Renewable and Sustainable Energy Reviews 45 (2015) 530–539

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review on biomass energy resources, potential, conversion and policy in India

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ARTICLE INFO

Article history:
Received 21 May 2014
Received in revised form
25 September 2014
Accepted 2 February 2015

Keywords:
Biomass Energy
Resources
Potential
Conversion
Policy

ABSTRACT

In this communication biomass energy resource, potential, energy conversion and policy for promotion implemented by Government of India are discussed. The total installed capacity for electricity generation in India is 2666.64 GW as on 31st March 2013. Renewable energy is contributed 10.5% of total generation out of which 12.83% power is being generated using biomass. India has surplus agricultural and forest area which comprises about 500 million metric tons of biomass availability per year. In India total biomass power generation capacity is 17,500 MW. At present power being generated is 2665 MW which include 1666 MW by cogeneration. The various category of biomass in India is also discussed in this paper. And the research reveals that India has large potential for bio mass feed stock from different sources. Government of India deployed different policies and executed that the strategies for biomass power generation. Such approaches have included the whole biomass energy sector which incorporated the bio gas, bio diesel etc. in the policies. Government of India has focused on the deployment and development biomass energy sector with strategic policy and program which is notable portion of this review paper.

Contents

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http://dx.doi.org/10.1016/j.rser.2015.02.007
1364-0321/

1. Introduction

Many developed and developing countries has promoted biomass energy generation through instrumented policies and financial incentives. Many governments introduced feed in tariff schemes as a policy mechanism to accelerate investment in renewable energy sector.

India is a fast developing country; with high economic and industrial growth energy demand is also growing. The major source fulfill the energy requirement of India are Oil and coal. The energy consumption of India using these conventional sources are—151.3 GW by thermal (coal, natural gas and oil), 4.78 GW by nuclear energy, 30.49 GW by hydro and 27.54 GW by renewable energy. Fig. 1 shows the percentage share of various energy resources in India up to 31st March 2013 [1].

Non-renewable resources have used frequently in India due to lack of awareness and acceptability of renewable energy sources by power consumer. There are many disadvantage of using non-renewable energy resources as they have limited existence in environment, non-eco friendly and not economical as India import all these type of energy resources. Therefore it is essential to explore many others sustainable energy sources. One of those non conventional sources is biomass energy which can provide firm power of grid quality. Biomass is a renewable source of energy contains complex mix of carbon, nitrogen, hydrogen and oxygen. Biomass of this content is obtained from living or dead plants, by product of crop production, wood and agro based industry [2].

Biomass energy consumption is in practice in India since ancient time. It is used in the form of cow dung cake, firewood, husk and many available natural feed stocks. However, direct use of biomass in solid form was not safe and painless as they produce lot of smoke and ash. Therefore Biogas plant are being motivated by Indian Govt. as they produce no smoke i.e. pollution free. Many subsidies are provided for establishment of the biogas plant. New biomass gasification Technology was also evolved which converts biomass in to syngas, which are more efficient.

After judging the potential of biomass, technology also implemented the biological and thermo-chemical conversion for utilizing biomass to produce fuel gases. These fuel gases can be used for power generation. The biomass based power generation is now considerably on the rise trend. It is mainly because power demand is increasing in rural area also and less option for alternative fuel [3].

It has been fundamental now to provide energy by biomass for the development of civilization. In present scenario, global warming, decrement of resources and other international issues have led to the decision of sustainable development. And in power sector use of renewable energy like biomass is the need one of the major green source [4].

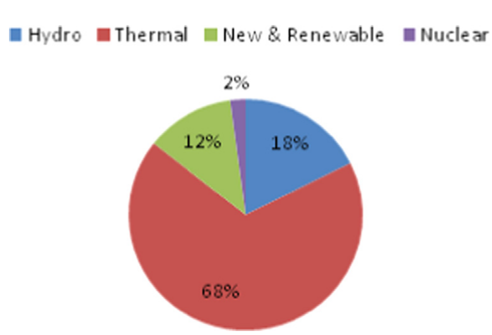

Fig. 1. Percentage share of various energy resources in India upto 31st March 2013 [1].

Larger population of India lives in rural area. According to census 2011, 68.84% population of India lives in rural area. There are 0.638 millions villages in India, therefore to plan for electrification in villages; biomass will be vital option as a renewable source of energy. Ministry of New and Renewable Energy Sources (MNERS) has proposed to reach total 4324.22 MW of power generation based on biomass power and gasification as well as co-generation. MNRE, Govt. of India, has taken initiative like central financial assistance and fiscal incentives for promoting the use of bio-energy from agro residues, plantations and from various waste of urban and industries. MNRE is using the methodology for providing the subsidies based on co-generation and generation by biomass gasification [5–7].

In this paper, state wise biomass potential of India is identified. The various category of biomass in India and their conversion processes are also presented briefly. This paper has discussed the scope, potential and scenario of implementation biomass power in India. Policy regarding providing the subsidies for biomass power in India is mentioned. Government of India has focused on the deployment and development biomass energy sector with strategic policy and program which is notable portion of this communication.

2. Available biomass resources in India

Biomass is defined as bio residue available by water based vegetation, forest or organic waste, by product of crop production, agro or food industries waste. Various biomass resources are available in India in different form. They can be classified simply in the way they are available in nature as: grasses, woody plants, fruits, vegetables, manures and aquatic plants. Algae and Jatropha are also now used for manufacturing bio-diesel. Core distinct sources of biomass energy can be classified as residue of agricultural crop, energy plantation and municipal and industrial waste [8]. Fig. 2 shows the various classification of biomass available in India.

2.1. Residue of agricultural crop

India has huge amount of agriculture land area, so massive residues are produced here. These residue contents the potential of biomass feedstock for the use of energy generation [9]. All the organic materials produced as the by-product from processing harvesting of agricultural crop are termed as agricultural residue. These agricultural residues can further be categorized as primary and secondary residue. Residue which is obtained in the field at the time of yield are field based or primary residue, whereas those are assembled during processing are defined as processing based or secondary residue [10]. Rice straw, sugar cane tops etc. are primary residue whereas rice husk and bagasse are example of secondary residue. Primary residues are also used as animal feed, fertilizers, etc. Therefore its availability for energy application is low. While secondary residues are obtained in large quantity at yielding site and can be confined as energy source. Based on survey and data collection, residues and their quantity available in India are complied in Table 1.

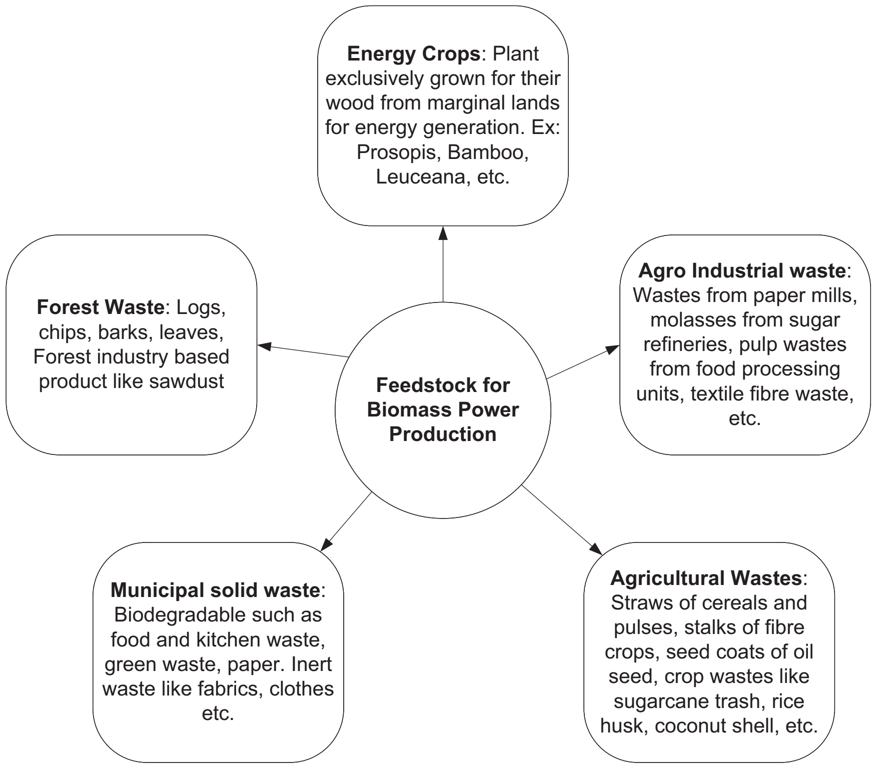

Fig. 2. Classification of available biomass resources in India.

Table 1
Indian renewable bio-feedstock's available for power generation [10].

Crop	Residues	Biomass potential (kt/yr)	Crop	Residues	Biomass potential (kt/yr)
Arecanut	Fronds, husk	1,000.8	Meshta	Stalks, leaves	1,645.5
Arhar	Stalks, husk	5,734.6	Moong	Stalks, husk	762.5
Bajra	Stalks, cobs, husk	15,831.8	Moth	Stalks	17.8
Banana	Residue	11,936.5	Mustard	Stalks, husk	8,657.1
Barley	Stalks	563.2	Niger seed	Stalks	94
Barseem	Stalks	71.6	Oilseeds	Stalks	1,143.1
Black pepper	Stalks	29.1	Onion	Stalks	66.5
Cardamom	Stalks	43.6	Others	Others	0.34
Cashew nut	Stalks, shell	189.4	Paddy	Straw, husk, Stalks	169,965.1
Castor seed	Stalks, husk	1,698.6	Peas and beans	Stalks	27.4
Casuarina	Wood	211.8	Potato	Leaves, stalks	887.3
Coconut	Fronds, husk, pith, shell	10,463.6	Pulses	Stalks	1,390.4
Coffee	Husk, pruning and wastes	1,591	Ragi	Straw	2,630.2
Coriander	Stalks	188.3	Rubber	Primary and secondary wood	2,492.2
Cotton	Stalk, husk, bollshell	52,936.5	Safflower	Stalks	539.3
Cow gram	Stalks	48.5	Sunnhemp	Stalks	14.1
Cumin seed	Stalks	182.6	Sawan	Stalks	0.22
Dry chilly	Stalks	268.6	Small millets	Stalks	600.1
Dry ginger	Residue	5.3	Soyabean	Stalks	9,940.2
Eucalyptus	Stalks	162.8	Sugarcane	Tops and leaves	12,143.9
Gram	Stalks	5,440.6	Sunflower	Stalks	1,407.6
Groundnut	Shell, stalks	15,120.4	Sweet potato	Stalks	12.8
Guar	Stalks	233.3	Tapioca	Stalks	3,959
Horse gram	Stalks	191.3	Tea	Sticks	909.8
Jowar	Cobs, stalks, husk	24,207.8	Til	Stalks	1,207.7
Kesar	Stalks	9.4	Tobacco	Stalks	204.8
Kodo millets	Stalks	3.13	Turmeric	Stalks	32.3
Linseed	Stalks	86.3	Urad	Stalks, husk	924.9
Maize	Stalks, cobs	26,957.7	Wheat	Stalks, panicle	112,034
Masoor	Stalks	600.3	**Total**		**511,041.39**

2.2. Agricultural feed-stocks-energy plantation

Due to dependency of large population of India on agriculture, cattle and livestock also survive on large scale. This makes the biomass potential availability of diverse kinds in Indian villages [11]. Crops that have been used for biomass power include the corn, sugarcane, grains, pulses, rubber, etc. [12]. Residues form crop obtained as biomass for energy application are dry and wet biomass. These crops differentiate themselves by several factors which enable them for considering as biomass potential like

Table 2
Zone wise distribution of available agro-feedstocks.
Source: EIA "A Market intelligence Report" September 2012.

Indian region	States	Available agro-feedstocks	Approximate cost range of feedstocks (Rs/t)
North-west	Rajasthan, Gujarat	Stalks of mustard, julieflora, maize, dhaniya, soybean, cotton, tuver and sesame	1300–2500
Central and South-west	Madhya Pradesh, Maharashtra	Cotton stalk, soy husks and mustards, maize stalks and chilly, rice husk, juliflora and bamboo	1500–2800
South	Andhra Pradesh, Karnataka, Tamilnadu, Kerala	Rice husk, juliflora, groundnut and coconut shell, bengal gram, chilly stalk, cane trash, maize and channa steam	1200–2500
North-east	Jharkhand, West Bengal	Wood chips, rice husk and sugar cane	1100–2600
North	Punjab, Haryana, Himachal Pradesh, Uttaranchal, Uttar Pradesh	Rice husk and straw, mustard stalk, straw and wheat husk, juliflora and cane trashes	1550–3000
Central and South-east	Orissa, Chattisgarh	Rice husk, cotton stalk, saw dust and juliflora	1100–2600

calorific value, moisture content, carbon proportion, ash content, etc. [13]. These properties are significant for wet and dry biomass conversion into useful energy. Research reported that the good potential crops have high yield of dry material. Prominent biomasses used currently as energy plantation are kadam, babul, bamboo, Julie flora, *Melia dubia* [14].

There are many others potential source of energy besides agricultural residue from farm and urban areas. The agro based industries, road side shrubs, plantation, vegetable market, road sweeping, etc. are the area where significant amount of biomass waste generates. As per Ministry of New and Renewable 200 million tones of agro processing and domestic wastes are generated annually in India and disposed in a distributed manner, because these areas are managed by poor farmers and the unorganized sector, rural worker and the low income small agro based industry sector [15]. Since this process is at no or little production costs therefore they are ignored and not utilized efficiently like major amounts of leafy wastes are burnt and cause air pollution. Table 2 shows the zone wise available agro-feedstocks and cost/t [16].

2.3. Biomass wastes—A potential feedstock for biomass power production

Large quantities of various biomass wastes are available in India. These wastes can be converted to the energy fuels called bio-fuels by bio-chemical as well as thermo-chemical conversion process [17].

Wastewaters and industrial wastes: Sewage and other wastes generate problems of water and soil pollution. Dumping has serious outcomes. In Organic decomposition of wastes on land, organic matter filters into the ground water or escape to surface waters spawning pollution which leads to health problems and fish mortality. Discharge from the industries such as black liquor from paper and pulp industry, milk processing units, breweries, vegetable packaging industry, and animal manure [18].

Food industry wastes: The hotel, restaurants and community kitchens produce a lot of waste such as vegetable flay, stale food e. g. uneaten bread, rice, vegetables, etc., from dish washer, fruit and vegetable rejects. Similarly, a large amount of wastes are produced from confectionary industry.

Solid wastes obtained from these industries are fruits and vegetables scrap, non standard food, pulp and fiber obtained from extraction of sugar and starch, filter sludge, etc. All these solid wastes make a potential feedstock for biogas generation by anaerobic digestion. These wastes are usually disposed off in landfill dumps [19].

Liquid wastes are generated by fruit and vegetables, meats washing process, cleaning of poultry and fish, wine making process. The wastewater contains dissolved organic matters like sugar, starch, etc. These industrial wastes are anaerobically digested to produce biogas and fermented to produce ethanol. Several commercial examples of waste-to-energy conversion already exist using these feed-stocks [20,21].

Animal wastes: Animal manure is principally composed of organic material, moisture and ash. Decomposition of animal manure can occur either in an aerobic or anaerobic environment. Under aerobic conditions, CO_2 and stabilized organic materials (SOM) are produced, while extra CH_4 is also produced under anaerobic conditions. Potential of CH_4 production is notable in India due to the more production of animal manure, which enables the huge energy potential [22].

Municipal solid waste: Millions of tones of household waste are collected each year with the vast majority disposed off in open fields. Major compositions of Municipal solid waste (MSW) are paper and plastic in India which are 80% of total MSW. Municipal solid waste can be converted into energy either using anaerobic digestion or direct combustion [23].

On the landfill sites the methane and carbon dioxide are produced by natural decomposition in 1:1 ratio. These gases are collected from the stored material and are swabbed and cleaned before feeding into IC engines or gas turbines to generate energy. The organic fractional part of MSW can be stabilized anaerobically in a high-rate biomass digester to obtain biogas for generation of steam and electricity [24,25].

Sewage: Sewage is also a source of biomass energy which is similar to the other animal wastes. Energy can be withdrawn from sewage by using anaerobic digestion process for the production of biogas [26].

There are some agencies and industries practicing the conversion of different biomass waste to energy in India and reported huge benefits from these. This clearly shows the enormous potential of conversion of various biomass wastes to energy in Indian scenario. Many of these technologies have profitably been implemented and are being used by industries by in-house energy saving, which increases their profits. Similar industries are adapting these technologies with the help of various government agencies e.g. MNRE (formerly known as MNES), academic institutions like Indian Institute of Science (IISc) and Indian Institutes of Technology (IITs), as well as certain non-government organizations [27].

There is large scope exists for the exploitation of bio-crops for their conversion to bio-fuels e.g. ethanol and bio-diesel, by thermo conversion as well as bio-chemical conversion routes. Apart from these energy crops, a huge potential exists for energy generation from the various industrial wastewaters by bio-chemical routes [28]. Similarly other biomass wastes e.g. wood wastes, crop residues, animal manures, and municipal wastes also bear a large potential for energy generation using bio-chemical as well as

Table 3
Source wise and state wise estimated potential of bio-energy in India as on 31.03.2013 [31].

States/UTs	Biomass power [MW]	Cogeneration-bagasse [MW]	Waste to energy [MW]	States/UTs	Biomass power [MW]	Cogeneration bagasse [MW]	Waste to energy [MW]
Andhra Pradesh	578	300	123	Nagaland	10	0	0
Arunachal Pradesh	8	0	0	Odisha	246	0	22
Assam	212	0	8	Punjab	3,172	300	45
Bihar	619	300	73	Rajasthan	1,039	0	62
Chhattisgarh	236	0	24	Sikkim	2	0	0
Goa	26	0	0	Tamil Nadu	1,070	450	151
Gujarat	1221	350	112	Tripura	3	0	2
Haryana	1333	350	24	Uttar Pradesh	1,617	1250	176
Himachal Pradesh	142	0	2	Uttarakhand	24	0	5
Jammu & Kashmir	43	0	0	West Bengal	396	0	148
Jharkhand	90	0	10	Andaman & Nicobar	0	0	0
Karnataka	1131	450	151	Chandigarh	0	0	6
Kerala	1044	0	36	Dadar & Nagar Have	0	0	0
Madhya Pradesh	1364	0	78	Daman & Diu	0	0	0
Maharashtra	1887	1250	287	Delhi	0	0	131
Manipur	13	0	2	Lakshadweep	0	0	0
Meghalaya	11	0	2	Puducherry	0	0	3
Mizoram	1	0	2	**All India total**	**17,538**	**5000**	**2707**

thermo-chemical routes. Thus biomass conversion to energy and fuels may be a quite rewarding in Indian scenario [29].

India has high potential of biomass about 500 metric tons per year availability. As per MNRE around 17,500 MW power can be generated by this available biomass and additional power about 5000 MW can be produce by surplus available biomass which is around 120–150 MT. Table 3 shows the state wise estimated potential of biomass as on 31.03.2013.

This surplus biomass can be collected from waste of various industries such as baggase in sugar mills. As on today around 550 sugar mills are available in India. Based on existing combustion technology in biomass, 4.5 EJ (105 Mtoe) of direct heat from the industrial and residential sectors, and 2 to 3 EJ (47 to 70 Mtoe) of heat from combined heat and power (CHP) plants are obtained [30]. As per MNRE, it is expected that 73,000 MW energy will be produce by 2032 using biomass as well as baggase cogeneration.

3. Installed potential of biomass energy in India

Total renewable energy based power generation was achieved 94,125 MW up to 31st March 2013. Out of which wind power contribute 52.20%, small hydro power 20.98%, biomass power 18.63%, cogeneration bagasse 5.31% and waste to energy contribute 2.88%. Biomass potential of different states is shown shows in Table 4. Punjab has highest potential for bio energy of 3517 MW in 2013 [31].

MNRE is promoting Biomass Gasifier based power plants for producing electricity using locally available biomass resources. These power plants are installed in rural areas where surplus biomass such as tiny wood chip, rice husk, arhar stalks, cotton stalks and other agro-residues are available to meet the unmet demand of electrical energy interlaid for lighting, water pumping and microenterprises counting telecom towers etc.

Various projects related to biomass power generation are installed in various state of India for fulfill energy requirement by biomass gasification. The leading state for biomass power projects are Chhattisgarh, Uttar Pradesh, Maharashtra, Andhra Pradesh and Tamil Nadu. The states which have taken position of leadership of baggase cogeneration projects are Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu and Uttar Pradesh. Table 5 shows state wise installation of off-grid/decentralized biomass energy system.

Table 4
State wise and source wise installed capacity of grid interactive biomass power [31].

States/UTs	Biomass power[MW]		States/UTs	Biomass power [MW]	
	March, 2012	March, 2013		March, 2012	March, 2013
Andhra Pradesh	363.25	380.75	Nagaland	–	–
Arunachal Pradesh	–	–	Odisha	20.00	20.00
Assam	–	–	Punjab	90.50	124.50
Bihar	15.50	43.30	Rajasthan	83.30	91.30
Chhattisgarh	249.90	249.90	Sikkim	–	
Goa	–		Tamil Nadu	532.70	538.70
Gujarat	20.50	30.50	Tripura	–	
Haryana	35.80	45.30	Uttar Pradesh	644.50	776.50
Himachal Pradesh	–		Uttarakhand	10.00	10.00
Jammu & Kashmir	–		West Bengal	16.00	26.00
Jharkhand	–		Andaman & Nicobar	–	–
Karnataka	441.18	491.38	Chandigarh	–	–
Kerala	–		Dadar & Nagar Have	–	–
Madhya Pradesh	8.50	16.00	Daman & Diu	–	–
Maharashtra	603.70	756.90	Delhi	–	–
Manipur	–	–	Lakshadweep	–	–
Meghalaya	–	–	Puducherry	–	–
Mizoram	–	–	**Total**	**3135.33**	**3601.03**

In baggase cogeneration we use waste of sugar mills known as baggase (The dry pulpy residue left after the extraction of juice from sugar cane, used as fuel for electrical energy generators by

Table 5
Installation of off-grid/decentralized biomass energy system as on 31.03.2013 [31].

State/UT	Biogas plants (nos.)	Biomass gasifiers (rural-industrial) (nos.)	State/UT	Biogas plants (nos.)	Biomass gasifiers (rural-industrial)
Andhra Pradesh	505,712	22,914	Nagaland	7,399	2,100
Arunachal Pradesh	3,472	750	Odisha	260,056	270
Assam	102,302	2,933	Punjab	155,289	–
Bihar	129,823	10,224	Rajasthan	68,647	2,464
Chhattisgarh	44,594	1,210	Sikkim	8,577	–
Goa	4,039	–	Tamil Nadu	220,861	11,762
Gujarat	426,374	21,530	Tripura	3,218	1,050
Haryana	58,577	1,963	Uttar Pradesh	435,554	23,702
Himachal Pradesh	46,949	–	Uttarakhand	16,535	1,400
Jammu and Kashmir	3,033	200	West Bengal	366,018	26,168
Jharkhand	7,237	500	Andaman & Nicobar	137	–
Karnataka	459,071	7,447	Chandigarh	97	–
Kerala	137,717	–	Dadar & Nagar Haveli	169	–
Madhya Pradesh	336,703	9,008	Daman & Diu	–	–
Maharashtra	843,011	7,150	Delhi	681	–
Manipur	2,128	–	Lakshadweep	–	250
Meghalaya	9,996	250	Puducherry	578	–
Mizoram	4,520	250	**Total**	**4669,074**	**155,495**

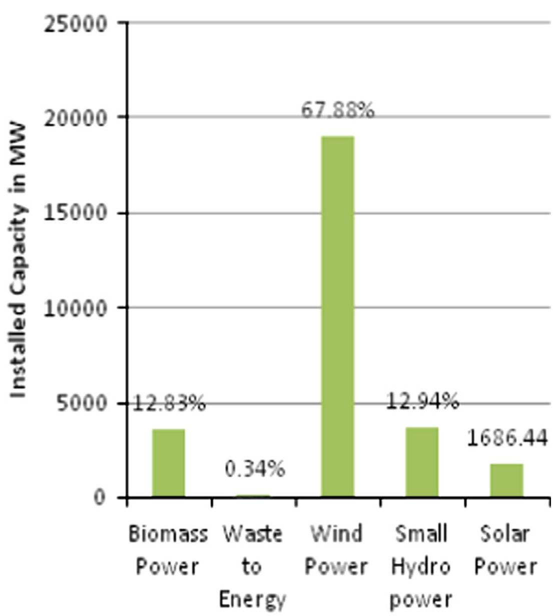

Fig. 3. Total installed capacity biomass power and other renewable powers, 31st March 2013.

gasification technology) by co generation sugar mill improve their audit of energy [32].

MNRE has installed 130 biomass power projects this is total aggregate to 999.0 MW and 158 bagasse cogeneration projects in sugar mills with additional capacity which aggregate to 1666.0 MW power to feed the grid. In addition, around 30 biomass power projects aggregating to about 350 MW are under various stages of execution. Approximately 70 Cogeneration projects are under implementation with surplus capacity aggregating to 800 MW [33]. Fig. 3 shows total installed capacity of biomass energy and another renewable energy on 31st March 2013.

The contribution of bio-energy to the total primary energy consumption in India is over 27%, mainly because biomass is used in a significant way in rural areas. Total contribution to bio-energy is 25,245 MW in power generation. However, the contribution of biomass to power production in India is less than 2%—currently, biomass comprises only about 3601 MW of installed capacity, out of a total of 17,500 MW of total biomass power installed capacity (May 2013).

4. Biomass energy conversion technologies

It is clear from the potential of biomass in India that various feedstocks are available for conversion to the bio-fuels as well as for power generation applications. The variety of processes exists for biomass conversions are depends on the type and quantity of biomass feedstock, environment and economic conditions etc.

Conversion of biomass to energy is undertaken using two main process technologies: thermo-chemical and bio-chemical/biological. Mechanical extraction (with esterification) is the third technology for producing energy from biomass, e.g. rapeseed methyl ester (RME) bio-diesel. The thermal conversion processes consist of pyrolysis, biomass gasification, combustion and liquefaction [34–36].

4.1. *Thermo-chemical conversion*

Three main processes are used for the thermo-chemical conversion of biomass i.e. combustion, gasification and pyrolysis [37].

4.1.1. *Combustion*

Combustion is the burning of biomass in air, and it is used to convert the chemical energy stored in biomass into heat energy, mechanical power and also in electricity by different process and devices e.g. furnaces, stoves, steam turbines, boilers, etc. It is possible to burn any type of biomass but in practice combustion is feasible only for biomass with a moisture content less than 50%, unless the biomass is pre-dried. High moisture content biomass is better suited to biological conversion processes [38].

The scale of combustion plant ranges from very small scale (e.g. for domestic heating) up to large-scale industrial plants in the range 100–3000 MW. Co-combustion of biomass in coal-fired power plants is an especially attractive option because of the high conversion efficiency of these plants.

Net bio-energy conversion efficiencies for biomass combustion power plants range from 20% to 40%. The higher efficiencies are obtained with systems over 100 MWe or when the biomass is co-combusted in coal-fired power plants. One heat engine cycle, the Stirling cycle, uses combustion to provide shaft power directly but the development of the cycle is presently limited to small power outputs.

4.1.2. *Gasification*

Gasification is the conversion of biomass into a combustible gas mixture by the partial oxidation of biomass at high temperatures, typically in the range 800–900 LC. The low calorific value (CV) gas produced can be burnt directly or used as a fuel for gas engines and gas turbines. The application of this produced gas can be used as a feedstock (syngas) for the production of chemicals like methanol [39].

One promising concept is the biomass integrated gasification/combined cycle (BIG/CC), where gas turbines convert the gaseous fuel to electricity with a high overall conversion efficiency. An important advantage of BIG/CC systems is that the gas is cleaned before being combusted in the turbine, allowing more compact and less costly gas cleaning equipment to be used, as the volume of gas to be cleaned is reduced. The combination of gasification and combustion ensures high conversion efficiency, producing net efficiencies of 40–50% for a plant of 30–60 MWel capacity.

The produced syngas from biomass is used for the production of methanol and hydrogen, which can be considered as fuels for transportation and others. In the methanol production, either oxygen blown or hydrogen indirect gasification process are preferred in production of methanol and the higher value CV gas (typically 9–11 $MJ=N\,m^3$) are produced by these processes.

4.1.3. Pyrolysis

Pyrolysis is the conversion of biomass to liquid (bio-oil or bio-crude), solid and gaseous fractions, by heating the biomass in the absence of air to around 500 LC. Pyrolysis can be used to produce bio-oil if flash pyrolysis is used, enabling the conversion of biomass to bio-crude with an efficiency of up to 80%. The bio-oil can be used in engines and turbines and its use as a feedstock for refineries is also being considered. But there are some problems which are still there to overcome such as corrosivity, less thermal stability. Upgrading bio-oils by lowering the oxygen content and removing alkalis by means of hydrogenation and catalytic cracking of the oil may be required for certain applications [40].

4.2. Bio-chemical conversion

Two main processes are used, fermentation and an-aerobic digestion, together with a lesser-used process based on mechanical extraction/chemical con-version.

4.2.1. Fermentation

Fermentation is used commercially on a large scale in various countries to produce ethanol from sugar crops (e.g. sugar cane, sugar beet) and starch crops (e.g. maize, wheat). The biomass is ground down and the starch converted by enzymes to sugars, with yeast then converting the sugars to ethanol. Purification of ethanol by distillation is an energy-concentrated step, with about 450 l of ethanol being produced by 1000 kg of dry corn. Solid residue obtained from this process can be given to cattle to feed and bagasse which is obtained from sugar cane can be used for next gasification or as a fuel for boilers [41].

The conversion of lignocellulosic biomass (such as wood and grasses) is more complex, due to the presence of longer-chain polysaccharide molecules and requires acid or enzymatic hydrolysis before the resulting sugars can be fermented to ethanol. Such hydrolysis techniques are currently at the pre-pilot stage.

4.2.2. Anaerobic digestion

In Anaerobic digestion (AD) organic material is directly converted to a gas which is termed as biogas. It is a mixture of mainly methane and carbon dioxide with small quantities of other gases such as hydrogen sulphide. The biomass is converted in anaerobic environment by bacteria, which produces a gas with an energy of about 20–40% of the lower heating value of the feedstock [42]. AD is a commercially proven technology and is widely used for treating high moisture content organic wastes, i.e. 80-90% moisture. Biogas can be used directly in spark ignition gas engine (s.i.g. e.) and gas turbines and can be upgraded to higher quality i.e. natural gas quality, by the removal of CO_2. The overall conversion efficiency can be 21% [43]. As with any power generation system using an internal combustion engine as the prime mover, waste heat from the engine oil and water-cooling systems and the exhaust could be recovered using a combined heat and power system.

4.3. Mechanical extraction

Extraction is a mechanical conversion process in which oil is produced from the seeds of various biomass crops such as groundnuts, cotton, etc. The process produces not only oil but also a residual solid or 'cake', which is suitable for animal fodder. Three tons of rapeseed is required per ton of rape-seed oil produced. Rapeseed oil can be processed further by reacting it with alcohol using a process termed esterification to obtain [44].

5. Indian biomass energy conversion policy

In recent years, India's energy consumption has been increasing at a relatively fast rate due to population and economic growth. With rapid urbanization and improving standards of living for millions of Indian households, the demand is likely to raise a lot. Therefore, Govt. of India is now making various planning and policies in energy sector. Since Sustainable Development is now the key target of the world, therefore Renewable Energy Resources are considering for power generation. Ministry of New & Renewable Energy of India has developed many project and policies in this field and promoting to adopt these methodologies by providing various subsidies and incentives [45,46].

In the 12th five year plan period government is allocating total Rs. 46.00 crores for biomass Gasifier scheme which includes the promotional and other administrative activities.

Programs implementation during 12th five year plan period has included the following components:

→ Off-grid/distributed power program based on Biomass Gasifier, to be implemented for rural areas to fill the unmet demand of electricity.
→ 100% engines based on producer gas are supported at MW level in Biomass gasifier based grid connected power program.
→ Boiler Turbine Generator (BTG) based on biomass, would be supported with maximum acceptable capacity of 2 MW.
→ Programs also cover promotional activities, publicity, seminars/training programs etc.

Indian Government providing many types of subsidies for promoting the growth of bio power market. They are making various patterns to attract investor in bio power market, in both types of schemes i.e. off grid and on grid. MNRE providing various types of subsidies for, private and government sector [47].

5.1. Subsidy for generation based projects

MNRE, Government of India, is administering a MNRE—UNDP/GEF assisted Project on "Removal of Barriers to Biomass Power Generation in India". The objective of the Project is to increase the use of environmentally sustainable biomass power and cogenerations based technologies in the country and enhance electricity supply through renewable energy sources.

The proposals are invited by MNRE for establishment of Model Investment Projects (MIPs) based on gasification technology, which should be of minimum 1 MW capacity using 100% producer gas engines for generation of grid interactive power. The proposals of higher capacity can be considered on merit such as innovative technology configuration/power utilization pattern; economy of scale etc.

Financial supports are provided for MIPs based on installed capacity as per details given below [48]:

a. Grid connected power projects with 100%: Rs 150 lakh/MW producer gas engine of at least 500 KW each.
b. Creation of infrastructure for fuel supply linkages, Rs 30 lakh/MW evacuation of energy, biomass drying, utilization of char etc.
c. 50% cost of the plant and machinery subject to max of Rs 20 lakh towards installation of Vapor Absorption Machine (VAM) for cooling/chilling and steam generating system from waste heat.

5.2. Subsidy for cogeneration based projects

Scope of Co-generation by biomass is to meet the requirement of captive power and thermal power. The setting up of biomass co-generation projects (excluding bagasse co-generation) is to be promoted in industry, with at least 50% of power for confined use, and a stipulation for the surplus power to be selling to grid. This will amplify the use of non-conventional energy sources and conserve the use of fossil fuels such as natural gas, coal and oil.

5.3. Central financial assistance and fiscal incentives

The Ministry of New and Renewable Energy (MNRE) provides Central Financial Assistance (CFA) in the form of capital subsidy and financial incentives to the biomass energy projects in India. CFA is fixed to the projects on the basis of installed capacity, energy production mode and its application etc. Economic support will be made accessible selectively through a transparent and competitive procedure.

The government provides a onetime capital subsidy based on the installed capacity of the project. The entire capital subsidy amount is transferred directly to the lead bank/lending financial institution for the purpose of offsetting the loan amount after winning commissioning of project. In case the project is situated by the promoters through their personal resources, the CFA would be transferred directly to promoters after thriving commissioning of the project. Table 6 shows the various financial supports given by MNRE.

Besides the Central Financial Assistance mentioned in Table 6, other incentives are also offer by MNRE for Biomass Power projects this is shown in Table 7. Various types of relaxation are provide in custom duty and taxes.

6. International acceptance of biomass

By the end of 2012, global bio-power capacity was approaching 83 GW, up 12% over 2011, with notable increases in some of the BRICS countries [49]. Around 350 TW h of electricity was generated worldwide in 2012, a 5% increase over the previous year. Averaging national bio-power generation outputs over the phase 2010–2012, the United States had a significant lead, with Germany second, chased closely by Brazil and China, both of which are gaining ground quickly (Fig. 4). Almost 90% of biopower is generated with solid biomass fuels. Landfill gas, biogas, synthesis gas (also known as syngas), and liquid biofuel are also usually used for bio-power generation and make up the remaining 10% [50].

Table 6
Method of Central Financial Assistance (CFA) for various components [11].

S. nos.	Items	Pattern of CFA
i.	Distributed/off grid power projects in rural areas and grid connected power projects with 100% producer gas engines or biomass based combustion projects	Rs. 15,000 per kW
ii	Biomass gasifier projects for distributed/off-grid for rural areas and grid connected power projects for ensuring regular accessibility of biomass, provision of collection, processing and storage and operation and maintenance including compulsory AMC for 5 years after the guarantee period	Rs. 1.50 lakh per 50 kW
iii	Support towards lighting devices and distribution Network	Financial support limited to a maximum of 3 km i.e. Rs. 3.00 lakh per project (@ Rs. 1.00 lakh per km)
iv	Support towards project formulation	Financial incentives of Rs. 5000/- per projects to the banks/FIs, manufacturers, promoters, consultants and service providers for developing firmed up and bankable proposals for a minimum of 10 projects or above
v	Service charges for verification and certification	Rs. 10,000/- per 100 kW subject to maximum of Rs.1.00 lakh for a project of 1 MW capacity. A minimum service charge would be Rs.10,000/- per site
vi	Preparation of detailed project report (DPRs) for centralized distributed/grid connected/captive power generation project:	Rs. 1.00 lakh
	– Projects among 100–500 kW capacities	Rs. 0.50 lakh
	– Projects above 500 kW capacities	
	– DPR is not required for the projects below 100 kW capacities	
vii	HRD and training	– @Rs.2.00 lakh per course – @Rs.3.00 lakh per course
	– O&M technician's course – Gasifier entrepreneur expansion course – consciousness promotions such as organization of seminars, business meets, workshops etc.	Maximum upto Rs. 3.00 Lakh
viii	Support for gasifier manufacturers/suppliers for establishing service centers in areas where cluster of systems, minimum 10, have been set up in one district/region	Rs. 5.00 lakh (One-time funding)
ix	Special category states and Islands	20% Higher CFA

Table 7
Other fiscal incentives for biomass power generation [11].

Item	Description
Accelerated depreciation	80% Depreciation in the first year can be claimed for the following equipment required for co-generation systems: 1. Back pressure, pass-out, proscribed extraction, extraction-cum-condensing turbine for co-generation with pressure boilers 2. Vapor absorption refrigeration systems 3. Organic rankine cycle power systems 4. Low inlet pressures small steam turbines
Income tax holiday	Ten years tax holidays
Customs/excise duty	Concessional customs and excise duty exemption for machinery and components for initial setting up of biomass power projects
General sales tax	Exemption is accessible in certain States

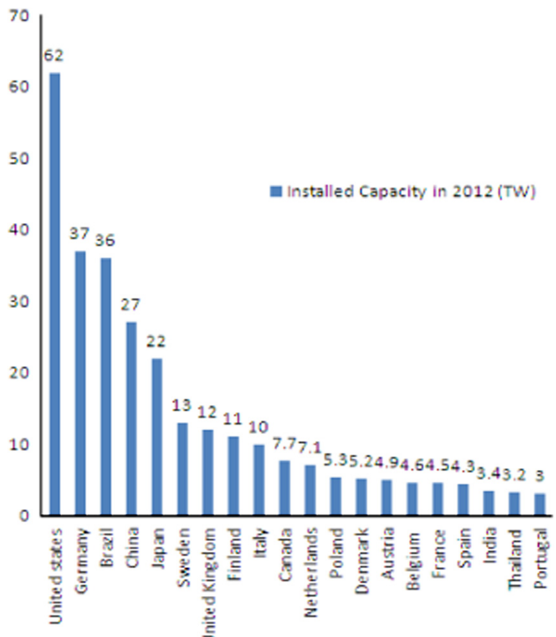

Fig. 4. International status of power production [40].

In the United States, 100 bio-power projects (543 MW) came on line in 2012, bringing total capacity to 15 GW—about 18% of the global total 42 Net bio-power generation increased from 60.5 TW h in 2011 to 65.0 TW h in 2012 [51]. Germany, Europe's leading bio-power producer, increased its generation by 11% to 41 TW h, with half of this coming from biogas plants. In Asia, China increased its capacity by around 14% to 8 GW by the end of 2012 and saw generation increase 21% to 36 TW h. Japan's capacity remained at 3.3 GW but generation declined 8% to 17.2 TW h. India leads the world in total capacity of small gasifiers for electricity generation, with a capacity exceeding 155 MW [52]. At the end of 2012, India had approximately 1.3 GW of solid biomass and MSW-fired power capacity, as well as more than 2.7 GW of CHP capacities.

The biomass power plants market will grow throughout the world in the future. 3500 biomass power plants will be operational in 2020. This makes the growth of almost 50% in 8 years. Similar increment can be soon in the installed biomass power capacities as they will increase from 37.5 GWel at present to almost 55 GWel in 2020. The increasing subsidization of renewable energies is the main reason for this growth internationally. Biomass has a special status among the renewable energies as generating energy from biomass can follow the demand—contrary to the energetic use of sun or wind. More and more countries want to increase their dependency on renewable energy sources for improve economy and environment. They are creating the necessary framework conditions for a fast growth of the biogas industry.

7. Conclusions

A robust analysis of the resources and potential of biomass has been presented. It can be concluded that huge potential exist for exploration of available biomass in India to convert it to energy. Various resources in wide variety and different form of biomass are available in India. Diverse sources are there to obtain waste biomass e.g. agricultural waste, food wastes, industrial wastewaters generated in large volumes which hints the tendency to switch over to non conventional source of energy. Agencies and industries are practicing the conversion of different waste biomass to energy in India and reported benefits from these. MNRE showed the huge potential data of installed capacity and surplus biomass.

At present two major technologies are being used to convert biomass into energy; thermo-chemical and bio-chemical. Selection of conversion technologies for biomass depends upon the form in which the energy is required like combustion produce heat, mechanical, electricity energy; pyrolysis, fermentation and mechanical extraction produce liquid fuels suitable for use as transportation fuels etc. Gasification processed biomass to form syngas.

Various projects related to biomass power generation are installed in various state of India for fulfill energy requirement by biomass gasification. The states are also generating power by baggase cogeneration which uses the waste of sugar mills. A number of power generation projects are already proved successful in India based on gasification based cogeneration rural electrification plants. These plants have not only solved the rural electrification problem for the remote villages, where infrastructural costs could have been quite high for conventional electrification, but also the power generation cost has also been relatively low. The prime motto of Govt. to provide the subsidy or providing financial assistance is to encourage the use of non conventional sources of energy, which helps in sustainable development of nation.

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