 1200 gasifier systems in the field with major fraction of these being for irrigation water pumping. The system configuration was wood gasification system coupled with diesel engine to operate on dual fuel mode. But an evaluation conducted in early period of 1993 indicated that quite number of installed gasifiers were not functional and had severe limitations in terms of (i) life of the gasifier reactor, (ii) cumbersome operation, (iii) tar problem hampering engine operation

etc.[19]. It was recognized that the generous cost sharing mechanism resulted in manipulation of the program to acquire gasifier systems solely for getting subsidized diesel engine pump sets/ gen sets[18]. Thus this was not considered a resounding success. However, these early examples of transfer of technology from research institutions to manufacturers provided immense lessons learnt[19].

Based on the experience gained during the first phase, DNES modified biomass gasification dissemination program in the early 1990s. In the modified scheme, subsidy levels were substantially reduced, and in place of percentage of the capital cost subsidy given earlier, fixed subsidy that varied based on gasifier ratings and applications was implemented. Further, diesel engines were not subsidized anymore; but the government widened the biomass gasification applications that would eligible for subsidies[17]. Further, gasifier development and dissemination was also supported by other bilateral and multilateral agencies also. Gasifeirs have found utility in a range of industries for thermal applications across the country[19].

In the meantime, DNES was converted to full-fledged Ministry which came to existence in 1992 and named as Ministry of Non-Conventional Energy Sourcses(MNES). The Ministry was renamed as Ministry of New and Renewable Energy (MNRE) in October, 2006[9].

MNRE supported four Action Research Centres (ARCs) to catalyze and coordinate R&D in various areas such as biomass characterization, technology modification, cost reduction etc. The areas of specialization of various ARCs area given below[19]:

- IIT, Delhi : (i) biomass characterization, and (ii) development of process technology packages
- IIT, Bombay: (i) product development and research, (ii) technology modification, (iii) testing and instrumentation, and (iv) standardization and development of procedures and methods, quality assurance criterion and cost reduction.
- IISc, Bangalore: (i) basic research in biomass gasification for non woody biomass materials, and (ii) up-grading and scaling-up wood based systems
- Madurai Kamaraj University: (i) Field evaluation and testing, (ii) monitoring, revalidation and training, and (iii) development of application packages including implementation

The institutions that had begun work on gasifiers in the area of technology design, development applications and testing in the early 1980 were IISc, TERI, IIT, Bombay, and Delhi; SPRERI; Punjab Agricultural University, Ludhiana; and Nimbkar Agricultural Research Institute, Phaltan.

Efforts towards development of reliable industrial package for both power generation and thermal application were initiated in the later period of the year 2000. In the power generation sector, the emphasis was shifted from dual fuel to pure gas engine mode in order to compete with the grid costs as the fossil fuel prices was increased. Gas engine to operate with 100% producer gas as a fuel was not commercially available. Some of the research groups carried out R&D to operate engines on producer gas. Subsequently, indigenous gas engines operating with producer gas as fuel were developed. Primary reason for substituting fossil fuel (diesel, light diesel oil, furnace oil etc.) in the thermal application was due to increased fossil fuel cost. Different biomass gasification based thermal applications from low temperature driers to high temperature kilns, furnaces, and other heat treatments were attempted[21].

Most of the biomass gasification based systems technology designing and development has happened with the support of the GoI. MNES, now MNRE, has remained the main funder of biomass gasifier R&D in the country and also its deployment through subsidy program. It has

supported 5 gasifier action research projects (GARPs) at IIT, Delhi and Bombay; Indian Institute of Science, Bangalore; Madurai Kamaraj University, Madhurai and Sardar Patel Renewable Energy Research Institute (SPRERI) in Vallabh Vidyanagar, Gujarat during the earlier part of the decade (2000-2010). The main features of the GARPs are given in Table 2[19].

*Table 1: Main features of the gasifier action research projects (GARPs)*

**Main features of the GARPs :**

- Basic and applied research, and design and development of biomass conversion and utilization devices and systems
- Field demonstration of the technology with action research for resolving the problems in field applications and technology improvements
- Quality assurance through testing and performance evaluation of the gasifier systems

MNRE has designated above R&D institutions as its testing centers of the gasifier systems in the country and approve the one that qualify the benchmarked standards. Technology that approved and recognized by the MNRE are eligible for subsidy/ incentives. However, the gasifier systems have to go through a series of tests for gasification efficiency, maximum permissible levels of tars and particles content in generated gas, capacity realization, engine exhaust emissions, duration sustainable for uninterrupted continuous operation, fuel conservation/ consumption, overall system efficiency at rated load for performance compliance with qualifying norms prescribed in the MNRE[19].

Economy of operation of biomass gasification systems was very attractive to adapt this technology for captive electrical and thermal requirements of rice mills and other industries in India. Biomass gasification systems with electrical output 10 - 2000 kWe range and thermal output 25 $kW_{th}$ – 5 $MW_{th}$ were successfully deployed in India to cater industrial requirements and decentralized power generation[22]. More than 850 biomass gasifiers were installed in India to meet the thermal energy requirements of the micro, small and medium enterprises (MSMEs) clusters during 2008-2018[23]. Cumulative total installed capacity of biomass power and bagasse cogeneration in India as on 30.06.2021 is 10170 MW which includes biomass independent power production (IPP) – 1836 MW, bagasse cogeneration – 7562 MW and Non-Bagasse Cogeneration - 772 MW[9]. Around 18 MW off-grid biomass gasifier systems are being used for meeting electricity needs in rural areas and 152 MW equivalent biomass gasifier systems have been deployed for thermal applications in industries in India in the year 2015[24].

MNRE is currently providing Central Financial Assistance(CFA) in the form of back ended subsidy for installation of waste to energy projects for recovery of energy in the form of biogas or bio-CNG or power from Urban, Industrial, Agricultural Waste/ Residues and Municipal Solid Waste. Details of existing CFA/ capital subsidy for setting up biomass gasifier systems are given in Table 1[25].

*Table 2 : Existing CFA/ capital subsidy for setting up biomass gasifier systems*

| Application | Capital subsidy |
|---|---|
| Biomass gasifier for captive power applications in industries and other institutions | Electrical - Rs. 2500 per kWe with dual fuel engines |
| Distributed / off-grid power for villages and up to 2 MW Grid connected power projects using biomass | Electrical - Rs. 15000 per kWe with |

| | |
|---|---|
| gasifier systems with 100% producer gas engines | 100% gas engines |
| Biomass gasifier for captive thermal applications in industries and other institutions | Thermal - Rs.2.0 lakh / 300 $kW_{th}$ for thermal applications |

Currently several small scale entrepreneurs are trying to manufacture and/ or install gasifiers on purely commercial basis. Certification is a requirement for only those manufacturers/ users who wants to avail subsidies. Partly as a result of this situation, there is a large variation in the performance of the systems, capital costs, and maintenance requirements/ commitments. There appears to be uncertainty on many of the claims of gasifier manufacturers/ installers may not stand the scrutiny of a rigorous field evaluation. Lack of systematic data-gathering about experience and performance of installed systems accentuate this problem further[19].

### 6.1 Major organizations associated with development of biomass gasification in India

During the initial demonstration of biomass gasification technology in India, there were mainly five research groups involved in development and implementation of technology directly or through licensing mechanism. The technology packages developed by these groups were different. The research group at IISc has developed a multi fuel gasification system to accept woody or biomass briquettes using novel open top downdraft reactor design. M/s Ankur Scientific Energy Technologies Pvt. Ltd. developed technology for woody biomass, fine biomass and a combination of the two using closed top gasification system. M/s Ankur separately designed rice husk gasification system to handle rice husk as received. The research group at TERI developed gasification technology for woody and briquetted biomass using a throat less gasifier with closed top. SPRERI was involved in the development of technology packages for dual fuel and thermal applications, using both forced and natural draft depending upon the requirements[21].

Currently many research institutes and organizations such as IISc, TERI, Ankur Scientific Energy Technologies, Husk Power Systems, Infinite Energy Pvt. Ltd, GP Green Energy Systems Pvt. Ltd, Urja Gasifiers Pvt. Ltd., Radhe Renewable Energy Development Associate, Cosmo Powertech Pvt. Ltd. etc. are involved in biomass gasification technology development and providing biomass gasifier based clean energy solutions[24].

### 6.2 Indian biomass gasifier system configuration

Biomass gasification systems are deployed in India primarily for power and thermal energy generation. Indian biomass gasifiers are air blown fixed bed type and based on end application either down-draft and up-draft configuration is being used. Biomass gasification system consists of a fuel and ash handling system, biomass gasifier, gas cooling and cleaning system. It also includes auxiliary systems like water treatment plant to meet the requirements of industry and pollution control board. Syngas to power generation consists of either a diesel engine or a spark-ignited engine coupled to an alternator. In case of thermal application, end device is a standard industrial burner.

Biomass gasification system configuration developed by Combustion, Gasification, and Propulsion Laboratory (CGPL) division of IISc is shown in fig. 3. IISc biomass gasifier is open top and throat-less down draft reactor with ceramic lined cylindrical vessel and bottom screw for ash extraction[26].

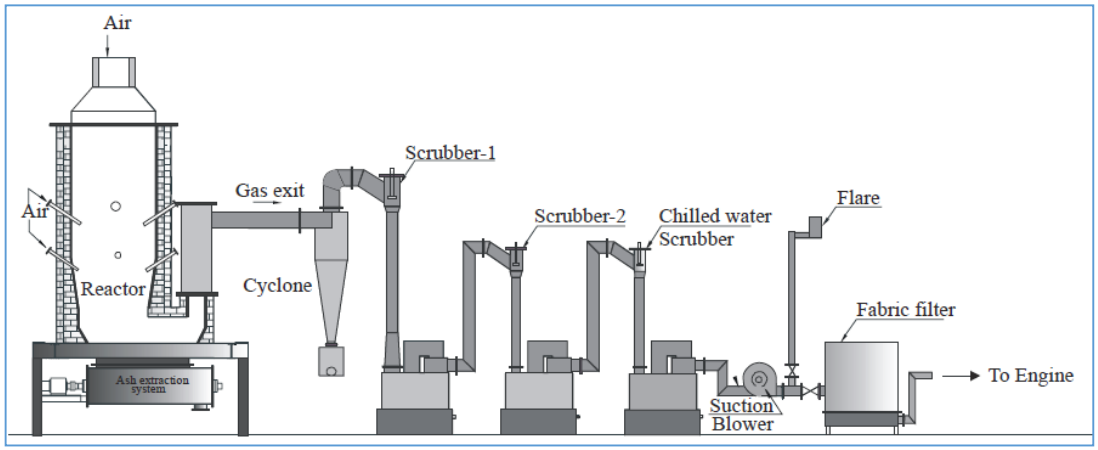


*Figure 3 : Typical Indian biomass gasifier system configuration*

## 7. Biomass gasification system technology providers and manufacturers

This section presents key agencies/ organizations that are involved in the biomass gasification systems technology development and manufacturing. This information is collated from the data available in the in the public domain. Details of the key technology providers and manufacturers in India with their contact details are given in the Table 3.

*Table 3 : Biomass gasification system technology providers and manufacturers in India*

| S No | Name of the organization | Address |
|---|---|---|
| 1 | Ankur Scientific Energy Technologies Pvt. Ltd. | Ankur Scientific Energy Technologies Pvt. Ltd.<br>'Ankur', Near Navrachana School,<br>Sama, Vadodara - 390 024<br>Gujarat, India<br>Phone : +91-265-2793098<br>Fax : +91-265-2794042<br>Email : info@ankurscientific.com<br>Website : www.ankurscientific.com |
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| 3 | The Energy Resources Institute (TERI) | The Energy and Resources Institute (TERI)<br>Darbari Seth Block,<br>IHC Complex, Lodhi Road,<br>New Delhi - 110 003, INDIA<br>Tel: (+91 11) 2468 2100<br>Fax: (+91 11) 2468 2144, 2468 2145<br>Email: mailbox@teri.res.in |

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| 4 | Husk Power Systems | Husk Power Systems<br>2nd Floor, Sai Tower, New Dak Bunglow Road<br>Patna - 800001, Bihar, India<br>Email: info@huskpowersystems.com<br>Website : https://huskpowersystems.com/ |
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| 6 | GP Green Energy Systems Pvt. Ltd. | GP Green Energy Systems Pvt. Ltd.<br>Bengal Eco Intelligent Park Tower 1<br>Module 21 14th Floor EM Block<br>Salt Lake City Sector V<br>Kolkata 700091<br>Phone: 033 - 4601 6961<br>Email : info@gpenergy.net<br>Website : http://gpenergy.net/ |
| 7 | Urja Gasifiers Pvt. Ltd. | Urja Gasifiers Pvt. Ltd.<br>M.G College Road<br>Gorakhpur, Uttar Pradesh – 273001<br>Ph : +91 9559818181<br>Email : info@urjagen.in<br>Website : https://www.urjagen.in/index.php |
| 8 | Radhe Renewable Energy Development Pvt. Ltd. | Radhe Renewable Energy Development Pvt. Ltd.<br>Plot No. 2621/22, Road D-2<br>Gate No. 1(Kranti Gate), Lodhika GIDC<br>Metoda, Kalawad Road, Rajkot – 360021<br>Gujarat, India<br>Ph : 912827-287888<br>Email : info@radhegroup.com<br>Website : http://radhegroup.com/ |
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Details of key biomass gasification systems technology providers are given below:

### 7.1 Ankur Scientific Energy Technologies Pvt Ltd.

**Technology :** Downdraft with closed top

**End use :** Electrical and thermal applications

**Product range :** 10 kW - 1500 kW

WBG series : Process wood pieces/ chips, coconut shells, corn cob etc.

FBG series : Process fine biomass such as rice husk and straw

COMBO series : Process both fine and woody biomass

**Profile**

Ankur Scientific Energy Technologies Pvt. Ltd., a company established in 1986, has been in the forefront of research and development activities in the area of non-conventional energy sources. Since its inception, Ankur has an enviable record of development in the area of biomass to energy solutions.

Ankur has successfully developed and commercialized a wide range of biomass gasifiers ranging in size from as small as 5 kg/h biomass consumption to 2000 kg/h biomass consumption. Ankur's competitive edge lies in its long history of developing and improving the technologies that drive its business. It has patents for various technical features and it has also won awards from the Federation of Gujarat Industries (FGI) as well as Government of India for excellence in Research in Science and Technology. The company has extensive manufacturing facilities and as the sole focus is on production of biomass to energy equipment, the facilities have been specifically designed and are frequently upgraded to ensure least cost and most efficient production.

Ankur's number of field installations (>900) in India and abroad (in Europe, USA, South America etc.) are a testimony not only to the long-tem reliability of the gasifiers, but also of the growing acceptance of the Ankur's gasification technology[27].

**Salient features of Ankur gasifiers**

- The following are salient features of Ankur's biomass gasification technology:
- Gasifier is very versatile that can handle different feed stocks

- Designed to use feedstock in the original form with minimum pre-processing of materials
- Gasifiers can burn most tars inside to generate clean gas (lowest tars in the industry)
- State of the art gas clean up systems which generate no liquid emissions
- Solid and gaseous emissions within permissible limits specified by Pollution Control departments
- One of the prime gasifier manufacturers that develops its own technology, manufactures, installs and maintains the systems as per customer needs

## 7.2 Combustion, Gasification and Propulsion Laboratory, Indian Institute of Science

**Technology :** Open top re-burn throat-less downdraft gasification

**End use :** Electrical and thermal applications

**Product range :** 10 kW - 1200 kW

**Profile**

Combustion, Gasification and Propulsion Laboratory (CGPL) at the Indian Institute of Science (IISc) has been involved in innovative research and development activity in the field of bio-resource utilization. IISc started research work on biomass gasification in 1982. Besides fundamental studies, CGPL has developed techniques of gasification of wide range of biomass including agro-residues. These techniques have been perfected into small independent power plants, which could serve thermal or electricity needs of industry and rural society.

One of the principal features of the work at the CGPL has been a pursuit to further efficient ways of harnessing energy through gasification process. The development work became so substantive and relevant that a separate society called Advanced Bioresidue Energy Technology Society (ABETS) was established in the laboratory to function as an independent society under the chairmanship of the director of IISc. In order to pursue these activities, funding for basic research has been sought from several agencies.

One of the Action Research Centers was set up at IISc by MNRE to undertake research in developing and up-scaling woody and non-woods biomass gasifiers. IISc has several licensees who have paid a fee and acquired the technology from IISc. The following are the 8 licensed holders who manufacture biomass gasificers based on IISc technology[19]:

i. Bioresidue Energy Technology Private Limited (BETEL)
ii. Arrya Hi-Tech Energy
iii. Synergy Renewable Energy(P) Ltd. “Trishul”
iv. SunTechnics Energy Systems Pvt. Ltd.
v. OVN Bioenergy Private Ltd.
vi. Aruna Electricals Works Pvt. Ltd.
vii. High Temperature Furnaces
viii. Satake Corporation, Japan

**Salient features of CGPL gasifiers**

The following are salient features of IISc biomass gasification technology:

- Open top, twin air entry, re-burn gasifier
- Longer residence time in the reduction zone at higher temperatures results in the cracking of higher molecular weight products, leading to a gas that is very clean and lower tar content
- Gasification efficiency in the range of 75-85%
- The patented syngas clean system is capable of reducing the particulate matter from 1000 mg/$Nm^3$ to just 5 mg/$Nm^3$
- The gas can be used for thermal and electrical applications including 100% Gas engines.

## 7.3 The Energy and Resources Institute (TERI)

**Technology :** Closed top down-draft throat less gasifier and two stage gasifeir

**End use :** Electrical and thermal applications

**Product range :** 50 kWe -2000 kWe for electrical application

25 $kW_{th}$ to 5 $MW_{th}$ for thermal application

**Profile**

TERI started research work on biomass gasification technology in the mid 1980s. It has carried out extensive work in the development of biomass gasifiers for thermal applications for small and medium scale industries. TERI has developed patented throat-less biomass gasifier with closed top which can process multi-feed. TERI developed ovens, kilns, and furnaces based on its biomass gasification technology for industries such as silk reeling, textile dying, magnesium chloride production, brick drying, and spices drying. It has designed biomass gasifier systems that can meet thermal energy needs ranging from 25 $kW_{th}$ to 3 $MW_{th}$, and meet the temperature requirements of MSME units ranging from 60 to $1000^0$C[23]. TERI has licensed its technology to eight Indian manufacturers and one Srilanka manufacturer for commercializing the biomass gasifier systems.

**Salient features of TERI gasifiers**

- The following are key features of TERI gasification system :
- Multi-fuel capability - can process fuel wood, wood chips, Agriculture stalk, Coconut shells, Briquettes of several residues, Mustard stalk, Cashew-nut shells etc.
- Air pre-heating for gasification maintains high temperatures resulting in better quality of generated gas
- Insulated firebox, which maintains high temperatures resulting in better quality gas and longer service life
- Efficient cleaning and cooling train

## 7.4 Husk Power Systems

**Technology :** Modified proprietary downdraft gasifier to process 100% rice husk

**End use :** Electrical applications

**Product range :** 25 kW to 100 kW

**Profile**

Husk power Systems convert rice husks into energy and has created proprietary technology that cost-effectively converts rice husks into electricity using biomass gasification technology. Husk was the first company to use 100 percent biomass gasification from rice husks to generate electricity for households and small businesses. It currently designs, builds, owns and operates one of the world's lowest cost hybrid power plant and distribution network in India, Nigeria and Tanzania. Husk gasifier systems use agricultural waste as its feedstock, enabling benefits of reducing agri-waste burning on farm lands and creating an additional revenue stream for farmers. It has developed a proprietary system by combining and synchronizing solar PV, biomass gasification system and batteries to deliver highly reliable, 24×7 power[27]. In India, Husk Power currently has 100 minigrids (up from eight in 2018) and services 6,000 customers, with a focus on MSMEs and small-scale factories, the backbone of the economy. Particularly for commercial customers, Husk Power's electricity is competitively priced during the day time. Husk Power Systems plans to grow to 300 minigrids across India, Tanzania and Nigeria by 2022 and a 1,200 minigrids by 2025[29].

**Salient features of Husk Power Systems gasifiers**

- Proprietary gasification process wherein the producer gas goes through a water-less scrubbing and filtration process
- Deploys heat exchanger process that has eliminated any need for water, making the only company in the Indian gasification industry that does not waste even a single gallon of clean water

## 7.5 Infinite Energy Pvt. Ltd.

**Technology :** Gasifiers with updraft, downdraft with closed top, stratified downdraft and entrained configuration

**End use :** Thermal and power applications

**Product range :** 30 $kW_{th}$ to 2000 $kW_{th}$ and

**Profile**

Infinite Energy Pvt. Ltd. is a recognized leader in biomass conversion and processing technology in India. It is technology driven company with two decades of experience in "Biomass to Energy" solutions. Over the years, Infinite Energy has built up a substantial reputation in the field of biomass utilization techniques and has indigenously designed and developed various systems for biomass gasification, biomass pyrolysis, biomass briquetting and biomass drying[30].

Infinite Energy supplies biomass gasifiers with updraft, downdraft closed top, stratified downdraft open top and entrained configuration. Generation capacity of biomass gasification systems supplied by Infinite Energy is in the range 6 kW to 400 kW for power application and 75 kW to 2000 kW for thermal application[31].

**Salient features of infinite energy gasifiers**

- Entrained gasifier technology with heat recovery
- Stratified gasifier for loose biomass such as husks, shells, stalks and chips

- Updraft gasifier with jet pump evacuator
- Scrubber less gas cooling systems with microprocessor based gasifier controls
- Automated reactor control with dry gas cleanup system
- Very low maintenance, no operative risk and easy to operate
- Highest overall efficiency with zero tar/ effluent system
- Compact foot print and typical payback is within 12 months

### 7.6 GP Green Energy Systems Pvt. Ltd.

**Technology :** Updraft gasification

**End use :** Thermal and power application

**Product range :** 10 kW to 1 MW

**Profile**

GP Green Energy Systems Pvt. Ltd. (GP Energy), headquartered in Kolkata, India, had entered into the field of renewable energy through its parent organization in 1987. GP Energy has its Technology and Engineering Centre in Pune. It is first in India to successfully implement industrial sized biomass gasification plant by adopting the updraft gasification technology. The technology and basic engineering package was supplied by an expert from Power Gas Corporation, UK. With continuous R&D both in-house as well as with assistance from Indian Institute of Technology, Central Fuel Research Institute etc., GP Energy successfully developed cogeneration systems for various innovative industrial applications with consistent performance. GP Energy offers design, manufacturing, turnkey services as well as comprehensive EPC services to meet the needs of the industrial customers.

GP Energy has designed biomass gasifier systems for cogeneration in the industries based on requirement of the clients. GP Energy biomass gasification systems are highly suitable as a decentralized power station - both for captive use in the industries as well as for rural electrification, where transmission of power through grid line is very expensive and electrical load growth is minimal[32].

**Salient features of GP Energy gasifiers**

- It is a continuous operating system which can run on 24×7 basis
- It is a multi fuel system and can accept any biomass in the same plant
- Fuel consumption can be controlled as per actual requirement
- The plant is sturdy in construction having adequate safety measures
- GP Energy is approved by the Ministry of New & Renewable Energy, New Delhi and its systems attract cash subsidy and income tax benefit from the government. It also qualifies for carbon credit having scope for huge revenue inflow.

### 7.7 Urja Gasifiers Pvt. Ltd.

**Technology :** Updraft and downdraft gasifiers

**End use :** Thermal and electrical applications

**Product range :** 10 kW – 500 kW

**Profile**

Urja Gasifiers Pvt. Ltd. formerly Rishipooja Energy and Engineering Company was established by a group of highly experienced, dedicated engineers and technocrats committed to developing renewable energy, energy efficient and environmental friendly products. Urja Gasifiers is offering a wide gamut of biomass gasifier under the brand name "Urja". Dedicated to attain an unrivaled position in the markets through an uncompromising commitment towards quality and services, Urja Gasifiers established reputation in quality of manufacturing, exporting and supplying, performance of Gasifiers and after sales services. The company manufacturers "CE" marked products. Urja's comprehensive range of product profile encompasses gasifier crematorium system, cremation furnace, Rice husk and wood gasifier (both down and up draft).

Urja selects technology and design for every emerging products based on continuous R&D, both in house and field trials in technical assistance from various consultants and technocrats. The company has also signed MOU with Madan Mohan Malviya Technical University and IIT BHU for various R&D project and technology up-gradation. Urja believes that major strength of a technological company lies in the quality of its product design, customer care and after sales services, and for this purpose the company has very strong team of engineers and technicians[33].

**Salient features of Urja Gasifiers**

- Multi-fuel capability which can accommodate wood chips, wood waste from timber harvesting and saw mill operations, coconut shells, cashew nut shells, agri stalk, briquettes of agricultural residue and saw dust
- Better conversion (solid to gas) efficiency (>75%)
- Releases clean flue gases in the exhaust
- Can be tailor-made for a range of output ratings and used for variety of applications
- Uses castable insulation material in the fire box capable of withstanding high temperature (up to $1860^0$C)

## 7.8 Radhe Renewable Energy Development Pvt. Ltd.

**Technology :** Updraft gasification

**End use :** Thermal and power application

**Product range :** 250 kW – 5 MW

**Profile**

Radhe Renewable Energy Development Pvt. Ltd. (RREDPL), a flagship company of Radhe Group of Companies, was founded in 1998 and has headquartered in Rajkot, Gujarat, India. The company engaged in development, designing, supplying, installing and serving turnkey energy projects that integrate seamlessly with customer's operations. RREDPL has an in-house R&D centre recognized by Government of India which is developing new applications that will

continue to increase the value of the customer's. The biomass gasification system developed by RREDPL is suitable for both thermal and electrical end applications[19].

RREDPL is constantly thriving on effort to develop environment friendly technology which will be helpful to society and in long terms for the sustainable growth. It's main line activities are research, development, manufacturing and marketing of non-conventional and renewable energy equipments like up-draft gasification technology, fluidized bed hot air generator, waste heat recovery heat pipe based technology, waste tyre/ waste plastic continuous pyrolysis technology, CO (carbon monoxide) generation technology, power plant(gasification - DG route) and drying technology. Radhe is mainly involved in manufacturing and supply of up-draft gasification technology along with recently developed hot gas filtration technology[34].

**Salient features of Radhe gasifiers:**

- Acceptability of range of carbonaceous material
- Flexibility in terms of raw material availability at various periods of the year with changes in atmospheric and market position
- No emission of air from the gasifier environmentally friendly equipment, which produces cleaner energy thus permitting simplified and low cost of operation
- Flexibility in operation capacity - This feature offers optimum capacity of utilization on variation of requirements
- Low temperature and pressure during operation - Result is lower capital cost as well as well as operation cost
- Robust construction and simple operation - Maximum continuous operation and minimum shutdown time

## 7.9 E. B. Mechanism Pvt. Ltd. (Manglam Biomass Gasifier)

**Technology :** Up-draft and down-draft biomass gasifier

**End use :** Electrical and thermal applications

**Product range :** 110 $kW_{th}$ – 2300 $kW_{th}$

**Profile**

E.B. Mechanism Pvt. Ltd. is a Rajasthan based company, established in August 1992 under the aegis of the Shevkani Brothers. The company entered into the corporate world with bakery business, but later on ventured into alternate energy production in the year 2000 to cut down the ever-increasing fuel costs. Today, E.B. Mechanisms Pvt. Ltd. is a leading manufacturers and suppliers of eco-friendly biomass gasifier systems and DSH Burners. E.B. Mechanisms provide standardized models in simple and compact plants.

Being one of the largest manufacturer and supplier of biomass gasifier in India, E.B. Mechanisms vision is to become world's leading supplier of biomass gasifier and DSH Burners. E.B. Mechanisms vision is business world full of connection, meaning and prosperity for all by optimizing the production and keeps their product competitive and effective. Its mission is to provide their customer a considerable saving, a pollution free, dust free and smoke free environment and boost in the production and improvement in the quality of their products[36].

**Salient features of Manglam gasifiers**

- Simple and reliable solution for bringing down the fuel cost by over 50%
- Offers clean combustion; compact burning equipment, high thermal efficiency and a good degree of control just like conventional diesel burner
- Clean working environment as the gasifier system is situated away from the load
- Zero Tar/ effluent system and highest overall efficiency
- Payback period : 6-8 months
- No emission of smoke from the gasifier

### 7.10 Cosmo Powertech Pvt. Ltd.

**Technology :** Up-draft gasifier to process fuels like biomass, coal and waste

**End use :** Thermal applications

**Product range :** 300 $kW_{th}$ to 10,000 $kW_{th}$ in single reactor modules (Equivalent to 25 to 875 litres/hour oil substitution)

**Profile**

Cosmo Powertech Pvt. Ltd. is dedicated to research, development and commercialization of technologies and products in the areas of renewable energy, energy conservation, environmental protection and petroleum substitution. Cosmo updraft gasifiers convert low cost solid fuels like biomass, coal or wastes into clean combustible gas that can be used to substitute any petroleum derived fuels (FO/LDO/LPG/HSD) catering to almost any thermal applications. COSMO updraft gasifiers are air-blown (air and steam) and operate at near atmospheric pressure[36].

**Salient features of Cosmo gasifiers**

- Built gasifiers from 1.2 m to 4.0 m diameters and offer the most suitable gasifier as per the specific requirements of the customer
- Fuel feeding system enables fully automatic feeding with load sensing
- Unique grate design ensures uniform distribution of air over entire cross-section of gasifier reactor, minimum clogging of air path with ash and long operating periods between shut downs.
- All the critical operations, such as fuel feeding, ash removal, jacket water filling etc. are fully automatic.
- Full water jacket – No refractory lining
- Fuel flexibility: Wide fuel flexibility is an important feature

### 7.11 Chanderpur Works Pvt. Ltd.

**Technology :** Up-draft and downdraft gasifiers

**End use :** Thermal and power application

**Product range :** 20 kWe to 1200 kWe gasifers

**Profile**

Chanderpur Works Pvt. Ltd. is a flagship company of Chanderpur Group which has around 60

years of experience. It is a leading designer, manufacturer and supplier of industrial biomass gasifiers, and gasification based power plants for thermal and electrical applications. It is manufacturing gasifiers under Technical Collaboration with TERI, New Delhi. Chanderpur Works is currently offering "CE" marked gasifiers. It has supplied more than 100 gasifiers of different capacities for rural, industrial and urban projects. Its biomass gasifier technology is approved by Ministry of Non-Conventional Energy Sources (Government of India) and also tested and approved by Indian Institute of Technology, New Delhi and Mumbai. It is also undertaking the thermal projects as well as providing power production from agricultural waste technology[37].

**Salient features of Chanderpur Works gasifiers**

- Manufactures fully automatic control gasifiers
- Manufacture gasifiers keeping in mind all safety measures. Due to safety features, CPG gasifiers are "CE" marked
- Provides energy audit along with TERI for the customers to aware them regarding energy saving and make their system cost effective
- Gasifiers are standardized and use all components as per international specifications
- Suitable for any application – generated gas is suitable for power generation and any type of thermal applications

## 8. Some of the successful biomass gasification case studies

To meet captive electrical and thermal energy requirements of micro small and medium enterprises, and decentralized electrical energy requirements of rural India, quite a large number of biomass gasification systems were set up in India. Details of the some of the successful biomass gasification system case studies are given below.

### 8.1 1 MW grid connected biomass gasification power, Coimbatore, Tamilnadu

Arashi Hi-Tech Bio-Power Private Limited (AHBPPL) established 1 MW biomass gasification power project in Coimbatore district, Tamilnadu. AHBPPL is the first 1 MW grid connected biomass gasification power project in India. Coconut residues, which were available abundant quantities in this region, were the major fuel for this project activity. Biomass was subjected to gasification process in two 500 kW gasifiers, and then the generated producer gas was supplied to five numbers of 250 kW producer gas engine. The generated electricity was exported to Tamilnadu Electricity Board (TNEB) grid and consumed by its sister company by wheeling. AHBPPL started its power generation from January 2005 with 100% producer gas engine. CGPL division of IISc was the technology provider for this project. The specifications and drawing of the gasifiers were provided by IISc. The gasification technology designed and developed by the IISc was the state-of-the-art Technology[38]. The plant was operated over 20,000 hours[39]. Flow scheme and images of 1 MW biomass gasification power plant of Arashi Hi-Tech Bio-power Pvt. Ltd are shown in fig. 4 and 5, respectively.

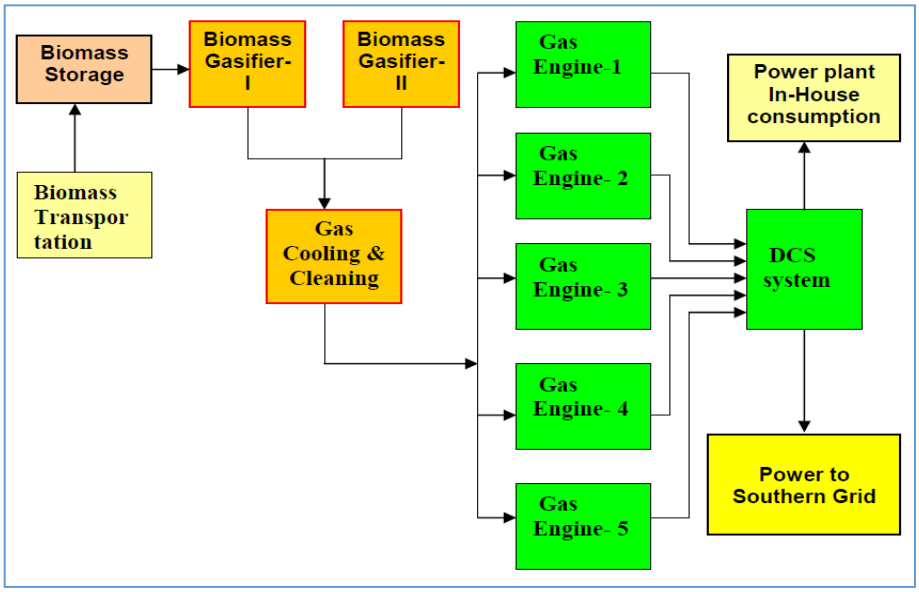


*Figure 4 : Flow scheme of 1 MW biomass gasification power plant of Arashi Hi-Tech Bio-power Pvt. Ltd.*

*Figure 5 : Images of 1 MW biomass gasification power plant of Arashi Hi-Tech Bio-power Pvt. Ltd.*

A team from IISc and AHBPPL evaluated performance of producer gas as fuel in an internal combustion engine operating on natural gas. Systematic monitoring of the system was carried out on all the engines at the end of 1000 hours of operation. Lubricating oil samples were drawn at regular intervals to assess the replacement schedule. At the end of 5000 hours of operation, one engine was dismantled to evaluate the performance at component level. Components from the carburetor till the valve and cylinder were dismantled by Cummins India Limited and were evaluated[39]. Following were the major observations:

- Extremely fine dry dust in the gas path; can be blown using a blower
- Extremely fine ash deposition on the turbine
- No wear on the turbine or compressor blade and the shaft assembly
- Turbocharger internal components like bearing housing, bush bearings, thrust washer, seal rings etc. were in good condition

- Dry dust deposition on the intake valves. However the seating area shows normal wear. Exhaust valves shows hard layer of ash. Exhaust valve seat area shows slight wear marks.
- Spark plugs tips found normal wear and clean

## 8.2 Gosaba Island Rural Electrification project, West Bengal

A 500 kW (5 x 100 kW) biomass gasifier based power plant was installed and commissioned in Gosaba Island, West Bengal in July 1997 for electrification of five villages comprising more than 10,000 people. In the Gosaba power plant, the gasification technology was from M/s Ankur Scientific and consists of five 100 kW down draft closed-top gasifiers. Each 100 kW unit was equipped with a water-sprayed gas cooling system, a two-stage gas cleaning system, a blower and a Ruston engine (165 HP- diesel engine). Fuel wood was supplied to the plant from local saw mills. The Gosaba power plant was commenced operation in July 1997. Image of the biomass gasifier installed in Gosaba Island is shown in fig. 6. Total electricity generated during the period July 1997 to December 1999 was 351,798 kWh. Average fuel wood and diesel consumption per kWh of electricity generated were 0.822 kg and 0.135 l, respectively. The producer gas replaced about 59% of the total diesel requirement if the plant would run by diesel only[40]. The island developed dramatically since the power station installed. There were so many commercial stores and more than 10 hotels, and people from nearby islands used to visit Gosaba for shopping[41].

In the Gosaba power plant, engine lubrication oil required to be changed and the turbo chargers required cleaning after about 225 hours of operation. Water was circulated separately at a flow rate of 2880 l/hr through the gas cooling tower and the ash removal system. Water used to be replaced with fresh water after about 220 h of operation. In the gas cleaning system, wood dust filter bed and the cotton filter required to be changed after about 48–50 h of operation[40].


*Figure 6 : Biomass gasifier installed in Gosaba Island, West Bengal*

## 8.3 1 MWe grid connected biomass gasifier in Mullana, Ambala, Haryana

Chanderpur Renewable Power Company Pvt. Ltd. of The Chanderpur Group (CPG) has installed 1 MW biomass gasifier at one of their factories in Mullana, Ambala district, Haryana. This plant is using wood waste from plywood industries such as branches of trees etc. This plant supplies power to all three units of Chanderpur Group through grid. Power produced is directly synchronized with the grid and is being purchased by the group companies for their daily requirements. It is the first project of its kind in North India. This plant not only fulfilling all electricity needs of CPG, rather it is also giving extra income to the farmers by selling their extra biomass waste. The used engine oil by the gas generators in the power plant is being used as coolant in the gear cutting machine after cleaning, so there is no need of fresh cooling oil, thus saving cost.

In the first phase, a 1000 kg/hr gasifier system was integrated with 4 numbers 250 kW Producer Gas Engines in the year 2012. The specific biomass consumption is 1.2 to 1.5 kg/kWh. Tar content in generated gas is less than 15 mg/$Nm^3$ and water consumption is about 0.6 liter per kWh. This plant was successfully operated for more than 7000 hours annually in field operation[42]. Images of 1 MWe biomass gasifier installed in Mullana, Ambala, Haryana are shown in fig. 7.

*Figure 7: Images of 1 MWe biomass gasifier installed in Mullana, Ambala, Haryana*

### 8.4 Captive heat generation for biscuit plant of ITC at Mangaldoi, Assam

GP Green Systems Pvt. Ltd, Kolkata has set up three biomass gasifiers (nominal capacity 600 kg/hr biomass) at Mangaldoi, Assam, to produce gas having calorific value of 1,250 - 1,350 kcal/$Nm^3$ (or 5.25 MJ–5.65 MJ/$Nm^3$). This gas was meant to replace high speed diesel (HSD) used as a fuel in the biscuit plant of ITC. The venture proved to be a great success to the satisfaction of the customer. Images of biomass gasification based captive heat generation plant at Mangaldoi, Assam are shown in fig. 8.

The plant was commissioned in June 2016 and since then it has been in continuous operation. The experience gathered during initial 10 months of continuous operation was highly encouraging because a raw material, that is, bamboo over which there had been enormous reservation in respect of its successful gasification was proved to be a mere apprehension in

the updraft gasification technique of GP Energy[43].


*Figure 8 : Images of biomass gasification based captive heat generation plant at Mangaldoi, Assam*

## 8.5 Sankheda 1.2 MW Biomass Gasifier project in Gujarat

Ankur Scientific Energy Technologies Pvt. Ltd. has set up a 1.2 MW grid- connected biomass power plant based on its own gasification technology in Sankheda taluka of Vadodara district. This project is the first of its kind in Gujarat and also the first project to be set up under the status of 'Model Investment Project' implemented under a project by MNRE - UNDP funded by GEF. The project was commissioned in 2011 in a short duration of 6 months with the help of local villagers and farmers, panchayats, the taluka offices, the collectorate and departments

of land conversion and town planning etc. Images of Sankheda 1.2 MW biomass gasifier project in Gujarat is shown in Fig 9.

The overall system designed has two woody biomass based gasifiers which are coupled to three units of 400 kWe engine gensets, each running on 100% producer gas. The plant uses biomass fuels such as cotton stalk, tuver stalks, maize cobs, mango seeds, castor husk etc. The plant has the state of art technology with up-gradation from time to time. Bio-char (charcoal generated from biomass), a by-product of gasification process was sold to farmers at a low price as a fertilizer[44].


*Figure 9: Images of Sankheda 1.2 MW Biomass Gasifier project in Gujarat*

## 8.6 Captive power generation at Vishwashanti Dnyanpeeth, Parbhani, Maharashtra

Vishwashanti Dnyanpeeth, a renowned educational institute in Parbhani has grid connection but is not stable and reliable. In 2009, Ankur Scientific supplied, installed and commissioned biomass gasification system with suitable 100% producer gas genset of 20 kWe rating and provided training to college personnel to operate and maintain the plant smoothly. Main objective of setting up biomass gasification plant was to provide electricity to the entire school and hostel of 1200 students. Prosopis juliflora, which is collected at a cheap rate from local farmers, is used as feed in gasifier. The installation was showcased as a modern technology for converting the agro-waste to energy to the local people[27].


*Figure 10 :Location of 20 kWe biomass gasification system installed by M/s Ankur*

## 9. Recent initiatives on biomass gasification for advanced biofuels generation

IISc and Indian Oil Corporation Limited have signed a MoU to develop and demonstrate biomass gasification based hydrogen generation technology for producing fuel cell-grade hydrogen at an affordable price. Under this MOU, which was signed on October 29, 2020, IISc and IndianOil will work jointly on the optimization of both biomass gasification and hydrogen purification processes. The developed technology will be scaled up and demonstrated at IndianOil's R&D Centre. Hydrogen generated from this demonstration plant will be used to power fuel cell buses as part of a bigger project conceived by IndianOil towards ushering in the country's hydrogen economy[46].

Mangalore Refinery and Petrochemicals Limited (MRPL) has awarded LanzaTech a contract to commence the basic engineering for an integrated processing facility to convert locally available agricultural residues to approximately 16 ktons/year (5.3 MGal/year) of fuel grade ethanol. To convert the solid biomass wastes to syngas gases, LanzaTech will deploy commercially proven gasification technology from Ankur Scientific, a waste to Energy Company that specializes in distributed energy generation. The resulting carbon rich syngas will then be converted to ethanol using LanzaTech's gas fermentation platform. The integrated technology will have the flexibility to process a wide range of biomass feed stocks enabling rapid replication at other locations[47].

## 10. Other notable bioenergy related initiatives in India

Government of India has introduced new biofuels policy in 2018, which aims to increase usage of biofuels in the energy and transportation sectors of India in the next decade. The policy aims to utilize, develop and promote domestic feedstock and its utilization for production of biofuels thereby increasingly substitute imported fossil fuels while contributing to national energy security, climate change mitigation, apart from creating new employment opportunities in a sustainable way. Simultaneously, the policy also encourages application of advance technologies for generation of biofuels[10].

The goal of the Policy is to enable availability of biofuels in the market thereby increasing its blending percentage. An indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel is proposed by 2030[10]. India advanced its national average target of 20 percent ethanol blended with gasoline to 2025, while allowing the sale of E-20 blended gasoline from April, 2023[47]. The blending target is planned to be achieved by reinforcing ongoing ethanol/ biodiesel supplies through increasing domestic production, setting up Second generation (2G) bio-refineries, development of new feedstock and technologies for biofuels etc.

Currently ethanol is mainly generated from molasses based distilleries in India. Under PM-JIVAN scheme, 12 commercial plants and 10 demonstration plants of 2G bio-refineries (using lignocellulosic biomass as feedstock) are planned to be set up in areas having sufficient availability of biomass so that ethanol is available for blending throughout the country. Already Rs. 1969.50 Crores have been earmarked for this scheme[49]. Currently, there are two operating 2G ethanol facilities - one pilot and one demonstration plant - with a combined production capacity of 1.75 million litres per year.

Biodiesel use in India remains negligible due to limited feedstock availability and lack of an integrated and dedicated supply chain, and import restrictions. Domestically sourced used cooking oil (UCO) was identified as a feedstock with a large, untapped potential for biodiesel production. Indian government is working on developing a consistent UCO supply chain for biodiesel production[49].

Under the Sustainable Alternative Towards Affordable Transportation (SATAT) scheme, government is supporting potential entrepreneurs to set up compressed biogas (CBG) plants. Government has a production target of 15 MT of bio-CNG by 2023 from 5000 biogas plants. The initiative aims to produce compressed biogas (CBG) from waste and biomass sources like agricultural residue, cattle dung, sugarcane press mud, Municipal Solid Waste (MSW) and sewage treatment plant waste. PSU Oil Marketing Companies (OMCs) are inviting Expression of Interest (EoI) from potential entrepreneurs to set up CBG plants, and supply of CBG to OMCs for sale as automotive and industrial fuel[16].

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