Development of Integrated Energy System for a Goshala Complex (Intensively Live Stocked Farm)

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ABSTRACT

A study was carried out to assess the energy demand and resource availability in goshalas (Intensively Live-stocked Farm) and to suggest appropriate integrated model. Survey was carried out in three goshalas (small, medium and large) of district Hisar, Haryana. The assessment of thermal, mechanical, electrical and human energy demand in the goshalas was made. The availability of resources in the goshalas was also determined. Thermal, mechanical, electrical and human energy demand per animal per day was 0.668 MJ, 0.099 MJ (0.36 hp-hr), 0.204 MJ (0.056 kWh), and 0.432 MJ respectively. The average dung availability per animal per day was 4.28 kg. For economic analysis two arbitrary goshalas having cattle head population of 600 and 1200 were chosen. Four models viz. Model-I consists of the goshalas without biogas plant and biomass gasifier, Model-II consists of the goshalas with biogas plant, Model-III consists of the goshalas with biogas plant and vermicomposting unit, Model-IV consists of the goshalas with biogas plant, vermicomposting unit and biomass gasifier for both the goshalas were developed and the economic evaluation was carried out. The Model-I and Model-IV were found to be uneconomical for both the goshalas. The Model-III was found to be more economical as compared to Model-II. Therefore, Model-III was suggested for both the goshalas to make them self-sufficient in energy.

Keywords: Biogas production, biogas plant, goshala complex, integrated energy model, vermicomposting, India

1. INTRODUCTION

The energy consumption pattern of rural area in India or other developing country is based on the supply of non-commercial energy sources like firewood, agricultural waste, dung cakes etc. Very little amount of commercial energy is used. Based on the level of local demand and availability

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Y.K.Yadav, Anil Mehra, Surjeet Jain, M.K.Garg. "Development of Integrated Energy System for a Goshala Complex (Intensively Live Stocked Farm)". International Commission of Agricultural and Biological Engineers, Section V. Conference "Technology and Management to Increase the Efficiency in Sustainable Agricultural Systems", Rosario, Argentina, 1-4 September 2009.

of energy resources, a traditional system of technologies has existed in rural areas for centuries. After independence efforts were made for rural electrification and provide grid energy supply to villages in the country. But it is a barren fact that this energy supply has been grossly inadequate and energy demand of rural sectors could not be fulfilled in the required quantity and quality. There had been some progress in the development of alternative decentralized sources of energy like biogas, biomass fuelled gasifier utilizing local raw material and inputs. But still lots of efforts are required before these sources become economically viable and can supplement effectively to the present supply of energy from the central grid system. Introduction of new technologies with higher efficiencies and use of non-conventional energy sources are not always a least-cost option. Cost of energy supply is one of the major factors for choice of energy technologies option. The integrated energy system is a complex system and involves a comprehensive assessment of locally available energy resources. The design and development of an integrated energy system involves studying traditional energy consumption pattern and needs, improving traditional technology, adopting new technology to local condition and identifying effective methods for introducing innovative technologies. There are large numbers of goshalas in India particularly in northern India. Mostly these goshala falls in remote areas where the supply of electricity is either inadequate or erratic. Most of these goshala suffer losses because of improper utilization of resources available in these goshalas. In these goshalas, a large quantity of dung is produced daily. This dung is applied directly in the field as organic manure for crop production, which has low productivity. This dung has potential to generate biogas through installation of biogas plants. The biogas can be utilized for meeting thermal, electrical and mechanical energy demand of goshala complex. Also the residual slurry obtained from biogas plants can be utilized for the production of vermicompost that can be used as organic manure for the crop production. Goshala is a unique example of local resource utilization, decentralized energy generation, and diversified production activities, environmentally friendliness of technologies and self-sustenance through multi-sectoral network.

2. MATERIALS AND METHODS

Three goshalas (small, medium and large) were selected and survey was carried out for the basic data collection regarding total energy demand and resource availability in each goshala. Three goshala with different cattle head population of Hisar district selected were; Shri Ladwa Goshala at Ladwa, Shri Vaishnav Agarsen Goshala at Agroha and Shri Shala Dairy Goshala at Datta. The survey of major activities related to use of thermal, electrical, mechanical and human energy was conducted and total energy demand and energy use pattern was also studied in these selected goshalas. The data for energy demands and resource availability in each goshala were collected with the help of well-structured questionnaire developed for the purpose. The data collected from the goshalas were analyzed for assessing the different energy demands and resource availability in each goshala. The thermal, mechanical, electrical and human energy demand at three goshala complexes was calculated. The demand of various forms of energy for each animal in goshala per day and biomass requirement per year in any goshala was also calculated using standard procedure.

To calculate the quantity of vermicompost produced from the vermicomposting of the semisolid biogas slurry, two samples (20 kg each) of semi-solid slurry were put in the pit and 200g earthworms were introduced in each sample. The agricultural waste was spread at the top of slurry. Regular watering was done to maintain the optimum moisture for the earthworms. The vermicompost was ready within 30 days. After 30 days the agricultural waste was removed from the top of the slurry and it was left open for sun drying for half day. The earthworms were

separated from the ready compost. Then the vermicompost was sieved through the wire mesh. The quantity of vermicompost produced was weighed with the help of weighing balance.
For economic evaluation of goshala complex, two goshalas having 600 and 1200 animals respectively were chosen hypothetically. Four models viz. Model-I consists of the goshalas without biogas plant and biomass gasifier, Model-II consists of the goshalas with biogas plant, Model-III consists of the goshalas with biogas plant and vermicomposting unit, Model-IV consists of the goshalas with biogas plant, vermicomposting unit and biomass gasifier for both the goshalas were developed. The economic evaluation of all the four models was carried out for both of goshala.

For economic evaluation, five different standard economic indicators namely break even point (BEP), pay-back period (PBP), net present worth (NPW), internal rate of return (IRR) and benefit-cost ratio (B/C) were calculated. The life of biogas plants as well as of models was taken as 10 years. The discount rate was taken equal to the bank-lending rate of interest (12%). After evaluating all the four models, a suitable model based on integrated energy system for goshala complex was developed to match supply and demand of energy at goshala complex.

3. RESULTS AND DISCUSSION

The data for energy demand and resource availability in each selected goshala were collected with the help of well-structured questionnaire developed for the purpose. From the Table1, it was clear that the dung availability at Shri Ladwa Goshala complex was about 18 qt/day, at Shri Vaishnav Agarsen Goshala complex was about 72 qt/day and at Shri Shala Dairy Goshala Complex was 122.5 qt/day. From the data no systematic trend between collection of dung and number of cattle heads was observed. Therefore, the dung availability per animal per day was calculated by taking average. It was about 4.28 kg/animal/day.

The different forms of energy demands at these three selected goshalas are shown in Table 2. Thermal energy (ET), mechanical energy (EM), electrical energy (EE) and human energy (EH) demand at Shri Ladwa goshala was 529.57 MJ/day, 64.416 MJ/day, 157.35 MJ/day and 468.44 MJ/day respectively, at Shri Vaishnav Agarsen Goshala was about 764.24 MJ/day, 161.04 MJ/day, 450.93 MJ/day and 568.4 MJ/day respectively and at Shri Shala Dairy Goshala (G3) at Datta village was about 2026.29 MJ/day, 268.4 MJ/day, 406.8 MJ/day and 1068.2 MJ/day respectively. From the Table 2, it is also clear that total thermal energy (ET) demand, mechanical energy (EM) demand, electrical energy (EE) demand and human energy (EH) demand at three goshala complexes was about 3320.10 MJ, 1015.08 MJ, 493.856 MJ and 2141.04 MJ respectively. It was evident from the data that there is no systematic effect of cattle heads on the energy demands of the goshalas. Therefore, energy demand per animal per day was calculated by taking average values. The average value of thermal energy (ET), mechanical energy (EM), electrical energy (EE) and human energy (EH) demand per animal per day are 0.668 MJ, 0.099 MJ (0.036 hp-hr), 0.204 MJ (0.056 KWh) and 0.432 MJ respectively.

Two arbitrary goshalas complexes viz. a small goshalas (GS) with cattle heads population of 600 and a large goshalas (GL) with cattle heads population of 1200 respectively with provision of wasteland to produce biomass were selected and four models viz. Model-I consists of the goshalas without biogas plant and biomass gasifier, Model-II consists of the goshalas with biogas plant, Model-III consists of the goshalas with biogas plant and vermicomposting unit, Model-IV consists of the goshalas with biogas plant, vermicomposting unit and biomass gasifier for both the goshalas were assessed. A general model of integrated energy supply for a goshala complex suggested for small and large size goshalas is presented in Figure 1.

The different forms of energy demands viz. thermal energy (ET), mechanical energy (EM), electrical energy (EE) and human energy (EH) at the two arbitrary goshalas are shown in the Table 3. The thermal, mechanical and electrical energy demand for small goshalas (GS) complex was about 400.8 MJ/day, 58.24 MJ/day and 120.96 MJ/day respectively and for large goshalas (GL) complex was about 801.6 MJ/day, 115.95 MJ/day and 241.92 MJ/day respectively.

The cost of supplying energy by different energy sources is shown in the Table 4. Five economic parameters viz. break-even point (BEP), pay back period (PBP), net present worth (NPW), internal rate of return (IRR) and benefit-cost ratio (B/C) for all the four models for small and large goshalas are shown at Table 5. From the results of economic indicators, it was found that Model-I was uneconomical for both sizes of goshalas as this model shows loss instead of profit. Model-IV was also uneconomical for both the goshalas. Model-III was found to be more economical as compared to Model-II for both the goshalas as in this model BEP was less than one, PBP was less than the life of the model, NPW was greater than the capital cost, IRR was greater than assumed discount rate (12%) and B/C ratio was greater than one. In Model-III all the energy demands of the goshalas will be met by the biogas supplied from the biogas plants and semisolid slurry obtained from biogas plant will be utilized for production of vermicompost. The earthworms required per quintal of semi-solid slurry were 1000 (1 kg). The vermicompost produced from each kg of semisolid slurry was about 625g. Additional income will be generated to the goshalas by selling the vermicompost. By adopting Model-III (consisting of the goshalas with biogas plant and vermicomposting unit), goshalas can be made self-sustained from energy point of view. It was also found that large goshala (GL) was more economical than small goshala (GS) in all the models.

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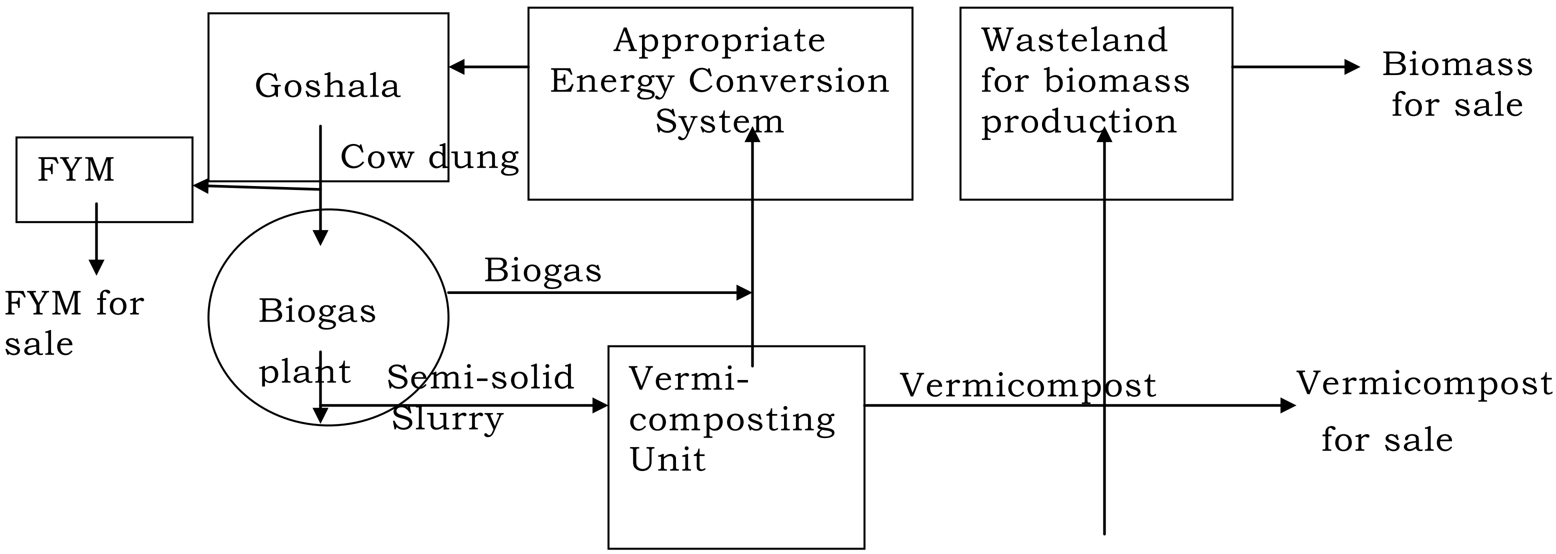

Fig. 1. Model of Integrated Energy Supply for a Goshala Complex

Table 1. Resource Availability in Selected Goshala Complexes

Name of Goshala	No. of Cattle Heads	Dung Produced (qt/day)	Dung Collected		FYM produced	
			qt/day	qt/day/animal	qt/yr	qt/yr/animal
Shri Ladwa Goshala,Ladwa (Hisar)	610	20	18	0.0295	1168	1.9147
Shri Vaishnav Agarsen Goshala, Agroha (Hisar)	1219	80	72	0.0590	6570	5.3896
Shri Shala Dairy Goshala, Datta (Hisar)	3131	136	122.5	0.0391	12410	3.9635

Table 2. Energy Consumption in Selected Goshala Complexes

Different forms of energy consumed in Goshala Complex	Shri Ladwa Goshala, Ladwa	Shri Vaishnav Agarsen Goshala, Agroha	Shri Shala Dairy Goshala, Datta	Total energy consumption (MJ/day)	Total energy consumption per animal (MJ/day))
Thermal energy consumption for water heating, milk boiling, cooking food & feed preparation (MJ/day)	529.57	764.24	2026.29	3320.10	0.668
Mechanical energy consumption for chaff cutting (MJ/day)	64.416	161.04	268.4	493.856	0.099
Electrical energy consumption for lighting, water pumping & grinding of feed (MJ/day)	157.35	450.93	406.8	1015.08	0.204
Human energy consumption for fodder chopping, feeding animals, grazing animals, milking, washing, dung removing & food preparation (MJ/day)	468.44	568.4	1068.2	2141.04	0.432
Total	1219.77	1944.61	3769.69	6970.076	1.403

Table 3. Estimated Energy Demand of Two Arbitrary Goshalas

Goshala	**Thermal Energy demand (MJ/day)**	**Mechanical Energy demand (MJ/day)**	**Electrical Energy demand (MJ/day)**	**Total Energy demand (MJ/day)**
Small Goshala with 600 cattle heads (G_S)	400.8	58.24	120.96	580
Large Goshala with 1200 cattle heads (G_L)	801.6	115.95	241.92	1159.47

Table 4. Cost of Energy Supply Source and Income of Goshalas

Models	Type of Energy	Source of Energy Supply	Cost (Rs.)	Income (Rs/yr).
G_SM_1	Thermal	Biomass produced on wasteland	65172	
G_SM_1	Mechanical	Chaff cutter with diesel engine	47145	
G_SM_1	Electrical	Commercial grid supply	36792	
G_SM_1	Human	Human beings	58400	
Total			207509	74986
G_SM_2	Thermal, Mechanical & Electrical	Biogas Plant with diesel engine	278389	376894
G_SM_3	Thermal, Mechanical & Electrical	Biogas Plant with diesel engine	583264	811660
G_SM_4	Thermal, Mechanical & Electrical	Biogas Plant with diesel engine & gasifier with diesel engine	500402	557111
G_LM_1	Thermal	Biomass produced on wasteland	129473	
G_LM_1	Mechanical	Chaff cutter with diesel engine	73541	
G_LM_1	Electrical	Commercial grid supply	73584	
G_LM_1	Human	Human beings	87600	
Total			364198	149971
G_LM_2	Thermal, Mechanical & Electrical	Biogas Plants with diesel engine	539525	753789
G_LM_3	Thermal, Mechanical & Electrical	Biogas Plants with diesel engine	1149025	1626366
G_LM_4	Thermal, Mechanical & Electrical	Biogas Plants with diesel engine & gasifier with diesel engine	939203	1108280

Table 5. Economic Indicators for Proposed Models

Goshala and Model Combination	BEP	PBP (Yrs)	NPW (Rs.)	IRR (%)	B/C Ratio
G_SM_1	-	-	-	-	-
G_SM_2	0.53	4.53	110625	17.9	1.05
G_SM_3	0.38	2.52	714538	38.2	1.18
G_SM_4	0.77	8.27	-148531	11.2	0.95
G_LM_1	-	-	-	-	-
G_LM_2	0.51	4	353310	21.5	1.09
G_LM_3	0.36	2.33	1584754	41.7	1.21
G_LM_4	0.58	5.6	9493	12.3	1.0

G_S=Small goshala with 600 animals
G_L=Large goshala with 1200 animals
M_1=Model-I (consists of the goshala without biogas plant, vermicomposting unit and biomass gasifier)
M_2=Model-II (consists of the goshalas with biogas plant)
M_3=Model-III (consists of the goshalas with biogas plant and vermicomposting unit)
M_4=Model-IV (consists of the goshalas with biogas plant, vermicomposting unit and biomass gasifier)