Village Dendro Plants for Rural Electricity Supplies: A Case Study

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Abstract

Rural electrification in Sri Lanka is presently based on four different sources namely extension of the national grid and off-grid village hydro schemes, wind systems and solar home systems. It is estimated that about 15% of the households will have to be eventually supplied through off-grid systems. Due to the ability to provide relatively large capacity and higher reliability and the localised nature of the fuel used, wood fuel fired biomass based off-grid generation plants have attracted increased attention in recent times.

This paper presents the results and the analysis of a feasibility study on a wood fuel fired biomass gasification based electricity generation system for a remote rural community in the North Central Province of Sri Lanka. This case study mainly focused on two isolated villages in the intermediate/ dry zone in Sri Lanka. The contents are based on the survey carried out in these villages, Welimuwapothana and Horrowpothana. Based on the analysis it is concluded that 80-100 households of this community can be successfully provided with electricity at an affordable cost using a gasifier based wood-fuel fired power plant.

Keywords *– Supply Chain, Producer gas, Gasifier, Dendro Power*

1. Introduction

Out of the main primary energy sources, it is evident that biomass energy dominates the energy supply in Sri Lanka. At present 50% of the total primary energy supplies in the country accounts from biomass energy. The industrial and commercial sectors use biomass to satisfy 63% of their energy requirements.

Electricity generation using biomass at village scale off-grid systems has never been field tested in Sri Lanka apart from the only plant established recently in Monaragala which is not yet fully operational. There is one grid connected power plant already in operation and a few other systems are immerging with the intervention of the private sector. Lack of coordination among plantation, power generation and social management is one of the main barriers for penetration of this technology.

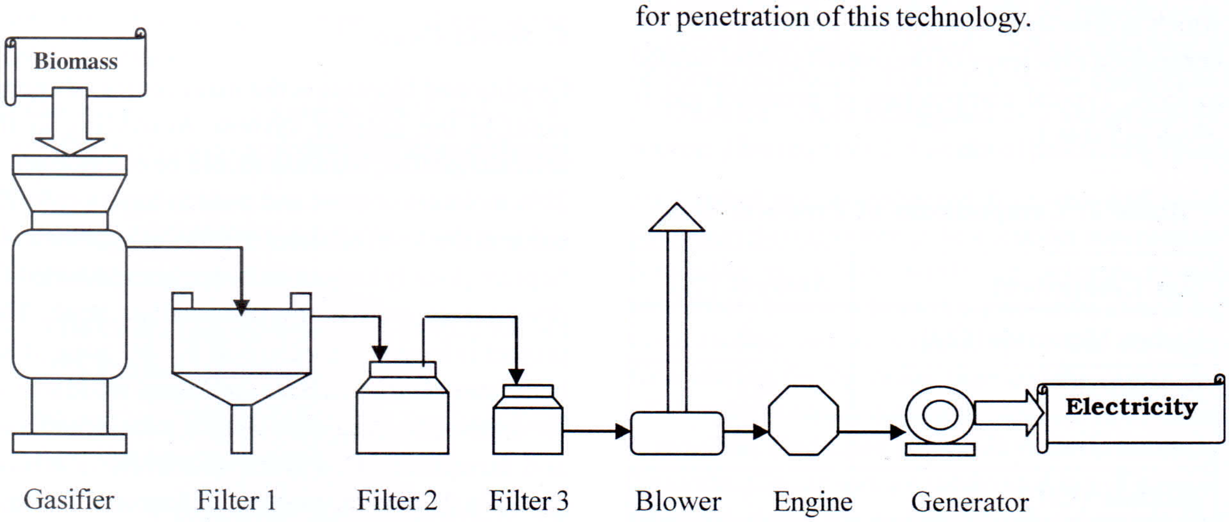


Figure 1: Energy Conversion

In this study the coordination among the key areas in Dendro Power Development has been achieved. Further a model has been designed considering Load Profile, Plantation & Supply Chain management, Generation & Distribution System management and Financial & Tariff structure.

It is possible to combine dendro plants with Solar/ Wind/Fuel Cell technologies to make optimal hybrid systems for rural communities. In addition to this, waste products of the gasifier (ash) and leaves removed from the trees can be utilized in producing natural organic fertilizer & biogas. These options have not been analyzed in the study though they remain for future development

2. Technology

Out of several mature technologies in biomass conversion, gasifier based technology is selected as the suitable conversion mechanism for small-scale power generation at village level.

Gasifier technology consists of the following. Conditioned biomass introduces to the gasifier, which converts it to producer gas according to the characteristics of the unit. Inside the gasifier wood chips are dried, pyrolized, partially combusted with low oxygen and brought into the form of producer gas [9]. This gas is directed through a process of filtration to the prime mover, which is a converted natural gas diesel engine, where it is burnt. Electricity is taken out from a three-phase alternator, which is directly coupled to the prime mover. The conversion efficiency of the overall system limited to 22%. Typical composition of producer gas is given in Table 1.

Table 1: Compositions of Producer Gas

Gas Component	Amount (%)
Carbon Monoxide (CO)	19
Hydrogen (H_2)	18
Carbon Dioxide (CO_2)	10
Methane (CH_4)	3
Nitrogen (N_2)	50

3. Plant Capacity

Plant capacity is determined using two options of connection capacity for each household. Table 8 gives the details of the two options available

Table 2: Capacity Options Available

	40kW Option	27kW Option
Number of Household Capacity for each	125	125
household (We)	200	150
Expected Max Capacity (kW)	27.5	20.63
Available Generating Unit	GAS-40	GAS-9

4. Load Curve

Based on the response of the Social Survey, the load curves can be derived for the community. It was evident from the survey outcome that the electricity requirement of the community is limited to the two periods 4am – 9am and 5pm-12pm. Thus, the design plant factor for both of these options becomes 50%. But once the plant is in place, it is likely that some economic activity driven by electricity supply would start which will eventually improve the plant capacity factor.

5. Supply Chain

Conditioned biomass is the main source of energy input to the gasifier system. According to the selected gasifier, biomass should be conditioned to 20% moisture content and need to have a calorific value at the level of about 3500kCal/kg. Gliricidia Sepium (locally know as Albizzia) is best suited for dry zone as well as the intermediate zone. This project is based on a village in the dry zone; it has been found Gliricidia is a suitable fuel wood species for cultivation in agro-forestry system, woodlands and farmlands [4]. Further Gliricidia is already grown in these villages along the fences of the lands and paddy fields

This tree exhibits many more advantages over other species and it has an average calorific value of 3500kcal/kg. It has an average fuel wood production of 4 tones per hectare per year. This species can be propagated through mature stem cutting or seeding. First method is recommended. It takes 12-14 month period before the fist harvest can be obtained. Thereafter harvesting of the same tree can be carried out every 3 months. During this 3 month time period branches acquire a stem in the range of 50mm to 60mm diameter and a length of 50mm to 100mm. Thus rotation period can be considered to be 3 months.

Considering the sustainability of the project energy plantation is divided into two components,

- Dedicated (Mainland) Plantation
  The Village Consumer Society owns this plantation. Hectare of this plantation yields 7681trees/ha/year, which accounts for 30724kg/ha/year.

- Voluntary Plantation (Paddy field based)
  This portion of land belongs to the energy consumers of the village. Hectare of this plantation yields 10000trees/ha/year, which accounts for 40000kg/ha/year.

The above calculations based on the optimum spacing available to our soil, which is 1m x 1m. Considering the overall growth phenomenon only 80% of the trees would survive after the initial plantation. This has been compensated during the plantation design.

Plantation has to be designed to 40kW and 27kW cases. The analysis is carried out for three different cases

- Best Case - This includes 100% Dedicated and 0% Voluntary plantation.
- Base Case- This includes 50% Dedicated and 50% Voluntary plantation
- Worst Case-This includes 10% Dedicated and 90% Voluntary plantation

Tables 3 and 4 shows the land requirements for 40kW and 27kW systems respectively.

Table 3: Land Requirement for 40kW

	40kW	
	Dedicated Plantation (ha)	**Voluntary Plantation (ha)**
Best case	7.23	0.00
Base case	3.61	2.77
Worst case	0.72	5.00

Table 4: Land Requirement for 27kW

	27kW	
	Dedicated Plantation (ha)	**Voluntary Plantation (ha)**
Best case	4.88	0.00
Base case	2.44	1.87
Worst case	0.45	3.38

The calculation show that a rate of 42.16 kg/h of biomass supply is required for 40kW option. Thus, it requires 185 tones of biomass per year. For 27kW option it is 28.4 kg/h and therefore it requires 125 tones of biomass annually. These requirements are met through different plantation arrangements mentioned in the three cases.

Biomass that is harvested needs to have a stem diameter in the range of 50mm to 60mm and a length of 50mm to 100mm. Further, biomass needs to be conditioned before being used as a useful energy source. This requires 2-3 weeks of processing time.

Fuel wood that is collected from the dedicated plantation is conditioned at the site under supervision. Since the voluntary plantation belongs to the consumers biomass from this plantation should be conditioned before supplying to the storage. Considering the operation time and the continuity of electricity supply a storage capacity of 10 tones is required. Dedicated plantation is harvested every 2 months. Consumers are subdivided in to 4 groups. Relevant group for that month should supply the required amount of biomass.

The 40kW option of Ankur Scientific (Ltd.) India consists of one gasifier unit named as GAS – 40. The 27kW option consists of three gasifiers, which has unit capacity of maximum 9kW that has been utilized in parallel operation. Since both these systems consist of induction generators no synchronization problem is expected.

Producer gas is fed through a filtration system containing Fine Filter 1 & 2, Static Filter and Coarse Filter (as in figure 1), which control the moisture content, dust/ash partials and small wood pieces contain in the producer gas. A blower is used to obtain uniform gas flow to the engine. There might be a backfire problem associated with the natural gas converted diesel engine. A separate unit is installed to rectify this problem. For the optimum use of the generated energy, three-phase distribution system needs to be incorporated.

Since this is a variable load condition, a frequency controller is installed into the engine. Thus, conventional dummy load for frequency control can be eliminated from this generating system.

6. Financial Analysis

Project costs vary substantially depending on the case under investigation. Final project costs excluding taxes are as shown in Table 5. These costs include cost for land, construction cost (powerhouse, fuel wood storage, etc.), cost for generating unit, cost for distribution system, initial working capital, interest during construction, owners cost and project development costs.

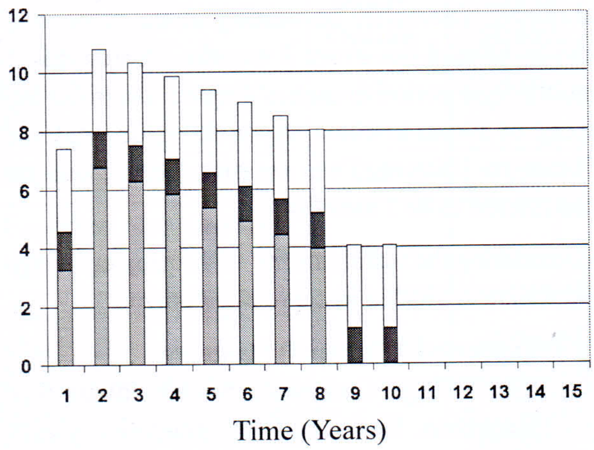
Table 5: Project Costs

	40kW (Rs million)	27kW (Rs million)
Best case	7.05	4.72
Base case	6.54	4.38
Worst case	6.14	4.10

Funding for this kind of projects is available through Global Environment Fund (GEF), Village Consumer Societies, Commercial Bank Loans and from NGOs and the local or provincial Government.

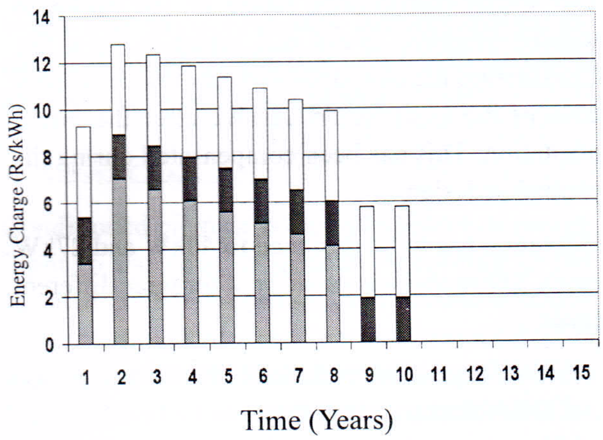
Operation & maintenance and other costs related to the power generation are taken as fixed tariff from each household. Figure 2 & Figure 3 show the relevant tariff schemes and composition of energy charge for Base Case of 40kW option and 27kW option.

Figure 2: Composition of Energy Charge for Base Case of 40kW Option



The bottom portion represents the capital repayment while the middle portion represents the fixed operation and maintenance cost. The top portion represents the variable costs.

Figure 3: Composition of Energy Charge for Base Case of 27kW Option



In this analysis it was assumed that 70% of the total project cost is funded by a loan of which the repayment period is 8 years. The interest rate of the loan is assumed to be at the current rates of 12.5%. It can be seen that the capital repayment portion has the highest contribution to the final total energy cost.

During the repayment period the cost of energy varies between Rs 8-12.5 per kWh. This kind of costs are very much in line with those of off-grid village-hydro plants. After the end of repayment period, the energy charge comes down to around Rs 4-6 rupees per kWh depending on the capacity of the plant. This leads to a monthly payment of a consumer to be around Rs 275-425 per month, which is in the same range as the monthly kerosene cost for lighting in a household of this kind. This is calculated assuming that the number of units used by a consumer is 72 units.

7. Sustainability and Risk

Sustainability of the entire project depends on the efficiency and the continuity of the supply chain. Thus, main consideration needs to be given to plantation and fuel-wood supply from the villagers. This is the main reason for incorporation of the three cases in to the study.

If Best Case is adopted the risk involved in the implementation of the power plant will be minimum, and has the highest sustainability and highest project cost. Conversely the worst-case scenario has inherently high risk in the implementation of the power plant and has a poor sustainability and lowest project cost. Therefore the base case scenario which provides the compromise between the two extremes is recommended for implementation.

8. Conclusion

The study shows that the power project discussed in the paper is most suited for isolated off-gird villages in dry/intermediate zones of Sri Lanka. This is particularly useful in the remote villages where there is some economic activity during the day time which needs a source of continuous power. Such economic activities will further justify the investment on a plant of this nature.

Any selected village social feasibility is the first the most important step. If the technology is acceptable to the community, the model discussed in the paper can be easily applied. In order to ensure sustainability of the project it is important that the Village Consumer Society be given a major role and complete authority in controlling the supply chain.

It is concluded that off-grid dendro power is the answer to providing electricity supplies to remote rural communities in the dry-intermediate zones where it provides the same or better services as that of a village-hydro plant located in the wet zone.

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