International Research Journal of Advanced Engineering and Science
ISSN: 2455-9024

# Assessment of Bovine Dung Based Bio-Energy and Emission Mitigation Potential for Maharashtra

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***Abstract—*** *The well-being of society, economy and the environment depends on safe, clean, secure, sustainable and affordable energy. Much of the current energy supply is from the limited resources of fossil fuels which are environmentally unsustainable. In the wake of fast depletion of conventional fuels, global warming due to GHG emissions and rising energy costs, the efficient use of energy is continually gaining importance. India is having a very high potential for bovine dung based bio-energy systems. World's largest cattle inventory, a rural population of around 70% and millions of jobless youth are the factors that put forth the proposed Bioenergy Farm not just as a solution to energy poverty but also as a potential solution to the problem of rural unemployment. In this work a district wise assessment has been done for the bovine dung availability and bio-energy generation potential for the state of Maharashtra, as also the resulting emission mitigation potential. A layout of conceptual Bioenergy Farm has been proposed. Computations for revenue generation from Carbon Credit and Renewable Energy Certificate have been done to assess their potential contribution in the financial feasibility of the Bio-Energy Farm.*

***Keywords—*** *Biogas, bovine, bio-energy farm, emission mitigation, certified emission reduction, renewable energy certificate.*

## I. Introduction

India is now the eleventh largest economy in the world and fourth in terms of purchasing power. This appeal is partially due to the low cost of manpower and quality production. The expansion of investments has brought benefits of employment, development and growth in the quality of life, but only to the major cities, which represent only a small portion of the total population. The remaining population still lives in very poor conditions.[1] Energy poverty is one of the major characteristics of the lives of these deprived classes.

To accommodate the un-served communities and growing energy demands, generation has to be enormously improved; however increment in generation from fossil fuels has negative neighbourhood and worldwide environmental effects. The climate change and environmental conservation are the major issues of this century. India is the second largest in population, fourth largest in energy consumption, third largest in GHG production and burns ten folds fuel wood as compared to United State. In order to curb these emissions, the environmental carbon trading is being promoted by United Nation which has earning of carbon credits as its key premises.

In India the coal fired power generation is the biggest polluter and the biggest opportunity for emission reduction and hence can be the biggest carbon credits producer. Presently, next only to china, India is generating the highest number of carbon credits in the world, however in comparison with the developed nations the carbon emission level in India is much less. Carbon dioxide is typically present in the atmosphere as a noteworthy part of the Earth's carbon cycle. Elimination of energy generation related carbon emission is of course not possible but its mitigation to some extent is definitely possible [1].

## II. Bovine Inventory of Maharashtra

The word 'cattle' ideally means cow, bull or bullocks. But in India, which owns more than 56% of world's buffalo population, quite often the word 'cattle' denotes both the categories i.e. cattle and buffalo. In this paper, for clarity, the convention used by the Department of Animal Husbandry, Government of India, has been followed, which uses the word 'cattle' for cow, bull and bullocks only. The word 'bovine' is an adjective used for a diverse group of 10 genera of medium to large-sized hoofed animals. But here, again as per the convention of the department, 'bovine' includes only cattle and buffalo.

As per $19^{th}$ Livestock Census – 2012, All India Report, Ministry of Agriculture, Government of India, the cattle population of Maharashtra is around 15.48 million while the buffalo population is around 5.59 million. These are 73.47% and 26.53% of the total bovine population in the state respectively. The total cattle in the state are 8% of the total cattle at the national level, while the total buffalo are 5.14% of the total buffalo at the national level. In this work district wise bovine data for Maharashtra have been used for estimation of dung availability and subsequent bio-energy potential [2].

## III. Bio-Energy Farm

As has been stated above, this is a proposal for converting the scarcity of energy in rural India into an opportunity for setting up energy co-operatives based on Bio-Energy Farm (BEF). The BEF has been conceptualised to be a community biogas power plant with a shelter for bovine animals retired from their useful life. The dung produced by the in-house bovines and that collected from the villagers will be used to generate electricity in the BEF. The bio-fertilizer produced as a by-product, besides catering to the organic farming, will help generate additional revenue for sustenance of the BEF. Figure 1 below depicts the layout of the proposed Bio-Energy Farm.



Sourabh R. Bera and Prashant Jain, "Assessment of bovine dung based bio-energy and emission mitigation potential for Maharashtra," *International Research Journal of Advanced Engineering and Science*, Volume 1, Issue 3, pp. 119-124, 2016.

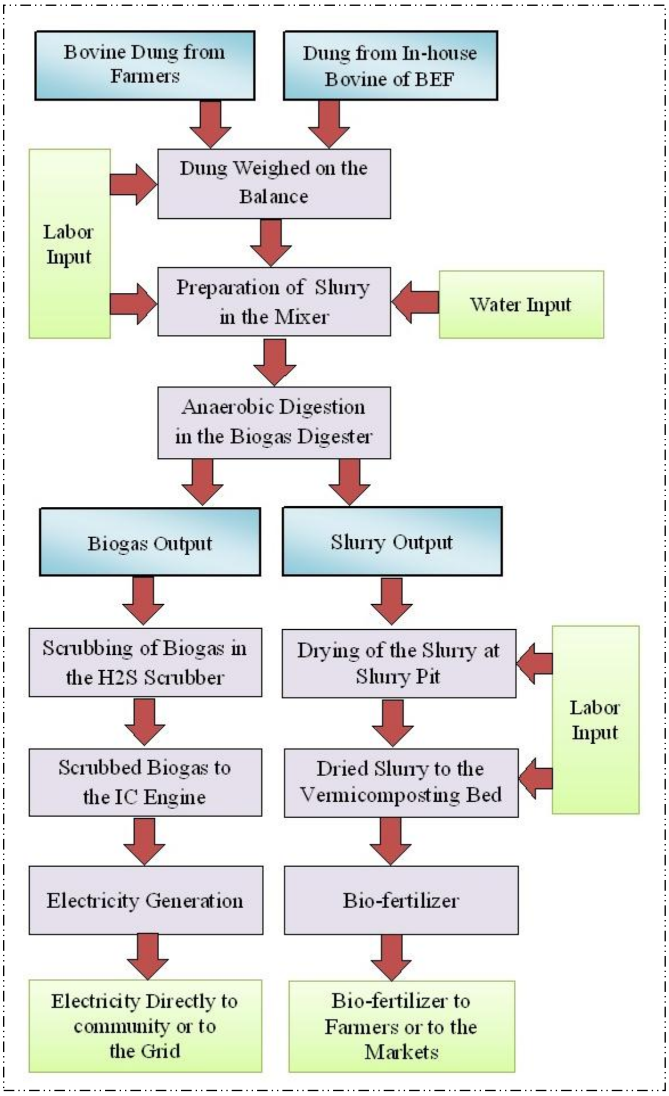


Fig. 1. Layout of proposed bio-energy farm.

## IV. Relevance of Bio-Energy Farm

The BEF is relevant especially in the following three ways:

1. In the wake of blanket ban on cattle slaughter imposed recently by the governments of Maharashtra and Haryana and their pursuit for a practical way for rehabilitation of retired and excess cattle, the BEF may prove to be a potential solution. Many of the other states and Union Territories also have legislation on banning or restricting slaughter of cow and its progeny. The central government also is considering formulation of a model law for the whole country for this purpose. This work is an attempt to find a way to make the cattle shelters financially sustainable by way of using them for generation of energy and bio-fertilizer.
2. In a big country like India, connecting remote rural areas with the central grid is a challenge. In this situation, the bovine dung based decentralized electricity generation systems may be a suitable alternative. Also, the farmers will get an opportunity to invest their unusable or surplus bovines in the energy cooperative of BEF and get dividend in cash or in the form of subsidized energy i.e. electricity or biogas or both.
3. The replacement of chemical fertilizers with bio-fertilizer, that will be the by-product of energy generation, will benefit the national economy in terms of the savings on fertilizer subsidy bills worth billions of rupees every year. Moreover, the fertilizer industry being highly energy intensive, the reduced production will lead to huge amount of energy saving and emission mitigation.

## V. Components of Bio-Energy Farm

### A. Biogas Plant Running on Bovine Dung

The type of biogas plant selected here is Bhabha Atomic Research Centre's 'Nisargruna' plant. This plant which works mainly on bovine dung has been found to be suitable for such a project to be financially viable. It's the most efficient biogas plant working under thermophilic temperature range of 55° to 60°C.[3] The highest capacity bovine dung based biogas plants in India are from 80 to 88 $m^3$ size and they have been found to have better efficiency than the smaller ones.[4] This size of plant will need around 2 tons of dung and will be fed by approximately 200 standard bovine units of a small village. It will serve the purpose of the community biogas plant based on the BEF very well. Figure 2 below presents a bird's eye view of the BEF.

### B. Solar Water Heater and Storage for Biogas

As the plant is working in the thermophilic temperature range, a solar water heater with flat plate collector will be used to heat the water for the digester. Daily feed of the hot water is 2000 liters. Flexible balloon of capacity 50 $m^3$ is used to store biogas generated from the digester. Balloon has a diameter of 3.4 m and a height of 5.5 m. It is placed in vertical orientation and it is enclosed in a sheet metal room with the length and width both as 4 m and height as 6 m. It is cylindrical type balloon storage and has one inlet, one outlet and one drain valves as accessories [8].

### C. Bovine Shed

The shed for bovines will house the retired cattle from the owners and also the stray and abandoned ones. In Indian villages most male bovines and calves are either sent for slaughter or let loose to starve. A limited number are used for breeding and some are used as draught animals, but they also are destined to head to slaughter houses after their useful life. In the states where there is ban on cattle slaughter, such an arrangement will not just provide shelter to the abandoned bovine but also will help recover the cost of their sustenance through the use of their dung for the BEF. The housing capacity of the bovine shed will depend on the land and other resources available with the BEF.

### D. Vermicomposting Yard

Vermicomposting is a technique for producing advanced bio-fertilizer with the utilization of earthworms. It is one of the least demanding techniques to reuse agro-waste and to produce quality manure. The terrestrial worms eat up biomass and discharge it in processed structure called worm throws or casts. Worm casts are prevalently called as black gold. The casts are rich in supplements, development advancing substances and are having properties of restraining pathogenic microorganisms. The worms can be raised synthetically in a block tank or close to the stem/trunk of trees (uniquely green trees). By nourishing these worms with biomass and observing appropriately the sustenance (bio-mass) of worms, the required amounts of bio-fertilizer can be obtained. [5] The size of the vermicomposting pit will depend on the amount of slurry output per day from the plant, and the number of pits will be same as the number of days of processing lead time i.e. around six weeks.

### *E. Biogas Scrubber and Electricity Generator*

A byproduct of biogas production is hydrogen sulfide. It's a poisonous gas and also is extremely corrosive to metallic components of the biogas plant. So, the biogas is scrubbed in a scrubber using steel wool that is replaced every month. The chemical reaction for scrubbing is as follows:

$$Fe_2O_3 + 6H_2S \rightarrow 2Fe_2S_3 + 6H_2O$$
$$2Fe_2S_3 + 3O_2 \rightarrow 2Fe_2O_3 + 3S_2$$

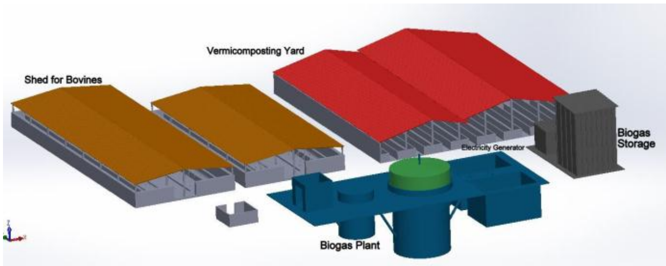


Fig. 2. A bird's eye view of a bio-energy farm.

The electricity generation unit is made up of a modified diesel engine coupled with a generator. The engine works at a smaller compression ratio as compared to a diesel engine and has a spark plug for ignition. Here, in this plant the use of a 25 kW engine has been considered for the energy output of around 150 units of electricity with six hours of running time [6].

## VI. Computations for Electricity Generation at the BEF of an Average Village

### *A. Number of Bovine Contributing to BEF*

Table I depicts this computations. It is based on the latest Livestock Census Data, 2012 and the Selected Socio-Economic Statistics, 2011 published by the government of India. The analysis for bovine dung based electricity and emission mitigation potential has been performed for this average village and the results have been used for district wise estimations for the state of Maharashtra. In the same way the estimations can be done for any geographical unit of India or even the whole country.

### *B. Standard Bovine Unit*

The bovine population in a village comprises of young to adult cattle and buffaloes. For adult cattle the dung production capacity has been assumed to be 10 kg/day while that for an adult buffalo has been taken as 15 kg/day as per prevailing norms for India. The dung capacity for cattle and buffalo calves has been taken as 50% as compared to their adults. Thus the bovine population of 485 in an average village comprises of cattle and buffaloes with 5 to 15 kg of dung production capacity. A Standard Bovine Unit has been defined as a bovine with 10 kg/day of dung production capacity.

TABLE I. Number of bovine contributing to BEF in an average village of India.

| Particulars | Quantity | Reference/ Calculation |
|---|---|---|
| Total number of bovines in Rural India (cattle + buffalo) | 288199575 | [2] 19th Livestock Census – 2012, All India Report, Ministry of Agriculture, Gov. of India, |
| Number of inhabited villages | 5.94 lacs | [7] Selected Socio-Economic Statistics, India, 2011, Gov. of India |
| No. of rural households | 137.7 *x* 106 | |
| Number of households in an average village | 232 | 137.7 *x* 106/ 594000 |
| Number of bovines per household | 2.09 | 288199575/ 137.7*x* 106 |
| Number of bovines in the average village | 485 | 231.81 *x* 2.09 |

### *C. Amount of Dung Collected for the BEF*

In a village, the bovines staying with the owner and those stationed at the BEF both contribute to the power generation. As computed in Table II, around 10% of the total population in a village are the retired, stray or abandoned animal and are stationed at the BEF. All these are adult cattle as their slaughter is prohibited in the state. The remaining are staying with their owners and are mixed population of cattle and buffalo, adult and calves. The dung production per head per day has already been defined in the previous section. The dung collection efficiency for bovine staying at BEF has been assumed to be 90% while that for the bovine staying with their owners has been taken as 50% as the villagers would use the dung for cakes for cooking and other purposes.

For computing the number of bovines in different categories in an average village, the ratios as per the Live Stock Census Data 2012, published by Department of Animal Husbandry, Ministry of Agriculture, Government of India have been used. The distribution of 485 bovines in an average village and their dung contribution has been depicted in table - II. The respective standard bovine units has been computed on basis of the category wise dung production per bovine per day and the dung collection efficiencies for in-house bovines and the bovines staying with the owners. It's obvious from the computations that the bovine population of the average village i.e. 485 is equivalent to around 200 standard bovine units and the considered 2 ton capacity plant matches the dung supply from this herd size.

### *D. Amount of Electricity Generation*

Considering methane content of biogas as 60% and corresponding calorific value as 21 MJ/m$^3$, the electricity generation per cubic meter of biogas will be 1.7007 kWh. The



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efficiencies of the IC Engine and the generator have been considered to be 35% and 98% respectively. Taking a power factor of 0.85 for the generator the overall efficiency of the system turns out to be 29.15%. So, from the biogas power plant of 88 cubic meter capacity with dung input of 2 tons the electricity generation will be 149.60 kWh per day. Assuming a six hour running time for the generator per day, power of the generator coupled with the internal combustion engine turns out to be 25kW.

TABLE II. Number of bovines in different categories with respective dung contribution.

| Category | Description | Number | Standard Bovines Units | Dung Collected in kg |
|---|---|---|---|---|
| **Bovine Staying at BEF** | | | | |
| Indigenous Male cattle | Surplus adults | 14 | 12.6 | 126 |
| Crossbred Male cattle | - | - | - | - |
| Indigenous Female cattle | Dry cows | 10 | 0.9 | 90 |
| Crossbred Female cattle | Dry cows | 4 | 3.6 | 36 |
| **Total** | | **28** | **17.1** | **171** |
| **Bovine Staying with Owner** | | | | |
| Indigenous Male cattle | Calves | 14 | 3.5 | 35 |
| | Used for breeding | 3 | 1.5 | 15 |
| | Used for draught and breeding | 71 | 35.5 | 355 |
| Crossbred Male cattle | Calves | 6 | 1.5 | 15 |
| | Used for breeding | 1 | 0.5 | 5 |
| | Used for draught and breeding | 3 | 1.5 | 15 |
| Indigenous Female cattle | Calves | 34 | 9.5 | 95 |
| | Milking cows | 38 | 18.75 | 187.5 |
| | Cows not in milk | 63 | 31.25 | 312.5 |
| Crossbred Female cattle | Calves | 16 | 4.0 | 40 |
| | Milking cows | 18 | 9.0 | 90 |
| | Cows not in milk | 15 | 7.5 | 75 |
| Male Buffalo | Used for breeding | 2 | 1.0 | 10 |
| | Used for draught and breeding | 7 | 3.5 | 35 |
| Female Buffalo | Calves | 46 | 11.5 | 115 |
| | Milking buffalo | 46 | 23 | 230 |
| | Buffalo not in milk | 45 | 22.5 | 225 |
| **Total** | | **428** | **186** | **1860** |
| Total Number of Bovine contributing to BEF and Dung Collection | | **456** | **203.1** | **2031** |
| **Bovine Disposed-off** | | | | |
| Male Buffalo | Calves + Surplus Adults | 17 | | |
| Female Buffalo | Dry buffalo | 12 | | |
| **Total** | | **29** | | |
| **Grand Total** | | **485** | | |

## VII. Computations for Emission Mitigation

### A. *Emission Mitigation through Renewable Electricity*

The coal based thermal power plants emit huge amount of greenhouse gases which leads to global warming. Replacement of the fossil fuel based energy with the renewable energy not only helps to mitigate the GHG Emission but also generates Certified Emission Reduction units (CERs) which might be exchanged in emissions trading scheme plans devised by Clean Development Mechanism (CDM). CDM is a mechanism characterized in the Kyoto Protocol for encouraging emission reduction projects [8], [9].

The BEF considered here will generate 149.6 kWh of electricity per day. In a coal based thermal power plant the amount of emission is 0.93 kg of carbon di-oxide and 4.25 grams of Nitrous Oxide per kWh of electricity generation. [10] The computation below depicts the amount of mitigation of equivalent carbon emission per day and per year by means of the considered biogas electricity plant.

TABLE III. Emissions Mitigation through Renewable Electricity Generation.

| Green House Gas | Global Warming Potential | Emission per kWh of Electricity from Coal Fired Power Plants | $CO_2$ Equivalent of Emission |
|---|---|---|---|
| $CO_2$ | 1 | 0.93 kg of $CO_2$ | 0.93 kg of $CO_2$ |
| $N_2O$ | 310 | 4.25 g of $N_2O$ | 1.32 kg of $CO_2$ |
| Total emissions mitigation per kWh | | | 2.25 kg of $CO_2$ |
| Emission mitigation per day = 149.6 *2.25 = 336.60 kg of $CO_2$ | | | |
| Emission mitigation per year = 336.60 *365 = 122.86 Tons of $CO_2$ | | | |

### B. *Emission Mitigation through Replacement of Inorganic Fertilizers through Bio-fertilizer*

The use of inorganic fertilizers contributes to GHG emissions by means of energy intensive production process, transport and energy use in machinery required for fertilizer application. Also after application of urea, the emission of nitrous oxide takes place from the soil. The emission values according to the IPCC (2006) protocol during the lifecycle of inorganic fertilizers are as given in the Table IV below. [11].It's obvious from the table that the emission intensity of Urea is much higher than the other two nutrients.

TABLE IV. Emission during the lifecycle of inorganic fertilizer.

| Inorganic Fertilizer | | Urea | Phosphate | Potash |
|---|---|---|---|---|
| Emission of $CO_2$ equivalent per kg of fertilizer production, transport and application (kg of $CO_2$ per kg) | | 2.792 | 0.738 | 0.352 |
| Emission of $N_2O$ and its $CO_2$ equivalent per kg of fertilizer applied to soil | kg of $N_2O$ per kg | 0.0125 | - | - |
| | kg of $CO_2$ per kg | 3.875 | - | - |
| Emission mitigation of equivalent $CO_2$ achieved through replacement of inorganic fertilizers through bio-fertilizer (kg of $CO_2$ per kg) | | 6.667 | 0.738 | 0.352 |

The Nitrogen, Phosphorus and Potassium content of Urea, Phosphate, Potash and the bio-fertilizer have been given in Table V. Table also shows the bio-fertilizer equivalent of the inorganic fertilizer derived from these data.

TABLE V. Bio-fertilizer equivalent of the inorganic fertilizers.

| Inorganic Fertilizer | Nutrients | | | Bio-fertilizer Equivalent of Inorganic Fertilizer (kg per kg) |
|---|---|---|---|---|
| | N | P | K | |
| Urea | 46 % | 0 | 0 | 23 |
| Phosphate | 0 | 43.7 % | 0 | 29.133 |
| Potash | 0 | 0 | 83.0 % | 69.166 |
| **Bio-fertilizer** | 2 % | 1.5 % | 1.2 % | 1 |

From the values in the last column the amount of inorganic fertilizers replaced by the bio-fertilizer can be calculated. Daily production of bio-fertilizer from the plant under consideration is 500 kg, so it can replace 21.739 kg of Urea, 17.162 kg of Phosphate and 7.229 kg of Potash. Therefore, based on the values in table IV, emission mitigation achieved per day due to avoidance of inorganic fertilizers can be computed as shown in table VI below.

TABLE VI. Emission mitigation due to avoidance of inorganic fertilizer.

| Inorganic Fertilizer | Amount of Production of Inorganic Fertilizer Avoided (kg/ day) | Emission Mitigation due to Avoidance of Inorganic Fertilizer | |
|---|---|---|---|
| | | kg of $CO_2$ per kg | kg of $CO_2$ per day |
| Urea | 21.739 | 6.667 | 144.933 |
| Phosphate | 17.162 | 0.738 | 12.665 |
| Potash | 7.229 | 0.352 | 2.544 |
| Total emission mitigation per day = 160.142 kg of $CO_2$ | | | |
| Emission mitigation per year = 160.142*365 = 58.451 Tons of $CO_2$ | | | |

From table III and table VI, for the plant under consideration, the total emission mitigation through renewable electricity generation and replacement of inorganic fertilizer through bio-fertilizer works out to be 181.31 tons of $CO_2$/ year.

## VIII. Revenue Generated Through Certified Emission Reduction (CER)

Though the bio-electricity has numerous tangible and intangible benefits, the financial feasibility of this option for rural energy excess is always crucial. Apart from public sponsorship and government subsidy, the revenue earned through Carbon Credit may help in making it a viable energy option. One CER (Certified Emission Reduction) is equivalent to 1 ton of $CO_2$ avoided. It is defined under article 16 of the Kyoto protocol. The rate of CER fluctuates with the price of crude oil. As per Carbon Trade Exchange (CTX), the leading market platform for buying and selling Carbon Credits, in May 2016 the price of one CER was around 3.5 Euro. Hence, for the biogas power plant under consideration with an emission mitigation of 181.31 tons of $CO_2$ per year the revenue generated will be 634.58 Euro or Rs. 48,228 per year.

## IX. Revenue Generated Through Renewable Energy Certificate (REC)

This may be another means for contributing to the BEF for its financial feasibility. The Renewable Energy Certificate (REC) system is a business sector based instrument to endorse renewable energy and encourage consistence of renewable purchase obligations (RPO). The Renewable Energy Certificate Registry of India has started issuing RECs to all third party owners who are generating electricity using renewable form of energy. There are two classifications of RECs, viz., solar powered RECs and non-solar powered RECs. Solar RECs are issued to qualified entities for generation of power with solar as renewable energy source, and non-solar based RECs are issued to qualified entities for generation of electricity through sources other than solar. The RECs might be sold to the obligated entities to empower them to meet their renewable purchase obligation [12].

The electricity generated has been computed to be 149.6 kWh per day or 54.604 MWh per year. As per Maharashtra Energy Development Agency (MEDA), for non-solar REC the current rate is Rs. 3480 per MWh. Hence for the BEF under consideration the revenue generated through REC will be Rs. 1,90,022.

## X. Biogas Electricity and Emission Mitigation Potential for Maharashtra

Biogas electricity and emission mitigation potential for an average village with bovine population of 485 have been estimated based on 200 standard bovine units and 2 ton - 88 $m^3$ biogas power plant. The revenue generated through CER and REC also have been computed for assessing their contribution in financial feasibility of the project. Based on this analysis for the average village, district wise computations have been done for the state of Maharashtra for biogas electricity and emission mitigation potential. The cumulative results for the entire state have been presented in Table VII. For 34 districts and 41,095 villages of different population sizes, the total bovine dung based bio-electricity potential has been found to be 265 MW and the emission mitigation potential has been estimated as 9,149 Megatons of $CO_2$/ year.

TABLE VII. Biogas electricity and emission mitigation potential for Maharashtra.

| Particulars | Average Village | Rural Maharashtra |
|---|---|---|
| Bovine Population | 485 | 2,02,99,649 |
| Standard Bovine Units | 203 | 84,96,554 |
| Daily Dung Availability | 2 tons app. | 84,966 tons app. |
| Number of Biogas Plant Units | 1 | 42,483 |
| Yearly Biogas Electricity Potential | 54.626 MWh | 23,20,696 MWh |
| Biogas Power Potential | 6.23 kW | 265 MW |
| Yearly Emission Mitigation Potential | 215.36 Tons of $CO_2$/ year | 9,149 Megatons of $CO_2$/ year |

## XI. Conclusion

The bovine dung based biogas power and the corresponding emission mitigation potential for Maharashtra as mentioned above are the direct benefits of the biogas power. There are manifold indirect benefits also, which are socio-economic in nature. If a well-planned and organised effort is there by the government to make it an inevitable component of state's energy portfolio, it will generate employment opportunities for lacs of rural youth. It will provide basic illumination and comfort to rural households. Use of biogas for cooking will help the women save the time wasted in collecting firewood and invest their energy in more meaningful tasks. It will also help in reducing in-house pollution due to use of firewood and dung cakes for cooking, which is one of the major causes for respiratory diseases among rural women and children.

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