ASSESSMENT OF BIORESOURCES POTENTIAL OF A RURAL VILLAGE FOR SELF ENERGY GENERATION

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The present research work assesses the bioenergy available in a rural village for self-sustainable development. The biomass consumption of the village for domestic as well as for all the activities has been collected. The study also entailed the collection of all bioenergy sources available in the village. The bioenergy sources, such as biomass available through forestry, agriculture waste and residues etc., and animal waste (animal dung), have been collected for the exact quantification of the bioenergy generation capacity of the village. From the study it has been found that the village has considerable bioenergy potential. The magnitude of the bioenergy density will help in achieving a self power-generating village. The bioenergy density will also help for the development of a bioenergy atlas for the particular location. A suitable renewable energy generation system in the studied village is being recommended.

Keywords: Assessment; Bioenergy; Biomass exact quantification; Bioenergy density; Sustainable development

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INTRODUCTION

An assessment of available bioresources can be helpful in revealing its present status and in taking conservation measures to ensure a sustained supply to meet future energy demands. Assessment of bioenergy potential can be theoretical, technical, or economic (Thompson and Laufman 1996). Natural conditions that favor the growth of biomass determine the theoretical potential. Technical potential depends on the available technologies that can be exploited for the conversion of biomass to more flexible forms and so is subject to change with time. Animal dung is a potentially large biomass resource, and dried dung has the same energy content as wood. When burned for heat, the efficiency is only about 10%. About 150 Million tonnes (dry) of cow dung are used for fuel each year across the globe, and 40% of such usage is in India.

Most unelectrified households in India are in remote locations. They have low purchasing capacity and would not be able to afford electricity, even if it were provided. The central government has until now used subsidies as an instrument to provide electricity at very low rates to protect the interests of the farmers and households.

The successful diffusion and adoption of renewable energy systems at the village level is predicated on organizational and institutional issues more than on technical ones.

The technical characteristics of renewable energy systems require collective social action for their purchase, operation, and maintenance. More importantly, successful diffusion of renewable energy technology requires the institutional scaffolding and associational behavior, which constitute the basic elements of civil society. Finally, the emergence of civil society surrounding the adoption of renewable energy technologies can only occur if these technologies are deployed on a commercial, cost-recovery basis (Fischer and Schrattenholzer 2001).

Since the geographical boundaries of a village are fixed, it can be thought of as a closed biomass and rainwater basin. This work has focused mainly on how a village can produce the majority of its demand for fuel from natural resources and the agro-based material in them. Renewable sources other than biomass can also be used to predict energy generation of the village. Keeping the above views in mind, a project entitled "Assessment of bioresources potential of a rural village for self energy generation" was undertaken in the village of Gorwha, Akola (MS), India.

METHODOLOGY

Data pertaining to the biomass available in the village was collected by personal interaction with the local farmers and households. Bioenergy supply was based primarily on land use statistics and yields of various crops (agriculture and horticulture), the plantation and forest biomass productivities, and the animal waste available (Ramachandra et al. 2000).

Village Information

The study was conducted at Gorwha in the Akola district of Maharashtra state. The major crops in village are cotton, sorghum, soybean, green gram, pigeon pea, and wheat, etc. The geographical area of the village is 12.56 sq. km., and the total population of the village is 1500, consisting of 98 households. The total cultivable land of the village is nearly 1200 acres. The selection of the village for the biomass and energy assessment was done purposefully in order to place more emphasis on this surveying area. The list of the families in the village was obtained from the *Grampanchayat* office.

Biomass resource from agricultural products and residues

The cultivated area and the biomass yield of each crop influencing the biomass potential from agriculture residues was collected from the village. The yield of a crop (according to season and variety) across an area was obtained by averaging the yields of the previous years. The energy equivalent of these residues was taken based on what would be obtained if they were subjected to the most energy-efficient transformation processes. A portion of the available residues is used as fuel, while some is used as fodder, and the rest is left behind in the field for nutrient recycling. Bioenergy from agriculture residues (BE_1) was computed by (Ramachandra and Kamakshi 2005):

$$\begin{aligned} BE_1 &= \text{Bioenergy from agriculture (kcal)} \\ &= \text{Total agro residue production - consumption of agro residue} \end{aligned} \tag{1}$$

Biomass resource from forestry

The biomass potential of the forests is dependent on the type of forest and its distribution cover. The biomass production varies with the type of the forest. The forest wood fuel collected annually by the households from the adjoining forest area was recorded in terms of energy equivalents. Total bioenergy from the forests (BE_2) was computed by

$$\begin{aligned} BE_2 &= \text{Bioenergy from forests (kcal)} \\ &= \text{Annually wood collected - Consumption of wood in household activities} \end{aligned} \quad (2)$$

Biomass resource from live stock (animals)

The livestock population of cattle, buffalo, sheep, and goats were collected from personal interaction with the respondents. It was taken as 12-15 kg/animal/day for buffalo, 3-7.5 kg/animal/day for cattle, and 0.1 kg/animal/day for sheep and goats. The total dung produced annually was calculated by multiplication of the animal dung production per year and the number of head of different animals. Assuming 0.036 m^3 to 0.042 m^3 of average 0.30 m^3 biogas yields per kg of cattle/buffalo dung, the total quantity of gas available was estimated (Marchaim 1992). Total bioenergy from livestock (BE_3) was computed by:

$$\begin{aligned} BE_3 &= \text{Bioenergy from livestock (kcal)} \\ &= \text{Total cow dung collection - direct dung consumption through cake} \end{aligned} \quad (3)$$

Total bioresources available from various sectors was computed by aggregating the energy computed from individual sectors (forestry, agriculture, agriculture residues, livestock) and is given by,

$$\text{Bioenergy availability} = \sum BE_1 + \sum BE_2 + \sum BE_3 \quad (4)$$

Energy Utilization Pattern of Village

In this study, the energy consumption pattern of the village was collected from the survey. All socio-economic activities related to the energy used were collected. The use of energy in houses, for irrigation, village lightning system, use of diesel in tractor of allied machineries, and use of petrol for two wheeler and small agro processing unit were collected (Kumar 1985).

Likewise, the consumption of energy in irrigation pumping system was surveyed. The capacity of an irrigation pumping system in horsepower (hp) and operating hours of the system were collected from personal interaction with farmers. By aggregating this information, the energy consumption in the irrigation pumping system was computed for one year (Shrivasta and Nilatkar 2005).

Bioenergy Density of Village

The bioenergy density of the village was calculated in order to determine the bioenergy potential available per hectare. The total possible bioenergy generation from all biomass sources was determined by using the heating value of the biomass available in the village. This means that the bioenergy density is simply the total possible bioenergy available through biomass sources in a particular area. The computational formula for the calculation of bioenergy density was taken as,

$$BED = \frac{\text{Total possible energy generation (kWh)}}{\text{Total geographical area of village (ha)}} \qquad (5)$$

where BED is bioenergy density in kWh per hectare.

RESULTS AND DISCUSSION

In this section, data collected from the village have been analyzed for determination of bioenergy potential and bioenergy density.

Status of Biomass Sources in Village

The biomass potential, demand, and energy consumption patterns across the village were calculated from the available data. Table 1 summarizes information about the significant sources of biomass available in the village. It was observed that cow dung and cotton residue were the major sources of biomass. Annual availability of the cow dung and cotton residue were found to be 5456.75 q and 1663.1 q respectively (q = quintal; 1 q = 100 kg). The annual availability of the biomass was observed to be 911.78 tonnes.

Table 1. Status of Biomass in Village

Sr.No.	Biomass source	Total Quantity (q)
1	Cow dung	5456.75
2	Cotton	1663.1
3	Pigeon pea	238.6
4	Sorghum	517.5
5	Safflower	75
6	Green gram / Black gram	86.82
7	Wheat	280
8	Gram	29
9	Wood	771
	Total biomass (q)	9117.77

Livestock bioenergy sources and collection of forest wood

Tables 2 and 3 reveal information about the production of the animal dung in the village. It was found that 5457 q of animal dung was available in the village in one year. It was also found that nine biogas plants were available in the village, and that those plants presently consume 810.3 q of the cow dung. The direct consumption of cow dung through cake as a cooking fuel was observed to be 8.4 q. per year. The total demand of the cow dung through the above operation amounts to 818.7 q annually. It was also observed that there was 4638 q of cow dung surplus in the village, which has potential to fulfill the energy demand of the village by using a suitable renewable energy conversion system.

Table 2. Use and Surplus of the Cow Dung in the Village

Total biogas plant	**Total consumption (q)**			**Surplus (q)**
	Through biogas	Through cow dung cake	Total cow dung	
9	810.3	8.4	818.7	4638.05

People in the village also use wood as a fuel for their cooking needs. The villagers were collecting wood from the surrounding forest of the village. The information for collection and consumption of wood by households is given in Table 3. It was observed that forest wood collection was around to be 771 q, of which nearly 537 q of wood have been consumed by the villagers. It was also found that there was 234 q. of forest wood surplus in the village.

Table 3. Yearly Collection, Consumption, and Surplus of Wood

Forest collection (q)	**Consumption (q)**	**Surplus (q)**
771	537	234

Collection and surplus of biomass in village

In the village all biomass resources were collected for the identification of the biomass generation capacity of the village as a whole. Simultaneously the consumption of the biomass from the personal interaction with the villagers have been collected, and all are shown in Table 4. For the most part, the demand for energy by the villagers has been satisfied by use of forest wood, pigeon pea residue, and cotton residue. A large amount of surplus residue was found. Cow dung and cotton residue were found to be the major surplus materials. Soybean residue and wheat straw were found in surplus amounts, because they are used for cattle feed. It is clear from the collected data (Table 4) that 30.78 per cent of the biomass resources were used for the household energy and other needs of the village. Nearly about 67.65 per cent of the biomass was surplus in the village for planning the suitable renewable energy generation system. The surplus quantity of biomass in village came to 6090 tonnes.

Table 4. Collection, Consumption, and Surplus of Biomass in Village

Biomass source	Collection (q)	Consumption (q)	Surplus (q)
Cow –dung	5457	818.7	4638
Cotton	1663	755	908.1
Soyabean*	75	75	--
Sorghum*	517.5	300	217.5
Pigeon pea	238.6	146	92.6
Wheat*	280	280	---
Wood	771	537	234
Total	9002	2912	6090
Percentage of total (%)		32.35	67.65

* Note that these biomass sources (agro residue) are used as cattle feed.

Consumption of conventional energy in the village

A detailed summary of energy consumption (biomass and allied energy) was carried out in this investigation. This section emphasizes the consumption of conventional energy in the village. The information about the liquid fuel consumption in the village for various needs have been collected. A very few motor-driven devices were found in the village. There are only two flour-grinding mills. Nearly 7800 litres of diesel fuel are needed annually for tractor operation. The consumption of kerosene for cooking was observed to be 3584 litres. Table 5 gives information for the consumption of conventional energy. The total electrical energy consumed in the small processing unit comes to be 21170 kWh per year. It was observed that yearly consumption of energy in the village came to 108,828 kWh. In domestic operation i.e. lighting, fans, and other electrical equipment, etc., the village consumed nearly 50224 kWh of electrical energy.

Table 5 reveals information about the energy consumption of the irrigation pumping system. It was observed that the total number of pumps was 16, having horsepower ranges between 3 and 5 hp. The total energy consumption in the irrigation pumping system came to 37434 kWh.

Table 5. Yearly Consumption of Energy in Village

Electricity consumption in household (kWh) (A)	Electricity consumption in irrigation (kWh) (B)			Agro. processing mill (kWh) (C)	Total (A+B+C) (kWh)
	Total pump	Total HP	Total unit		
50224	18	64	37434	21170	108828

Possible Bioenergy Generation from Biomass

Table 7 gives information about the quantity of biomass resources available in the village. Agricultural residue, i.e. cotton, pigeon pea, sorghum, soybean, wood, and animal dung, etc., are also the major available biomass resources. For calculating the energy capacity of the biomass resources, calorific values of the biomass were considered. The calorific value of cotton, pigeon pea, sorghum, wood and animal dung were taken as 3500 kcal/kg, 3000 kcal/kg, 3500 kcal/kg, 4800 kcal/kg, and 5300 kcal/m^3, respectively (Prasad et al. 1987). By multiplying these values with all the available surplus quantities of the biomass, the total possible energy generation from the village was around 2199,000 kWh, of which cotton residue and dung are the predominant resources, which contribute about 677,000 kWh and 1,009,000 kWh of energy generation, respectively. It was realized that electrical energy consumption is very much less than the bioenergy available in the village. It was found that conventional energy consumption in the village would be fulfilled by the available biomass. The proper implementation of a suitable renewable energy generation system will help in the achievement of self-sufficiency in terms of energy. The percentage of possible electrical energy generation from cattle waste was observed as 45.87 per cent. The energy from cotton agro residue was observed to be 30.77 per cent. After that, surplus wood collected from the forest contributed 19.58 per cent of the total possible energy generation from the biomass, which were available in the village itself.

By taking into account the total electrical energy consumption of the village and possible energy generation from the biomass resources, the ratio of energy availability in the village, versus consumption, came to 20:1 (2198875 / 108828). This means that 20 times more energy was found available through biomass, and this needs to be converted into electrical energy by using a suitable renewable energy generation system.

Table 6. Possible Bioenergy from Available Biomass Sources

Biomass Resources	Quantity (q)	Calorific Value (kcal/kg & kcal/m^3)	Total Energy Availability (kcal)	Total Possible Electrical Energy Generation (kWh)	Percentage of Total Electrical Energy Generation (%)
Cotton	1663	3500	582,050,000	676,802	30.77
Pigeon pea	238	3000	71,400,000	83,023	3.78
Wood	771	4800	370,080,000	430,325	19.58
Dung*	5456 (163680 m^3)	5300	867,504,000	1,008,725	45.87
Total bioenergy available (kcal)			1,891,034,000		100
Total of possible electrical energy generation (kWh)				2,198,875	

* Based on assumption that the available dung quantity is converted into biogas (1 kg = 0.30 m^3)

It is also realized that a gasification-based electrical energy generation system and biogas electrical energy generation project is suitable to generate the electrical energy required in the village. A newly proposed renewable energy system will not impact the ecological cycle of the village's bio system.

Bioenergy Density of Village

The bioenergy available in comparison to the total geographical area of the village represents the bioenergy density. In the study, around 2199,000 kWh of possible energy potential was available by harnessing the natural biomass sources. This potential was available through the 12.56 km^2 (1256 hectare) area of village. By considering the total possible energy and the geographical area of the village, the bioenergy density of village came to 1751 kWh per hectare throughout the year.

The bioenergy assessment study, including energy consumption in various sectors and biomass availability through various sources, gives a picture of the energy-generating capacity of the village. Such data collection in the village will help in planning the self-energy-generating village system and generate employment, while at the same time reducing the burden on the conventional energy sources, which will preserve them for future generations.

Techno-Economic Feasibility of Suitable Renewable Energy Generation System

The available surplus biomass of the village shall be utilized for the successful diffusion of the renewable energy technology in the village. Total crop residue and forest wood surplus in the village shall be utilized for the generation of electrical energy by means of gasification. Bhatnagar et al. (1986) studied that for generation of 1 kWh of electricity, 1.85 kg of biomass is required. The overall efficiency of the biomass-based gasification system was taken as 12.42 per cent. The wood gasification mode of power generation is quite feasible and offers immense scope for rural development.

In India, biogas has been promoted as an appropriate rural technology for utilization of local resources. Shyam et al. (2006) introduced a fixed dome type of biogas plant for digestion of cattle dung in solid state. The water requirement for dilution of the cattle dung in this plant has been reduced by 75-100 per cent, and gas yield enhanced by up to 25 per cent over a common biogas plant. This biogas plant can also be used for electricity generation in a village.

In a studied rural household, cooking energy accounts for about 85-90 per cent of the total energy consumption, mainly derived from crop residue and forest wood. These traditional wood based cooking stoves are only 8-10 per cent efficient and emit a lot of smoke during cooking. Rathore and Jain (2001) introduced two improved stoves for the cooking in rural households. The average thermal efficiency of these stoves is higher (25.54 per cent).

CONCLUSIONS

The present study assessed the status of biomass within a rural village in the Maharashtra state of India, considering the availability of bioenergy (from agriculture, forests, and livestock, etc.) and sector-wise energy demand (domestic, agriculture, and small processing unit etc.) for the most precise acheivable quantification of the surplus biomass.

The study revealed that the village has a considerable surplus of biomass. Among the surplus biomass resources, cotton residue contributes significantly toward bioenergy. The animal waste (cow dung) is also a vital source for bioenergy. Based on the bioenergy status, feasible management and technical options have been discussed, which help in optimizing the available bioenergy and in building a sustainable energy society. The proposed renewable energy systems will reduce the burden on the existing resources and also help the rural population to procure biomass on a sustained basis.

Based on the study the following conclusions could be drawn:

1. In the village the computation of the availability and demand of bioenergy showed that the village produces surplus energy for itself.
2. Analysis of the sector-wise contribution in the energy surplus showed that animal dung and cotton residue contribute the main bioresource in the village.
3. It was found that cotton residue was available with quantity 1663 q. per year.
4. The availability of the cow dung was found to be 5457 q. per year.
5. The study showed that a majority of the biomass available in the village is surplus and available for the planning of a suitable renewable energy generation system.
6. The village consumes conventional energy, which was observed to be 108,828 kWh.
7. The surplus bioenergy resource of the village has the potential to be used in the generation of up to 2.1 MWh of electrical energy.
8. Based on the possible bioenergy available and the area of the village, the bioenergy density came to 1751 kWh per hectare throughout the year.
9. It was realized that a suitable renewable energy generation system can be based on gasification, and the biogas is well suited to the village bioresources, which will not have adverse ecological impact on the cycle of bioresources.

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