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Harnessing Biomass Energy for a Sustainable Future: A Review

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ABSTRACT

Biomasses are one of the most important renewable carbon-negative alternative sources of energy. Biomass energy is one of the best alternatives to be used as a substitute for fossil fuels. Biomass functions as a sort of natural battery for storing solar energy. Biomass derived energies are clean because biomass contains low N and S contents compared to the fossil fuels. Further, use of biomass energy is a 'no-net' carbon emission process. Hence, use of biomass energy offers a win-win situation. In this paper, we tried to emphasize the present and future scenario of biomass-based energy with a special emphasis on Indian perspective. The available technologies, government policies and already existing market have been discussed in this review. Biomass energy holds the key of possibility to light every household which have no access to power. Biomass energy is the one of the best way to a sustainable energy system of the future.

Keywords: Renewable energy, biomass energy, classification, prospects

Energy is the driving power to run human civilization and civilization is progressing in accelerating speed. If coal drove the industrial revolution, oil fuelled the internal-combustion engine, aviation and the 20th century notion that mankind's possibilities are limitless; it flew people to the Moon and beyond. Among the energy sources, oil has changed history. The past 100 years have been pockmarked with oil wars, oil shocks and oil spills (Hall *et al.* 1993; Woods and Hall, 1994; Ministry of New and Renewable Energy, 2010-11). And even in the 21st century its dominance remains entrenched. It may have sped everything else up, but the rule of thumb in energy markets is that changing the fuel mix is a glacial process (Fig. 1). Near its peak at the time of the Arab oil embargo in 1973, oil accounted for 46% of global energy supply. In 2014 it still had a share of 31%, compared with 29% for coal and 21% for natural gas.

The world's increasing dependence on foreign oil poses problems for the economy that go far beyond those associated with oil deficits, oil prices, and volatility. Tenuous links to geopolitics have been made in the debate about our ability to quench our thirst for oil. The world is facing an energy crisis of immense proportions as cheap oil availability is coming to an end. Petroleum resources of most of the non-OPEC (Organisation of Petroleum Exporting Countries) countries have already peaked or are going to peak in the near future. The oil production from Indian facilities has already peaked in 1995 and the production will be lower while India witnesses steep increases in demand. The oil production from the non-OPEC countries is going to decline from now onwards and as a result, the world will be entering a regime dominated by OPEC countries. Global oil production on a per capita basis is consistently declining at a rate of 1.20 per cent per year since 1979 oil resources around the world and soon the world may face a grim energy challenge as far as petroleum resources are concerned. This rate is bound to dip steeply in view of peaking oil resources around the world and soon the world may face a grim energy challenge as far as petroleum resources are concerned. One of the ways to ensure energy security is to invest in developing renewable sources of energy (Grubler and Nakicenovic, 1988; Pathak, 2006; Gadde *et al.* 2009).

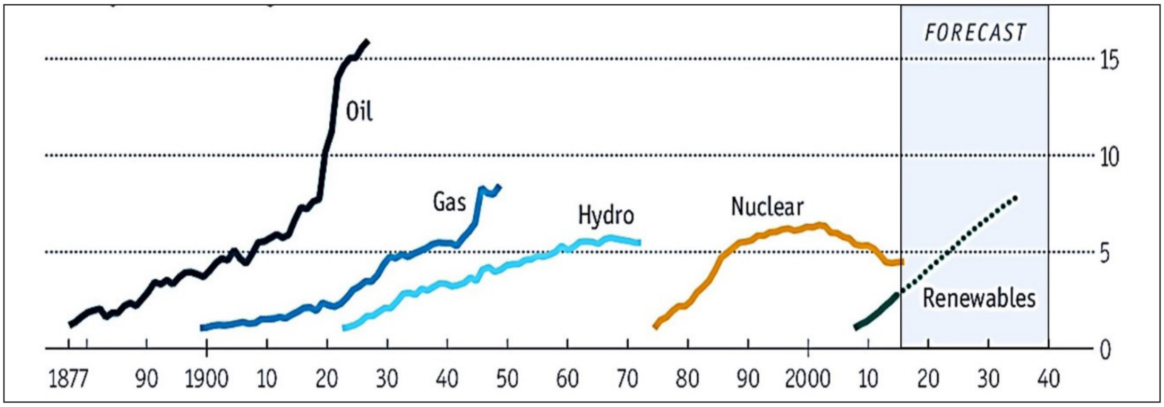

Fig. 1: Percent share of global primary-energy consumption (*Source*: BP,www.Economist.com)

Energy production scenario in India

The average electricity consumption in India is still among the lowest in the world at just 630 kWh per person per year, but this is expected to grow to 1000 kWh in the near future (FAO, 1981; FAO, 1986; NCAER, 1992; Sinha *et al.*, 1994; FAO, 1996). According to Central Electricity Authority (CEA), the peak electricity demand in 2008 was 120 GW of power, while only 98 GW could be supplied. According to an analysis by the Indian PV project developer Astonfield, this deficit is likely to grow to 25 GW by 2012. The Ministry of Power has set an agenda of providing "Power to All" by 2012. India's current installed capacity (end of 2010): 1,70,229 MW, from all sources. Power generation capacity is mainly based on thermal and hydro, with about 11% from renewable energy. In 2010, peak power shortage was 12 %.Electricity demand is expected to rise by 7.4% a year during the next quarter of a century. This will see generation capacity increase five-fold in India is to supply this growing demand. As of Feb 2011, India has over 18.3 GW of installed renewable energy capacity. Wind represents about 13 GW, small hydro represents 2.8 GW, and the majority of the remainder is from biomass installations.

Renewable energy in India

Renewable energy technologies are ideally suited to distributed applications, and they have substantial potential to provide a reliable and secure energy supply as an alternative to grid extension or as a supplement to grid-provided power. Over 400 million people in India, including 47.5% of those living in India's rural areas, still had no access to electricity. Because of the remoteness of much of India's un-electrified population, renewable energy can offer an economically viable means of providing connections to these groups. There is significant potential in India for generation of power from renewable energy sources, such as wind, small hydro, biomass, and solar energy (Yevich and Logan, 2003). Therefore, special emphasis has been laid on the generation of grid quality power from renewable sources of energy. In the past ten to twelve years, the capacity of small hydro projects up to 3 MW (megawatt) has increased fourfold from 63 MW to 240 MW. There exists an established potential of 19,500 MW, including 3,500 MW of exportable surplus power from bagasse-based cogeneration in sugar mills and 16,000 MW of grid quality power from other biomass resources. Grid-interactive solar photovoltaic power projects aggregating to 2.49 MW have so far been installed and other projects of 0.8 MW capacity are under installation. The wind power development in the country has been spurred by a mix of fiscal incentives and promotional measures. Consequently, generation from wind power projects has been increasing overtime from 0.03 BkWh (billion kilowatt hour) in 1970 to 2.2 BkWh in 2002 (Reddy, 2003).

Potential of Biomass for Rural Energy

The term 'biomass' is used to describe all organic matter produced by photosynthesis, existing on the earth's surface. Worldwide photosynthesis activities are estimated to store 17 times as much energy as is consumed annually by all nations of the world. Through the process of photosynthesis, chlorophyll in plants captures the sun's energy by converting carbon dioxide from the air and water from the ground into carbohydrates, i.e., complex compounds composed of carbon, hydrogen, and oxygen. When these carbohydrates are burned, they turn back into carbon dioxide and water and release the sun's energy they contain. In this way, biomass functions as a sort of natural battery for storing solar energy.

The harnessing energy from biomass has played a significant role in the evolution of human civilization (Joshi *et al*. 1992; Ravindranath and Hall, 1995; Pathak, 2006; Gadde *et al*. 2009). Until relatively recently, it was the only form of energy which was usefully exploited by humans and still more than half the world's population use biomass as a source for domestic energy needs. One of the simplest forms of biomass is a basic open fire used to provide heat for cooking, warming water or warming the air in our home. More sophisticated technologies exist for extracting this energy and converting it into useful heat or power in an efficient way. Biomass also is the only renewable energy source that releases carbon dioxide in use. However, the release is compensated by the fact that the biomass grown uses the carbon dioxide from the atmosphere to store energy during photosynthesis. If the biomass resource is being used sustainably, there are no net carbon emissions over the time frame of a cycle of biomass production.

Biomass can be classified into two types: woody and non-woody. Non-woody biomass comprises agro-crops and agro-industrial processes residue. Municipal solid waste or MSW, and animal and poultry wastes are also referred to as biomass as they are biodegradable in nature. The main biomass sources are:

1. Wood and saw dust.
2. *Agriculture residues:* rice husk, bagasse, groundnut shells, coffee husk, straws, coconut shells, coconut husk, arhar stalks, jute sticks and so on.
3. *Aquatic and marine biomass:* Algae, water hyacinth, aquatic weeds and plants, sea grass beds, kelp, coral reef, and so on.
4. *Wastes:* MSW, municipal sewage sludge, animal waste, industrial waste and so on.

Due to the variety and diversity of biomass, sufficient data and documentation regarding availability and consumption/utilization patterns is not easily available. Although biomass meets a major part of the total energy requirement, it does not find an appropriate place in the overall energy balance of India. Biomass residue generated by different crops was grouped in four categories based on the type of crop, namely cereals (rice, wheat, maize, jowar, bajra, ragi and small millets), oilseeds (groundnut and rapeseed mustard), fibers (jute, mesta and cotton) and sugarcane (Street *et al.* 2003; Sahai *et al.* 2011; Jain *et al.* 2014). The amount of crop residue generated was estimated as the product of crop production, residue to crop ratio and dry matter fraction in the crop biomass. The residue to grain ratio varied 1.5–1.7 for cereal crops, 2.15–3.0 for fiber crops, 2.0–3.0 for oilseed crops and 0.4 for sugarcane. Total amount dry crop biomass residue generated by nine major crops was 620.4 Mt (Table 1).

Table 1: Crop wise production and generation of biomass residue (in Mt)

Crop	Annual production	Dry biomass generated	Biomass residue to crop ratio	Dry matter fraction	Fraction burnt
Rice paddy	153.35	192.82	1.50	0.86	0.08–0.8#
Wheat	80.68	120.70	1.70	0.88	0.1–0.23*
Maize	19.73	26.75	1.50	0.88	0.10
Jute	18.32	31.51	2.15	0.80	0.10
Cotton	37.86	90.86	3.00	0.80	0.10
Groundnut	7.17	11.44	2.00	0.80	0.10
Sugarcane	285.03	107.50	0.40	0.88	0.25
Rapeseed & Mustard	7.20	17.28	3.00	0.80	0.10
Millets	18.62	21.57	1.50	0.88	0.10

There was a large variation in crop residues generation across different states of India depending on the crops grown in the states, their cropping intensity, and productivity. Generation of cereal crop residues was highest in the states of Uttar Pradesh (72 Mt) followed by Punjab (45.6 Mt), West Bengal (37.3 Mt), Andhra Pradesh (33 Mt) and Haryana (24.7Mt). Uttar Pradesh contributed maximum to the generation of residue of sugarcane (44.2 Mt) while residues from fibre crop was dominant in Gujarat (28.6 Mt) followed by West Bengal (24.4 Mt) and Maharashtra (19.5 Mt). Rajasthan and Gujarat generated about 9.26 and 5.1 Mt residues respectively from oilseed crops. Rajasthan, Punjab, Maharashtra and Haryana are states with high biomass potential. Together, they comprise close to 50% of the total estimated potential for biomass in India. Table 2 shows availability of various biomasses in different states of India and Table 3 indicated the seasonal availability of biomass. Table 4 represents the elemental analysis and calorific values of some biomasses. The biomasses with higher/H and O/C ratio are better for energy purpose.

Table 2: State wise availability of crop biomasses in India

States	Availability of Crop biomass residue (mainly stalk)							
	Arhar	Maize	Maize cobs	Cotton	Mustard	Jute & Mesta	Rice husk	Groundnut shell
Andhra Pradesh	√	√	√	√	√	√	√	√
Assam	X	X	X	X	X	√	√	X
Bihar	√	√	√	X	X	√	√	X
Gujrat	√	√	√	√	√	X	X	√
Haryana	X	X	X	√	√	X	√	X
Himachal Pradesh	X	√	√	X	X	X	X	X
J&K	X	√	√	X	X	X	X	X
Kerala	X	X	X	X	X	X	√	
Karnataka	√	√	√	√	X	X	√	√
Madhya Pradesh	√	√	√	√	√	X	√	√
Maharastra	√	X	X	√	X	√	√	√
Orissa	√	X	X	X	X	√	√	√
Punjab	X	√	√	√	√	X	√	X
Rajasthan	X	√	√	√	√	X	X	X
Tamil Nadu	√			√		X	√	√
Uttar Pradesh	√	√	√	X	√	X	√	X
West Bengal	X	X	X	X	√	√	√	X

√ = Available; X = Not available.

Methods for harnessing biomass energy

More than 70% of India's population depends on biomass and about 32% of the total primary energy use in the country mainly in rural areas is still derived from biomass. Biomass can be converted to thermal energy, liquid, solid or gaseous fuels and other chemical products through a variety of conversion processes. Biopower technologies are proven electricity-generation options in the United States, with 10GW of installed capacity. Generally, the prominent biopower technologies are comprised of direct combustion, co-firing, gasification, pyrolysis, anaerobic digestion, and fermentation (Frisch, 1993; Johansson *et al*. 1996; Reddy *et al*. 1997).

(a) Direct Combustion

This is the simplest method of extracting energy from biomass. Industrial biomass combustion facilities can burn many types of biomass fuel, including wood, agricultural residues, wood pulping liquor, municipal solid waste (MSW) and refuse-derived fuel. Biomass is burned to produce steam, the steam turns a turbine and the turbine drives a generator, producing electricity. Because of potential ash build-up (which fouls boilers, reduces efficiency and increases costs), only certain types of biomass materials are used for direct combustion.

(b) Gasification

Gasification is a process that exposes a solid fuel to high temperatures and limited oxygen, to produce a gaseous fuel. The gas produced by the process is a mix of gases such as carbon monoxide (18-22%), carbon dioxide (8-12%), hydrogen (8-12%), methane (2-4%), and rest is nitrogen (45-50%). This is known producer gas. The gas is then used to drive a high efficiency, combined-cycle gas turbine. Gasification has several advantages over burning solid fuel. One is convenience – one of the resultant gases, methane, can be treated in a similar way as natural gas, and used for the same purposes. Another advantage of gasification is that it produces a fuel that has had many impurities removed and could therefore cause fewer pollution problems when burnt. Under suitable circumstances, it can also produce synthesis gas, a mixture of carbon monoxide and hydrogen which can be used to make hydrocarbon (e.g., methane and methanol) for replacing fossil fuels. Hydrogen itself is a potential fuel without much pollution which can conceivably substitute oil and petroleum in a foreseeable future.

Producing gas from biomass consists of the following main reactions, which occur inside a biomass gasifier.

Table 3: Seasonal availability of crop biomasses in India

Residue	Availability											
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Arhar stalk	■	■	■						■	■	■	■
Maize stalk						■	■	■	■	■	■	
Maize cobs						■	■	■	■	■	■	
Cotton stalk	■	■	■						■	■	■	■
Mustard stalk			■	■	■							
Jute & Mesta sticks						■	■	■	■	■	■	
Rice husk			■	■	■	■	■	■	■	■	■	
Groundnut shell				■	■				■	■	■	■

Table 4: Elementary analysis and calorific values of various biomasses

Biomass	%C	%H	%O	%N	%S	Calorific value (Mj/kg)	C/H	O/C
Coconut shell	50.22	5.7	43.37	0	0	20.49	8.811	0.864
Cotton stalk	39.47	5.07	38.09	1.25	0.02	19.23	7.785	0.965
Bagasse	44.8	5.35	39.55	0.38	0.01	17.33	8.374	0.883
Rice husk	39.92	5.1	37.89	2.17	0.12	15.67	7.827	0.949
Saw dust	47.13	5.86	40.35	0.65	0.16	19.97	8.043	0.856
Corn cob	49	5.4	44.6	0.4	0	17	9.074	0.910
Groundnut shell	45.72	5.96	43.41	0	0	19.2	7.671	0.949
Castor seed shell	44.25	5.64	42.8	—	—	17.6	7.846	0.967
Wallnut shell	53.5	6.6	41.5	1.1	0.06	18.86	8.106	0.776
Almond shell	47.8	6	41.5	1.1	0.06	18.86	7.967	0.868
Sunflower shell	47.4	5.8	41.3	1.4	0.05	18.23	8.172	0.871
Wheat straw	45.5	5.1	34.1	1.8	0	17	8.922	0.749
Rice straw	35.97	5.28	43.08	0.17	—	14.55	6.813	1.198
Tea bush	47.67	6.13	43.16	1.33	—	19.84	7.777	0.905

- *Drying:* Biomass fuels usually contain 10%–35% moisture. When biomass is heated to about 100 °C, the moisture is converted into steam.
- *Pyrolysis:* After drying, as heating continues, the biomass undergoes pyrolysis. Pyrolysis involves burning biomass completely without supplying any oxygen. As a result, the biomass is decomposed or separated into solids, liquids, and gases. Charcoal is the solid part, tar is the liquid part, and flue gases make up the gaseous part.
- *Oxidation:* Air is introduced into the gasifier after the decomposition process. During oxidation, which takes place at about 700–1, 400 °C, charcoal, or the solid carbonized fuel, reacts with the oxygen in the air to produce carbon dioxide and heat.

  $C + O_2 \rightarrow CO_2 + \text{heat}$
- *Reduction:* At higher temperatures and under reducing conditions, that is when not enough oxygen is available, the following reactions take place forming carbon dioxide, hydrogen, and methane.

  $C + CO_2 \rightarrow 2\,CO$

  $C + H_2O \rightarrow CO + H_2$

  $CO + H_2O \rightarrow CO_2 + H_2$

  $C + 2H_2 \rightarrow CH_4$

Biomass gasifiers are appropriate for smaller capacities (few kilowatt to say 1-2 MW) and for decentralized application to exploit local renewable biomass (agro-residue as well as woody) potential. In India, gasifier technology is available and successfully field demonstrated at sub megawatt level capacities. Following are indicative performance norms, which can vary depending on fuel type, its properties and the design of various system components and its operation:

- Calorific value of producer gas: Approximately 1,000–1,200 kCal/Nm^3.
- Specific gasification rate: Approximately 2-3 Nm^3 producer gas per kilogram of air-dried biomass.

Indicative performance of a gasifier-based system to produce electricity:

- Approximately 0.9–1.1 kg biomass and 90–110 mL diesel per kWh electricity in dual-fuel engines.
- Approximately 1.2–1.6 kg biomass per kWh electricity in engines run only on producer gas.

(c) Pyrolysis

Pyrolysis is a process in which represents heating the biomass to drive off the volatile matter and leaving behind the charcoal. This process has doubled the energy density of the original material because charcoal, which is half the weight of the original biomass, contains the same amount of energy, making the fuel more transportable. The charcoal also burns at a much higher temperature than the original biomass, making it more useful for manufacturing processes. More sophisticated pyrolysis techniques are developed recently to collect volatiles that are otherwise lost to the system. The collected volatiles produce a gas which is rich in hydrogen (a potential fuel) and carbon monoxide. These compounds are synthesized into methane, methanol, and other hydrocarbons.

The two main methods of pyrolysis are “fast” pyrolysis and “slow” pyrolysis. Fast pyrolysis yields 60% bio-oil, 20% biochar, and 20% syngas, and can be done in seconds, whereas slow pyrolysis can be optimized to produce substantially more char (~50%) along with organic gases but takes on the order of hours to complete. In either case, the gas or oil can be used as a fuel for firing the boiler for steam production and subsequent power production.

Typically, pyrolysis plants work well beyond 2 MW scale, while gasification plants work well until 2 MW scale, at the current technological progress. Thus, it can be said that pyrolysis takes off where gasification ends.

(d) Digestion

Biomass digestion works by utilizing anaerobic bacteria. These microorganisms usually live at the bottom of swamps or in other places where there is no air, consuming dead organic matter to produce biogas (a 40%-75% methane-rich gas with CO_2 and a small amount of hydrogen sulphide and ammonia). By feeding organic matter such as animal dung or human sewage into tanks, called digesters, and adding bacteria, we collect the emitted gas to use as an energy source. This process is a very efficient means of extracting usable energy from such biomass. Usually, up to 2/3 of the fuel energy of the animal dung could be recovered. Another related technique is to collect methane gas from landfill sites. A large proportion of household biomass waste, such as kitchen scraps, lawn clipping and pruning, ends up at the local tip. Over a period of several decades, anaerobic bacteria at the bottom of such tips could steadily decompose the organic matter and emit methane. The gas can be extracted and used by capping a landfill site with an impervious layer of clay and then inserting perforated pipes that would collect the gas and bring it to the surface.

(e) Fermentation

Over centuries, yeasts and other microorganisms have been used to ferment the sugar of various plants intoethanol. Producing fuel from biomass by fermentation is just an extension of this process, although a wider range of plant material from sugar cane to wood fiber can be used. For instance, the waste from a wheat mill in New South Wales is used to produce ethanol through fermentation. Ethanol is then mixed with diesel to produce diesel, a product used by trucks and buses in Australia. Technological advances will inevitably improve the method. For example, scientists in Australia and the U.S. have substituted a genetically engineered bacterium for yeast in the fermentation process. The process has vastly increased the efficiency by which waste paper and other forms of wood fiber is fermented into ethanol. Bio-ethanol made from corn, has been blended with gasoline to improve vehicle performance and reduce air pollution. Similarly, biomass-derived methanol is produced through gasification. The biomass is converted into a synthesis gas (syngas) that is processed into methanol. Most of the 1.2 billion gallons of methanol annually produced in the U.S. are made from natural gas and used as solvent, antifreeze, or to synthesize other chemicals. About 38 percent is used for transportation as a blend or in reformulated gasoline. Biodiesel fuel, made from oils and fats found in micro-algae and other plants, is substituted for or blended with diesel fuel.

Benefits of biomass energy

- Distributed generation –Biomass is available in almost all places, and especially in rural areas, and more important, as gasification-based power production can be done on small scales (as low as 20 kW), this process can be used for distributed generation of power as against the centralized power production method followed today.
- Base load power – Many renewable energy sources such as solar and wind cannot be used for base load power generation due to their intermittency and variability. Biomass based power generation, on the other hand, can be used for base load power generation.
- Suited for rural areas – Biomass based power is well suited to remote villages with no access to grid but access to significant amounts of biomass
- Ability to have small (kW) scale power production – Biomass gasification-based power production can be done at small scales – as small as 20 kW – unlike other sources of power (say, nuclear) that require much larger scales. This will ideally suit small villages that have only a few households.
- Rural economic upliftment - The possibility of increasing the prosperity of rural areas especially if dedicated energy crops become common for biomass-based power production. Currently, most biomass-based power production uses waste biomass such as agro-waste and waste from agro-processing units. However, a trend is emerging in which companies are exploring the use of dedicated energy crops for biomass power production. This has the twin benefits of a more reliable biomass supply chain and at the same time providing the much-needed employment for the rural masses. Given that a 1 MW biomass-based power generation could require biomass growth in over 150 hectares, the opportunities for rural employment are indeed significant.
- Carbon neutral - Biomass power results in no new net GHG emissions as it is part of the carbon cycle. Unlike coal and other forms of fossil fuel which have been buried millions of years ago and burning them adds to carbon in the atmosphere, whereas biomass energy generation results in no new carbon emission or pollution.
- Efficient utilization of renewable biological sources - Biomass power is an efficient process which results in the use of mostly animal and crop wastes which would be converted into carbon dioxide anyway.
- Large variety of feedstock – Biomass power can use a large variety of feedstock such as wood pellets, rice husk, bagasse, jute stick etc.
- Low Cost Resource – Biomass power can be produced economically, at costs competitive to grid power, if there is a good availability of feedstock.

Constraints of biomass energy

Biomass based energy production process has some common limitations and technology-specific limitations, like:

- There exists high level of disagreement about gasification among engineers, researchers, and manufacturers. Several manufacturers claim that their unit can be operated on all kinds of biomass. But it is a questionable fact as physical and chemical properties varies fuel to fuel.
- Raw material is bulky and frequent refuelling is often required for continuous running of the system. Handling residues such as ash, tarry condensates etc. is time consuming and tedious work.
- Getting the producer gas in the proper state is

the challenging task. The physical and chemical properties of producer gas such as energy content, gas composition and impurities vary time to time. Inadequate fuel preparation is an important cause of technical problems with gasifiers.

- Biomass based energy generation technology requires hard work and tolerance.
- Fuel requirements are relatively strict for pyrolysis. Fuel must be uniformly sized from 4 to 10 cm so as not to block the throat and allow pyrolysis gases to flow downward and heat from the hearth zone to flow upward; therefore, palletisation or briquetting of is often necessary. The moisture content of the biomass must be less than 25% (on a wet basis).
- High tar and dust content of the producer gas could result in problems while using the gas in the engines.
- Incomplete carbon burnout results in lesser energy output.
- Complex operation which requires controlled supply of both air and solid fuel
- Need for power consumption for the compression of the gas stream.

Biomass based energy production in India

The Fig. 2 provides the total capacity of biomass-based power plants operating in the various Indian states (Ministry of New and Renewable Energy, 2010-11). It includes all forms of power production –combustion, gasification and cogeneration. Total biomass-based energy production was ~2600 MW in 2010-11. Table 5 presents biomass-based energy production in various states of India.

Government initiatives

More than 70% of India's population depends on biomass and about 32% of the total primary energy use in the country mainly in rural areas is still derived from biomasses. Use of these fuels in inefficient cooking stoves led to high levels of indoor air pollution, causing wide-spread respiratory and eye diseases, particularly among women. Hence, this hugely available biomasses can be judiciously utilized for energy production purposes. Due to high costs of connectingremote villages to the national grid, it is economical to promote projects based on solar energy, biomass gasifiers and small hydro power plants. The government provides up to huge percent financial assistance for non-conventional energy schemes in these areas (Table 6).

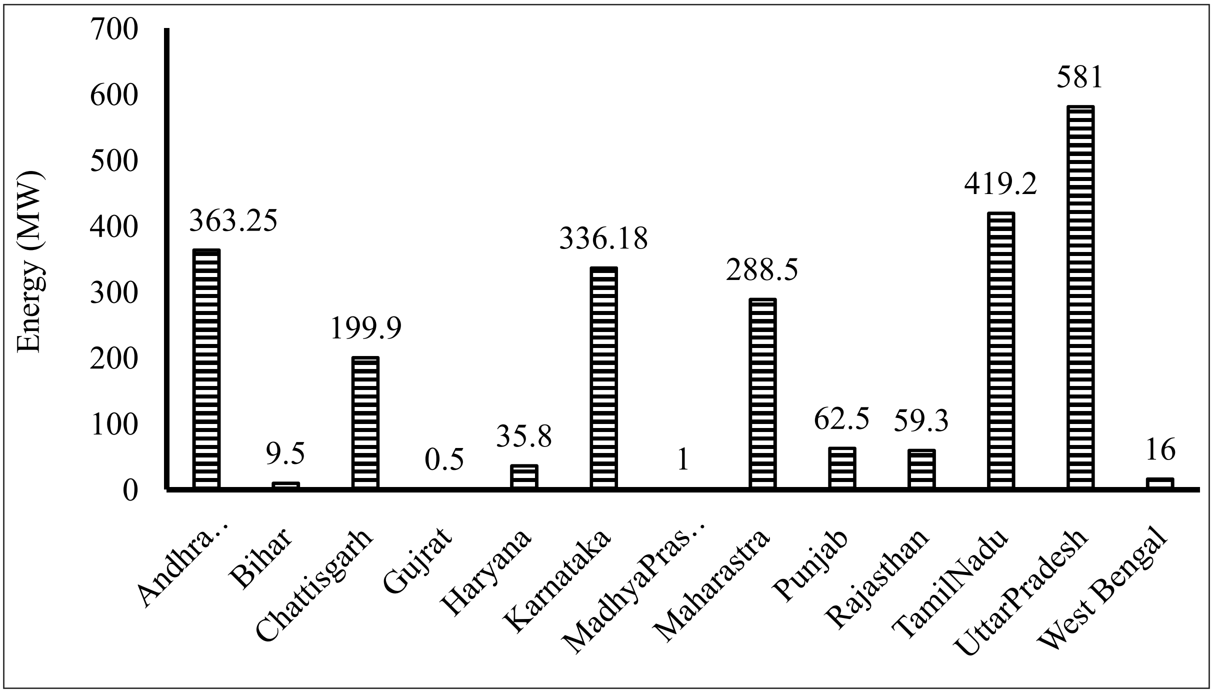

Fig. 2: Biomass based energy production in various states of India

Table 5: Biomass gasification plants installed in India

Power	State	Location of the plant	Built/Supported
1kW			
	New Delhi	UNIDO	CGPL
	Gujarat	Speri,Vallabha Vidyanagar	CGPL
	Maharashtra	IIT Bombay	CGPL
	Bihar	Chief Executive Officer, Shri Domen Mehto, C.G.C. Vaishali, Vaishal (Dist)	OVN
	UP	Arun Shah CAPART, Janak Puri, New Delhi-58	OVN
	WB	Tezpur University	CGPL
	WB	Banahut	CGPL
	WB	Dimapur	SYNERGY
	WB	Kolkata	SYNERGY
5 kW			
		NTPC	ARUNA
7.5 kW			
	Tamil Nadu	Dharmapuri	
	Tamil Nadu	Kanchipuram	ARUNA
	Arunachal Pradesh	Arunachal Pradesh	CGPL
10kW			
	Tamil Nadu	Periyambpattam, Dharmapuri	ARUNA
15kW			
	MP	Kasai	ARUNA
	MP	Debrabandi	ARUNA
20kW			
	Assam	Assam	
	Karnataka	Astra - CGPL	BETEL
	Karnataka	Hosahalli	CGPL
	Arunachal Pradesh	Central Instuite of Himalayan Culture Studies, Dahung, Bomdila Distt: West Kameng	OVN
	Arunachal Pradesh	Central Institute of Himalayan Cultural Studies, Dahung, Bomdia, PO: Dahung, Distt: West Kameng	OVN
	Bihar	Drishtee Foundation, Sarut, Madhubani	OVN
	Nagaland	NBM-IT, Pageland Bamboo Development Agency, Red Cross Building, Kohima	OVN
	WB	WBREDA	SYNERGY
25 kW			
	Karnataka	Siemens, Bangalore	BETEL
	Assam	Bashistha, Guwahati, Assam Forest Department.	OVN
	Manipur	Tamenglong Bamboo and Cane Development Centre, DC Office Complex, Tamenglong HQ	OVN
35 kW			
	Manipur	Tamenglong Bamboo and Cane Development Centre	
	Karnataka	Diwan Estate, Bethmangala	NETPRO
	Rajasthan	Sankalp	NETPRO
	Tripura	Common Facility Centre, Katlamara	OVN
	Tripura	Don Bosco Training School, Bishram Ganj	OVN
	Tripura	Rubber Producer Society, Rangmala	OVN
	Tripura	Rubber Producer Society, Laxmandepa	OVN
45 kW			
	Tamil Nadu	Javalgiri, Hosur	ARUNA
	Karnataka	JNNCE, Shimoga	BETEL
50 kW			
	Bihar	DESI Power Baharbari	NETPRO
	Karnataka	WSD, Varlakonda	NETPRO
60 kW			
	Karnataka	Gem & Sons, Chitradurga	BETEL
75 kW			
	Tamil Nadu	Aruna	ARUNA

	Kerala	Ideal Crumb, Palakkad	BETEL
	Mizoram	Malson Bamboo Pvt. Ltd, Bairabi	CGPL
	Karnataka	NIE, Mysore	ENERGREEN
	Tamil Nadu	Bhagavathi Bio-Power, Mettupalyam	ENERGREEN
	Tamil Nadu	Kongu	ENERGREEN
	Tamil Nadu	G.B.Engineering Enterprises	NETPRO
100 kW			
	Karnataka	Elite Crumb Rubber, Mangalore	BETEL
		Synergy	BETEL
	Karnataka	MVIT– II	NETPRO
	MP	DESI Power Orchha (P) Ltd.	NETPRO
	Tamil Nadu	Dev Power Corporation	NETPRO
	Tamil Nadu	Vellore Institute of Technology	NETPRO
	Tamil Nadu	VIT, Vellore	NETPRO
	Tamil Nadu	G.B Food oils	NETPRO
125 kW			
		Edathala Polymers	BETEL
150 kW			
	Karnataka	BERI, Kabbegiri Village, Tumkur	ENERGREEN
	Sagar Island	Sagar Island	SYNERGY
	WB	WBREDA	SYNERGY
225 kW			
	Karnataka	BERI, Kabbegiri Village, Tumkur	NETPRO
250 kW			
	Tamil Nadu	Pointech	ARRYA
	Jammu	Hindustan Pencils	BETEL
300 kW			
	Tamil Nadu	Tahafet	
415 kW			
		Sanghvi Woods	BETEL
	Jammu	Hindustan Pencils	BETEL
500 kW			
	Karnataka	Bethmangala	ENERGREEN
1 MW			
	Tamil Nadu	Arashi, Tamil Nadu	ENERGREEN
	Tamil Nadu	Gomathy	ENERGREEN
1.5 MW			
	Tamil Nadu	BMC, Kuttam	ARRYA

Table 6: Government subsidies on biomass derived energy units

	Type of biomass derived energy	Percent of cost
	Biomass gasifier with reactor, blower, manual feeding and manual cutter only	
A	For Projects upto 1MW capacity (3 MWth, 2.6 million kcal/hr) having CFA on benchmark on cost of ₹ 4.25 lakhs for gasifier units of 100 KW	
	Unit size upto 100 KWe (300 KWth, 2.5 lakhs kcal/hr)	
	Owned by Co-operative Panchayat, NGOs & Central/State Agencies (Socially Oriented Projects)	50
A1	Owned by Individual(s) / Entrepreneur(s)	30
	Unit Size > 100 kWe but < 200 kWe (600 KWth, 5.00 lakh kcal/hr)	
	Owned by Co-operative Panchayat, NGOs & Central/State Agencies (Socially Oriented Projects)	55
A2	Owned by Individual(s)/Entrepreneur(s)	35
	Unit Size > 200 Kwe	
	Owned by Co-operative Panchayat, NGOs & Central/State Agencies (Socially Oriented Projects)	60
A3	Owned by Individual(s) / Entrepreneur(s)	40
	Hi-Focus Areas, Islands, NE States, Ladakh & SC/ST Users	
B	Additional Financial Assistance (Over and above)	10

CONCLUSION

Biomass-based power systems are unique among non-hydro renewable power sources because of their wide range of applicability to a diverse set of needs. Biomass systems can be used for village-power applications in the 10-250 kW scale, for larger scale municipal electricity and heating applications, for industrial application such as hog-fuel boilers and blackliquor recovery boilers, in agricultural applications such as electricity and steam generation in the sugar cane industry, and for utility-scale electricity generation in the 100 MW scale. Biomass-based systems are the only non-hydro renewable source of electricity that can be used for base-load electricity generation. Tripling US use of biomass for energy provided as much as $20 billion in new income for farmers and rural communities and reduce global warming emissions by the same amount as taking 70 million cars off the road. Biomass energy has the potential to supply a significant portion of India's energy needs, while revitalizing rural economies, increasing energy independence and reducing pollution. Farmers would gain a valuable new outlet for their products. Rural communities could become entirely self-sufficient when it comes to energy, using locally grown crops and residues to fuel cars and tractors. Opportunities for biomass energy are growing.A key factor that can influence the future of biomass energy is the development of a market for biomass energy resources and services. The future of biomass energy lies in its use with modern technologies.

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