Biomass Production for Energy in India: Review

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Abstract: This paper presents a general view about biomass production in India and its potential energy for use in different fields. India has tremendous potential for energy generation through biomass and its residues. Biomass energy is normally produced from firewood, agricultural residues such as bagasse, crop stalks, animal dung and wastes generated from agro-based industries. With the estimated and predicted values, the generating power from the surplus biomass in India was significant and it will continue to be more effective in future. Residue use as a fuel in India is estimated to be 216 Mt as projected value in 2010, recently, around 605 MW of electricity is being produced from biomass firing and 720 MW from cogeneration activities for residue. About 185 Mt (40%) of the dung collected is used as fuel in cook stoves. The potential for biogas production annually is 8750 million m^3 from 251 Mt of dung. The amount of fuel-wood consumption during year 2004 was 205 million tonnes used as fuel for traditional cook stoves with low efficiency, 16 Mt used in industrial sector producing 10 PJ, and it was estimated that the production of fuel wood and charcoal increased to the rate of 1.98 per cent per annum. The total quantity of solid wastes generated in larger towns and cities has been estimated at 40 Mt in 2001, and in 2005 the average MSW generation in overall India was approximately 100,000 Mt/day. For the wastewater in India, in 2010, the energy estimated to be around 3929.8 TJ as energy value of CH4.

Keywords: Biomass, energy, crop residues, animal manure, fuelwood and municipal solid wastes.

1. INTRODUCTION

Biomass energy accounts for about 15% of the world's primary energy consumption and about 38% of the primary energy consumption in developing countries [1]. Due to technological developments and cost reductions, renewables, especially solar, hydro, wind and biomass energy are gaining momentum. Further, renewable sources, particularly biomass, are equitably distributed and less environmentally destructive than the current fossil fuel sources [2-4]. In India, the total installed capacity from non-conventional energy (nuclear, biomass, hydro, thermal, wind) is 108613 MW, biomass has only 640 MW (0.6 %) [5]. Biomass often accounts for more than 90% of the total rural energy supplies in developing countries, a survey carried out in India showed that the share of biomass fuels in rural household energy consumption had declined from 97% to 94%, but that of fuelwood had increased from 42% to 47% [6].

Biomass combustion provides basic energy requirements for cooking and heating of rural households and for process heat in a variety of traditional industries in the developing countries. In general, biomass energy use in such cases is characterized by low efficiency so that the biomass fuels used could potentially provide a much more extensive energy service than at present if these were used efficiently [4]. In India, biomass fuels dominate the rural energy consumption patterns, accounting for over 80% of total energy consumed Fuelwood, crop residues (including plantation crops) and livestock dung are the biomass fuels used in rural areas. Fuelwood is the preferred and most dominant biomass source accounting for 54% of biofuels used in India. Improving the conversion efficiency would be a significant step towards improving the quality of life and environment. Efforts are already under way to promote efficient devices and alternate energy sources for improving the quality of life and conserving biomass resources [7], over 370 million tonnes of biomass every year are generated. In addition to the direct harvesting from plants, biomass is also produced as a byproduct in many agro based industries such as rice husk from rice mill, saw dust from saw mill, bagasse from sugar mills etc. It has been estimated that about 17 GW of power can be generated through cogeneration, combustion and gasification routes from the available biomass. However, for this potential to be realized, data on production, present usage patterns, prices and seasonal fluctuation on biomass is essentially required [8].

Biomass energy plays a vital role in meeting local energy demand in many regions of the developing world. Biomass is a primary source of energy for close to 2.4 billion people in developing countries [9]. It is easily available to many of the world's poor and provides vital and affordable energy for cooking and space heating. Biomass-based industries are a

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significant source of enterprise development, job creation and income generation in rural areas [10-12]. Modern biomass energy is widely used in many developing countries as well as in parts of the industrialized world. With proper management backed by adherence to appropriate ecological practices, modern biomass can be a sustainable source of electricity as well as liquid and gaseous fuels. Biomass, therefore, is not only a vital source of energy for many today but is likely to remain an important source of energy in the future subject to its sustainable exploitation [13, 14]. The biomass industry will have to improve its image, ensure it is using only sustainably produced material, and become more efficient in biomass delivery and bioenergy conversion operations and less reliant on government incentives [15]. From implementation point of view, research and development in feedstock engineering also require continued support and guidance of a number of stakeholders. The prime industries of concern here include the users of feedstock, equipment manufacturers, and farmers. Several national laboratories and universities are actively involved in specific biomass research and conversion technologies. A full integration of all these activities minimizes duplication resulting in an accelerated approach to full utilization of bioenergy resources [16].

2. CATEGORIZATION OF BIOMASS ENERGY

Biomass energy use can be categorized in three clusters: Traditional, Improved and Modern

I. Traditional biomass energy is a local energy source, which is readily available to meet the energy needs of a significant proportion of the population, particularly the poor in rural areas of the developing world. Traditional biomass energy is low cost and it does not require processing before use [17].

II. Improved Biomass Energy; contributes to more efficient and environmentally sound use of biomass energy. Improved cookstoves, for instance, are designed to reduce heat loss, decrease indoor air pollution, increase combustion efficiency and attain a higher heat transfer [18, 19].

III. Modern Biomass Energy; Modern biomass technologies have the potential to provide improved energy services based on available biomass resources and agricultural residues. Widespread use of combined heat and power generation biomass options in rural areas can address multiple social, economic and environmental issues that now constrain local development. The availability of low cost biomass power in rural areas could help provide cleaner, more efficient energy services to support local development, promote environmental protection, provide improved domestic fuels and improve rural livelihoods. Bioenergy technologies based on sustainable biomass supply are carbon neutral and lead to net CO2 emission reduction if used to substitute fossil fuels [20-22]. Another advantage of modern biomass energy is its job generation potential, a very important attraction for many developing countries faced with chronic levels of unemployment or under-employment. Existing studies [11, 23] indicate that, in comparison to other primary energy sources, the job generation potential of modern biomass is among the highest.

3. COUNTRY DETAIL

India has a geographical area of 328.7 Mha and 2.3% of the world's forest stock [24] India's population of 966 million in 1997, 1.237 billion in 2012 and 1.4 billion by the year 2025, India's population is currently growing at 1.37 %, and accounts for 16% of the world's population [25, 26].

4. LAND CATEGORIES

4.1. Crop Land

The net sown area of India increased from 119 Mha in 1950 to 140 Mha in 1970–71, and has remained more or less stable at 142.02 till now. Cropping intensity increased from 134% in 1996-97 to 138 percent in 2008-09 [27, 28].

4.2. Forest Land

The area under forests in India has remained stable, at around 64 Mha since 1980. This has been due to the effective Forest Conservation Act, 1990, which fully regulates forest conversion [24]. The afforestation programme taken up in India, which is one of the largest in the world. The area afforested in India since 1951 has been a staggering 28.38 Mha during 1950–80, the area afforested was only about 3.54 Mha. During 1980 –85, the area afforested increased significantly to about 4:65 Mha at the rate of 0:95

Mha/yr and peaked during 1985–90, when about 8.86 Mha was further afforested, at the rate of 1.7 Mh a/yr. between 1990 and 1998, about 11.33 Mha has been afforested at the rate of about 1.4 Mha/yr [29].

4.3. Broad Land

Broad land use categories in India, other than cropland and foresting including non-agricultural area: accounts for about 22.51 Mha. This land is under settlement, buildings, road, railways, water bodies and other land uses and thus not available for agriculture; Tree crops and groves: Area under Casuarina trees, thatching grass, bamboo bushes and other tree groves which are not included under orchards, is under this category. This land category is in a degraded state; Culturable fallow: Includes lands available for cultivation but not taken up for cultivation or taken up for cultivation once but not cultivated during the current year and the last 5 years or more in succession. Such land may either be fallow or covered with shrubs; Permanent pastures and grazing land: These cover all grazing lands and meadows including village common lands and permanent pastures; Fallow land other than current fallow: All lands which were taken up for cultivation but are temporarily out of cultivation for a period of 1–5 years, and left fallow; Barren unculturable land: covers all barren and unculturable land, which cannot b e brought under cultivation except at a high investment cost; and Current fallow: includes cropped areas that are Kept fallow during the current year [29].

5. BIOMASS SOURCES

5.1. Agricultural Crop Residues

In India, out of the total geographic area of 328 million hectare (Mha), the net cropped area accounts for about 43% and it appears that the net cropped area has stabilized around 140 Mha since 1970. However, the gross cropped area has increased from 152.8Mha in 1960 to about 168.6 Mha in 1996–97 and is likely to reach 178.2 Mha by 2010. In India there are two main cropping seasons, namely Kharif (based on southwest monsoon) and Rabi (north-east monsoon). Gross cropped area includes land areas subjected to multiple

Table 1: Area Under Different Crops and their Respective Residue Production in India

Crop	Economic produce, 1996–97			Economic produce, 2010		
	Area, Mha	Production, Mt	Residues production, Mt	Area, Mha	Production, Mt	Residues production, Mt
Rice	43.3	81.3	146.5	46.1	118.8	213.9
Wheat	25.9	69.3	110.6	28.5	98.5	157.6
Jowar	11.6	11.0	22.3	5.3	6.1	12.2
Bajra	10.0	7.9	15.8	8.6	6.8	13.6
Maize	6.2	10.6	26.3	6.6	13.0	32.5
Other cereals	4.3	4.7	9.4	1.3	1.4	2.8
Red gram	3.6	2.7	13.5	3.6	2.7	11.2
Gram	7.1	5.7	9.3	7.7	7.0	13.5
Other pulses	12.5	5.8	17.1	12.5	5.9	17.1
Ground-nut	7.9	9.0	20.7	9.3	12.2	28.1
Rape seed & mustard	6.9	6.9	13.8	10.7	12.0	24.1
Other oil seed	12.1	9.1	18.2	18.0	13.5	27.1
Cotton	9.1	14.3	50.0	10.1	15.9	55.7
Jute	0.9	9.8	15.7	0.6	6.5	10.5
Sugarcan	4.2	277.2	110.8	5.5	463.5	185.4
Countnut + arecanut	2.0	-	20.0	2.8	-	28.2
Mulberry	0.3	-	3.0	0.3	-	3.3
Coffee + tea	0.7	0.8	3.42	0.8	1.0	3.9
Total	168.6		625.62			840.6

cropping (normally double cropping) in irrigated land. Net irrigated area has increased substantially from 24 Mha during 1960–61 to 55 Mha by 1996–97. Rice and wheat are the dominant crops, together accounting for 41% of cropped area, while pulses, oil seeds and other commercial crops account for 13.8%, 15.9% and 10.2%, respectively. Cereals dominate the agricultural crops and account for 60% of cropped area, followed by pulses, cotton and sugarcane [30].

5.1.1. Agricultural Crop Residues Production

The knowing of distribution of crop residues help to formulate and implement renewable energy programme utilization these resources, crop residues are classified on the basis of their properties such As diameter, flexibility, density, and particle size [31]. The area under different crops and their respective residue production in 1997 and projected 2010 in India presented in Table **1** [7].

The total crop residue production in India during 1996–97 is estimated to be 626Mt of air dry weight. The dominant residues are those of rice, wheat, sugarcane and cotton accounting for 66% of the total residue production. Sugarcane and cotton residue production is 110 and 50 Mt, respectively.

5.1.2. Current Use of Crop Residues

The use of crop residues varies from region to region and depends on their calorific values, lignin content, density, palatability and nutritive value. Residues of most of the cereals and pulses have fodder value. However, woody nature of residues of a few crops restricts their use to fuel purpose only.

The dominant end uses of crop residues in India are as fodder for cattle, fuel for cooking and thatch material for housing. Figures **1** and **2** give the estimated total residues utilized as fodder, fuel and for other purposes in India during 1996–97 and projected 2010 respectively.

Conversion of biomass residue into useful fuel either biochemical (biogas), thermo chemical (pyrolysis and gasification) processes are now possible to resulting fuel may be solid, liquid or gas specially using residues which not used as animal feed such as paddy straw in northern states in India [32]. Crop residues, which are used as fodder, will not be available as feedstock for energy. The total potential of non-fodder crop residues available for energy is estimated to be 325 and 450 Mt for 1996–97 and 2010, respectively; another figure about biomass generated from agriculture is a measured component of the energy mix used in rural India. In 2005–06, 316.8 million tonnes of agriculture-based biomass had been generated in the country comparison to 169.8 million tonnes in 1980-81. Figure **3** shows non fodder crop residue potentially available for energy use during year 1996-97 [30, 33]. Many agricultural wastes which not used, considered have heat values greater than some well-known

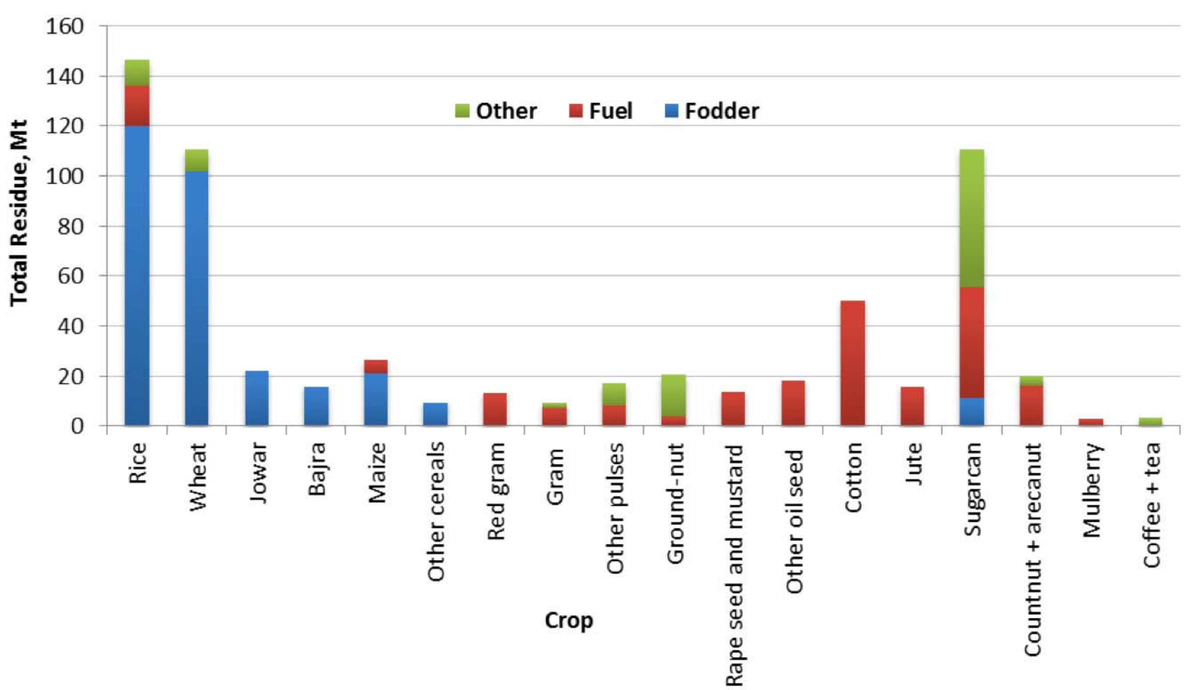

Figure 1: The estimated total residues utilized as fodder, fuel and for other purposes in India during 1996–97.

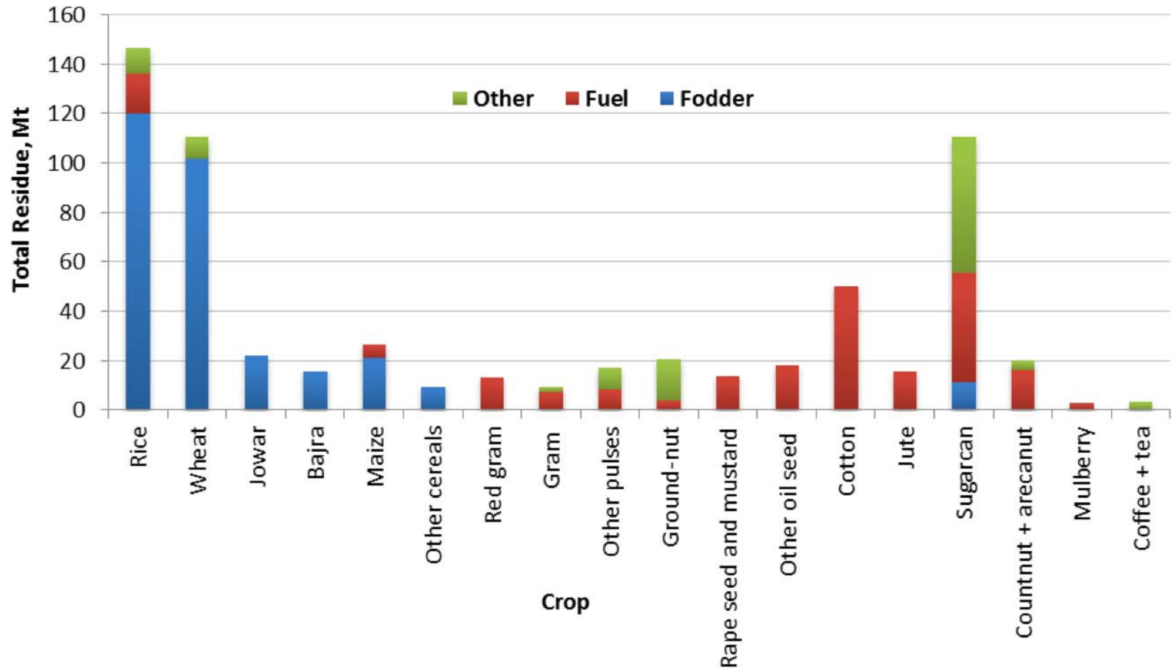

Figure 2: The estimated total residues utilized as fodder, fuel and for other purposes in India projected 2010.

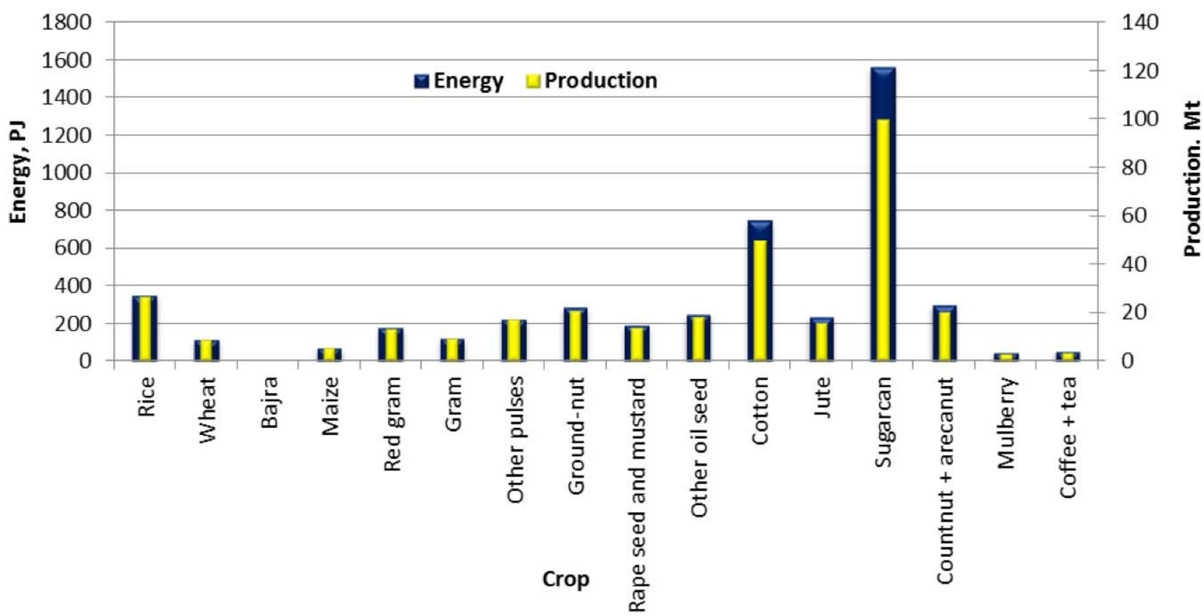

Figure 3: Non fodder crop residue potentially available for energy use during year 1996-97.

biomass-fuels and fall within the limit for the production of steam in electricity generation [34].

However, India's total installed capacity for electricity generation from biomass is 1,325 MW and 605 MW of electricity is being produced from biomass firing and 720 MW from cogeneration activities. An additional 1178MW power is being commissioned, which will take the total power generation from biomass to 3,100MW. Biomass as energy is gaining importance as a renewable source to strengthen the country's agriculture [35].

5.2. Animal Manure

India has the world's largest bovine population and recorded 294 million during 1996–97 (including cows, bullocks, buffaloes and calves), with cattle to human population ratio of 0.3. Cattle accounts for more than two-thirds of the bovine population, while buffalo account for 28.6% [36].

5.2.1. Current Dung Usage and Availability of Dung for Energy Generation

Based on mean annual average dung yield (fresh weight) of 4.5 kg day^{-1} for cattle and 10.2 kg day^{-1} for buffalo, total dung production is estimated to be 659Mt annually, with cattle dung accounting for 344 Mt and buffalo dung accounting for 315 Mt. The corresponding dung produced from cattle and buffalo for 2010 is estimated to be 368 and 362 Mt, respectively with a total dung production of 730 Mt [37].

About 185 Mt, 40% of the dung collected is used as fuel in cook stoves. The quantity of dung used annually in the existing 2.7 million family type biogas plants—assuming 5 animals per plant is estimated to be 22 Mt. Cattle dung use for biogas has large potential for the future, as only 22% of the total potential for biogas plants is being utilized [38]. Thus, the quantity of dung unused amounts to 251 Mt. If the potential of 12 million family biogas plants, is built by 2010 at the rate of one million annually, 98.5 Mt of dung produced could be used for biogas production. Rest of the dung is likely to be used as manure for crop production. The potential for family biogas plants in India is 12–17 million, but only 3.65 million plants had been built by 2003. Thus a large potential for family biogas is yet to be utilized. With the existing technology, the potential for biogas production annually is 8750 million m^3 (from 251 Mt of dung). This biogas could be used directly as cooking fuel (183 PJ) or for generation of 11.67 GWh of electricity annually. Figure **4** presents the dung use as fuel in India in two different years 1991 and 1995 with projected value in 2010.

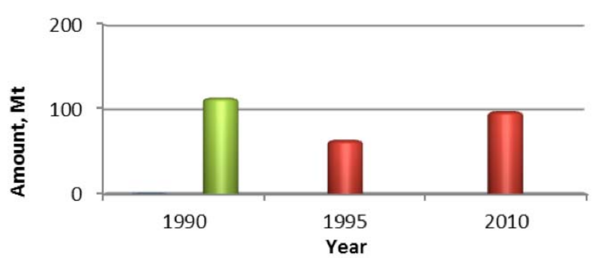

Figure 4: The dung use as fuel in India.

Recently and based on the availability of cattle dung alone from about 304 million cattle, there exists an estimated potential of about 18240 million m^3 of biogas generation annually. The increasing number of poultry farms is another source and can generate biogas of 2173 million cubic meters annually with 649 million numbers of birds [39].

5.3. Fuelwood

One of the important features of rural energy use is the dependence on locally available biomass resources. Over 77 per cent of rural households in the country were estimated to depend on firewood and chips for cooking [40]. It has been estimated that about 2–3 million people are engaged in fuel wood ‘head loading’ in India, making it the largest source of employment in the energy sector in the country. It is reported that most of the fuel wood is derived from forests, with some portion also being obtained from trees growing on homesteads, farmlands, and common lands.so, Fuelwood is the dominant fuel consumed in rural India. Dependency on fuelwood has consequences, firstly on environment due to non-sustainable extraction from forests, village commons and farms and secondly, on health and quality of life of women. Many projections indicate that rural communities would continue to depend on biofuels in the future while, the scarcity of fuelwood, associated with its high price, necessitates conservation through use of efficient stoves and switch over to other fuels. Hence, in this section, the fuelwood conservation potential through shifting to efficient stoves is estimated by considering only rural households. The feasibility of different biomass conservation options is also discussed in this section. Energy required efficiency of the fuel-device combinations and fuelwood conservation potential is given in Table **2** [41].

The traditional cook stoves using fuelwood have low thermal efficiencies of about 14%. Efficient stove designs with over 30% of thermal efficiency are available and are being intensively implemented in India as shown in Table **2**. Field studies have shown that use of efficient stoves results in only about 20% saving of fuelwood compared with traditional stoves due to variation in cooking practices, inadequate user education, and lack of repair and improper construction of improved stoves [7]. The amount of fuel-wood consumption during year 2004 was 205 million tonnes as shown in Table **3** [42].

Total wood production (round wood) in Indian forests has increased from 199.17 m. cum in 1970–80 to 248.52 m.cu m in 1981–2000, registering a compound growth rate of 2.03 per cent for the time period 1970–2000 (Table **2**). The production of fuel wood and charcoal increased at the rate of 1.98 per cent per annum [43].

Table 2: Energy Required and Efficiency of Device with Fuelwood Conservation Potential

Device	Consumption ($kgHH^{-1}$ yr^{-1})	Thermal efficiency of device (%)	Fuelwood conservation potential ($kgHH^{-1}$ yr^{-1})
Traditional cookstove	1800	14	-
Efficient cookstove	1440	33	360
Kerosene stove	159	60	1800
LPG	120	60	1800

Table 3: Fuel-Wood Consumption by Sector During Year 2004

Sector	Consumption, Million tonnes	% of total consumption
Household		
a- Forested rural	83	40.5
b- Non forested rural	65	31.7
c- Urban area	17	8.3
Subtotal	165	80.5
Cottage industry	22	10.7
Rituals	4	2
Restaurant, etc…	14	6.8
Total	205	

5.4. Municipal Solid Wastes

Generation of municipal wastes is not significant in rural areas. So, the energy potential of solid waste generated by urban population only considered. Municipal solid waste is normally collected, transported and dumped in the outskirts of towns and cities. Though sorting out for the recyclable materials by the rag pickers is common, other ways of handling, like composting, incineration, etc., also take place to some extent. The total quantity of solid wastes generated in larger towns and cities has been estimated at 20.7 Mt annually for an urban population of 217 million in 1991. This is increased to 40 Mt in 2001 and expected to reach to 56 Mt by 2010. As the urban population is increasing at a decadal growth rate of above 40%, the quantity of wastes generated per family in a week has also increased substantially from 7 kg during 1980s to 20–30 kg at present. The data from Table **4** reveals that MSW production per capita increases with the size of the urban centre and is highest for cities with a population greater than 5 million. In India, based on 1991 census data, the estimated quantity of MSW generated in 10 major cities is more than 10 Mt annually. Also, the average MSW generation in India is approximately 100,000 MT/day. Out of that, only 60% (60,000 MT/day) is collected by municipal corporations and councils. The rest is disposed of in an unscientific manner [44]. The disposal of such huge quantities has become a major problem. Thus, the utilization of MSW for energy would mean a solution of this problem. The MSW consists of glass, metal, paper, rubber, and other combustible organic matter. The organic matter component is of relevance to energy, particularly biomethanation. Paper plus other combustible matters together account for nearly 50% of MSW in urban areas [36].

[45] mentioned in his study that Municipal solid waste (MSW) is the solid waste generated by households, commercial establishments, and institutions etc. The waste consists of perishable organic wastes, glass, paper, plastics, metals etc. Generally, MSW does not include construction or demolition debris or automobile scrap. Figure **5** shows the percentage of composition of MSW in Delhi city. Though details vary from city to city, MSW can be completely converted into useful fuel products. The mean energy contents in char, tar oil and pyrogas are 89.89 MJ, 151.66 MJ and 4.03MJ respectively. The char produced can provide heat for the pyrolysis reactions and could be used as fuel for domestic

Table 4: Quantity of MSW Generated (Collected) Annually in India

Population range (Million)	MSW per capita (kg capita^{-1} day^{-1})	Towns	MSW per town wet wt (Kt)	At national level wet wt (Mt)
0.1-0.5	0.21	372	33±2	9.0
0.5-0.1	0.25	32	63±11	2.0
1.0-2.0	0.27	15	120±24	1.8
2.0-5.0	0.35	5	417±128	2.1
>5	0.50	5	1729±499	8.6
TOTAL		329		23.5

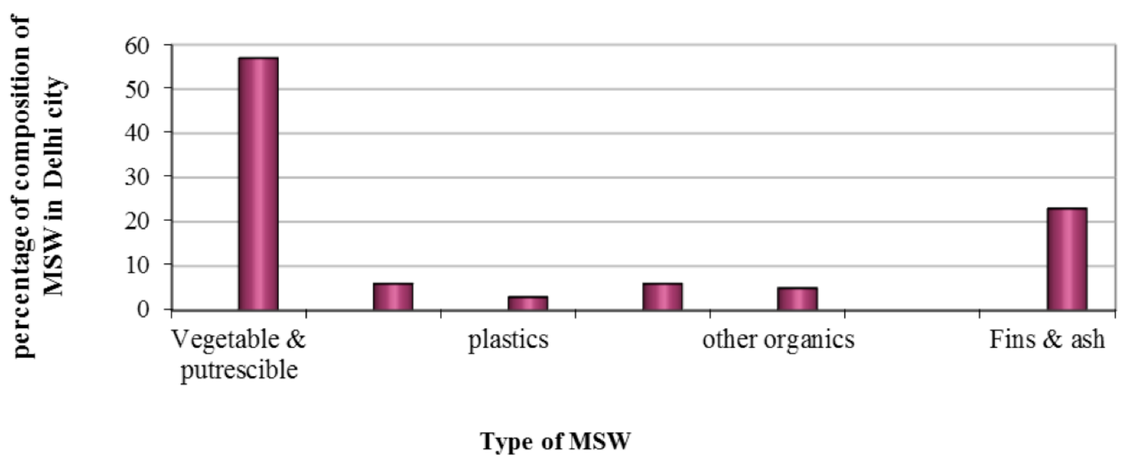

Figure 5: Percentage of composition of MSW in Delhi city.

purposes. The tar oil can yield some petroleum products when distilled and could be used as fuel and for industrial purposes [46].

5.5. Industrial Wastewater

In addition to MSW, large quantity of wastewater is generated in certain industrial plants like breweries, sugar mills, distilleries, food-processing industries, tanneries, and paper and pulp industries. Out of this, food products and agro-based industries together account for 65–70% of the total industrial wastewater in terms of organic load [47]. Table **5** gives the estimate of wastewater generated in India by industries [48]. Conventional digesters such as anaerobic continuous stirred tank reactors (CSTR) have been used in India for many decades in sewage treatment plants for stabilization of the activated sludge and sewage solids. In recent times, the emphasis has shifted to high-rate biomethanation systems such as up flow Anaerobic Sludge Blanket (UASB), fixed films, etc.

Large amount of wastewater is discharged from various industries under two broad categories: inorganic and organic. Wastewater from organic industries, such as, wood processing, pulp and paper, plastic, soap and synthetic detergent, tanneries and leather, oil refineries, textile, pharmaceutical and cosmetic, etc., are considered in this study. Each industry requires different methods for wastewater treatment depending on the characteristics and amount of wastewater. These methods can be classified as: (i) physical unit processes (screening, mixing, flocculation, sedimentation, flotation, filtration), (ii) chemical unit processes (precipitation, adsorption, disinfection), and (iii) biological unit processes (aerobic processes, anaerobic processes, anoxic denitrification) [49].

6. CONCLUSION

Using crop residues as fuel in India still limited compared with the high amount of production, only 48% from total residue production, and expected to go down in the future, which need further utilization to improve the amount of energy generated. The expected values of dung production indicated that there will be no significant increasing in future. The amount of fuelwood consumed increase with decreasing land

Table 5: Energy Potential from Wastewater in India

Industries	Wastewater produced (Mm^3)	COD* of waste water (kgm^{-3})	Energy value of CH4 (TJ)	
			1997	2010
Distillery	6000	118	2973.60	105138.00
Steel plants	1040000	0.60	936.00	92664.00
Paper and allied products	7200	0.72	7.73	765.55
Sugar industry	230	2.30	0.79	78.56
Cotton	1550	0.60	1.40	138.11
Fertilizers	52	2.00	0.16	15.44
Refinery	15	0.30	0.01	0.67
Dairy	206	1.35	0.42	41.38
Pharmaceuticals	56	0.39	0.03	3.24
Coffee	1.3	2.80	0.01	0.55
Edible oil	1425	4.50	9.62	952.56
Total	1056730		3929.77	199797.75

*COD: Chemical Oxygen Demand, is widely used in municipal and industrial laboratories to measure the overall level of organic.

forestation which makes this source of energy is limited. The total quantity of solid wastes and wastewater generated in larger towns and cities increased and still in increasing with increase the population, but these sources still not generate sufficient amount of energy to be valuable source for energy. So, further studies need to be done to increase biomass usage as energy source or to maximize the utilization of the existing sources.

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