Micro Scale Village Based Dendro Power Development

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***Abstract* – This paper introduces a renewable energy harnessing technology from fuel wood, which is known as Dendro Power. This is mainly focused for an isolated off-grid village (80–100 households) in intermediate/dry zones in Sri Lanka. The contents are based on the survey carried out at Welimuwapothana, Horrowpothana (dry zone), which has been selected as the model of the study.**

Index Terms –Supply Chain, Producer gas, Gasifier

I. Introduction

From the current sources, it has been evident that biomass energy dominated the sources of energy in Sri Lanka (SL). At present 53% of the total energy consumes in the country accounts from biomass energy [13]. The industrial and commercial sectors use 63% biomass energy to fulfill the energy requirement of the sector.

Biomass is the only large scaled indigenous primary energy source in SL, which is taken for electricity generation. This technology has been strengthened by considerable environmental benefits.

Electricity generation using biomass in village scale off grid systems have never been tested out in SL though grid connected systems are immerging with the intervention of the private sector. Lack of coordination among plantation, power generation and social management is the main constrains for the emerging of this technology.

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

In order to make the study viable a comprehensive sustainability & risk analysis has been incorporated. This has been achieved by dividing the study in to three major cases based on Supply Chain, which are, Best Case, Base Case and Worst Case.

Dendro is capable of combining with Solar/Wind/Fuel Cells technologies to make optimal efficient hybrid system in future. 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 mentioned options have not been analyzed in the study though remain for future development

II. Technology

Out of several mature technologies in biomass conversion, gasifier technology has been selected as the suitable conversion mechanism for small-scale power generation.

Gasifier technology consists as follows. Conditioned biomass introduces in to the gasifier, which converts in to producer gas according to the characteristics of the unit [9]. This gas directs through a process of filtration to the prime mover, which is a natural gas converted diesel engine. Electricity is taken out from a three-phase alternator, which is directly connected to the prime mover. Figure 1 illustrates the whole biomass conversion system.

Inside the gasifier wood chips are dried, pyrolized, combusted (partially with low oxygen) and reduced in to producer gas [9].

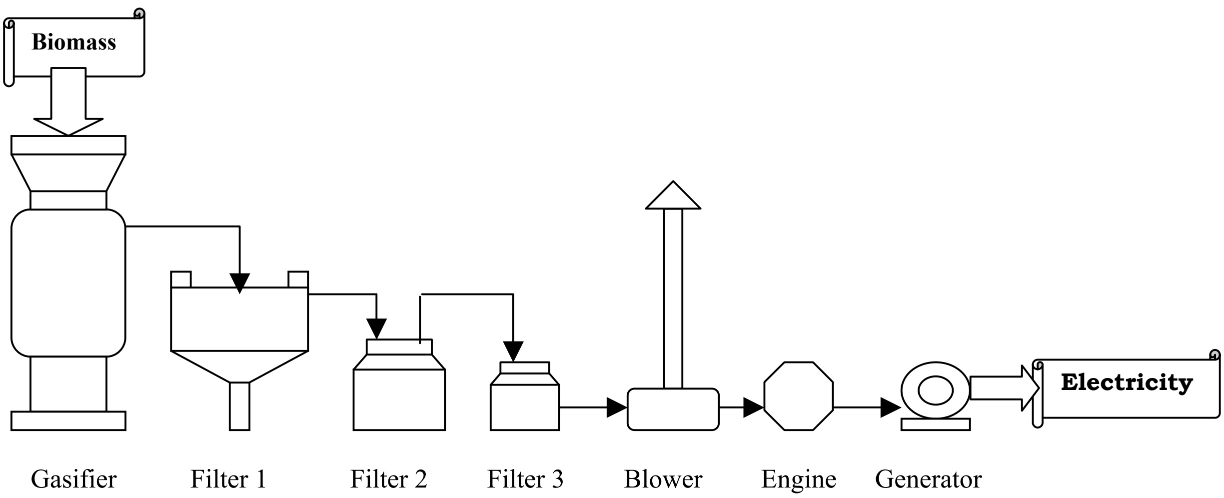

Fig 1: Energy Conversion system

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

(Courtesy: Ankur Scientific-India)

The conversion efficiency of the overall system limited to 22%.

Capacity Calculation (CC)

Capacity calculated according to two criterions. Table 8 gives the details

TABLE 2
CAPACITY OPTIONS AVAILABLE

	40kW Option	27kW Option
Household	125	125
Capacity	200 (We)	150 (We)
Exp. Max Cap.	27.5 (kW)	20.625 (kW)
Available Unit	GAS - 40	GAS - 9

Load Curve (LC)

Based on the facts on Social Survey, following Load Curves are reached as shown in figure 2 & 3. Blue line represents the maximum capacity available and Red line represents the maximum continuous running capacity available.

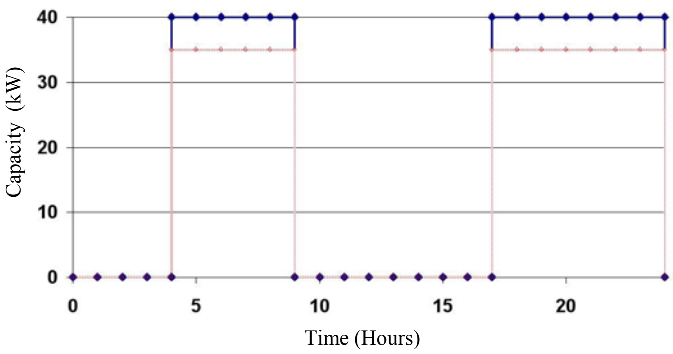

Fig 2: Expected Load Curve for 40kW Option

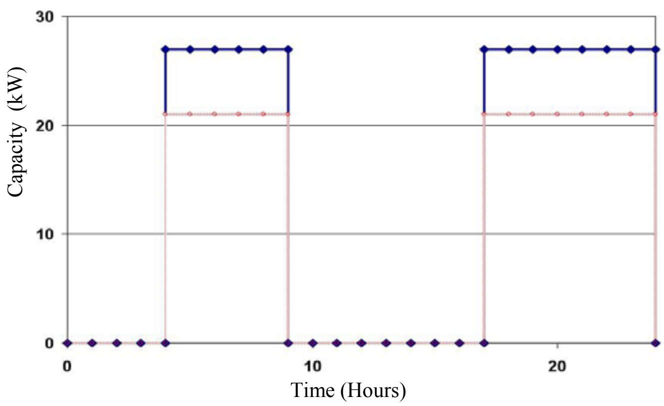

Fig 3: Expected Load Curve for 27kW Option

Thus, the design plant factor is 0.5.

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 should have a calorific value in the range of 3500kCal/kg [4]. 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 dry zone; it has been found Gliricidia is a suitable fuel wood species for cultivation in agro-forestry system, woodlands and farmlands [4].

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 4kg/ha/year [4] [2].

This specimen can be propagated through mature stem cutting or seeding. First method is recommended. It will take 12-14 months of incubation period, before the fist harvest is done. Then harvesting of the same tree can be done every 3 months [4]. During this time periods tree will acquire a stem in the range of 50mm to 60mm diameter and a length of 50mm to 100mm [2]. Thus rotation period would be every 3 months.

Considering the sustainability of the project energy plantation has been divided in to,

1. Dedicated (Mainland) Plantation

   The Village Consumer Society owns this plantation. Hectare of this plantation yields 7681trees/ha/year, which accounts for 30724kg/ha/year.

2. Voluntary Plantation

   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 [4]. Considering the overall growth phenomenon only 80% of the trees would survive after the initial plantation [4] [2]. This has been compensated during the plantation design.

Plantation has to be designed to 40kW and 27kW cases. The props and cons of the above diversion is analysed according to

1. Best Case

   This includes 100% Dedicated and 0% Voluntary plantation.

2. Base Case

   This includes 50% Dedicated and 50% Voluntary plantation

3. Worst Case

   This includes 10% Dedicated and 90% Voluntary plantation

Table 3 shows the land requirement for 40kW case

TABLE 3
LAND REQUIREMENT FOR 40KW

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

Table 2 shows the land requirement for 27kW case

TABLE 4
LAND REQUIREMENT FOR 27KW

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

The efficiency of the biomass supply system accounts from rate of fuel consumption. For 40 kW option it has been found that 42.16 kg/h rate of biomass supply required. Thus, it requires biomass 185 tones/year. For 27kW option it has been found that 28.44 kg/h required. Thus, it requires biomass 125 tones/year. This requirement is met according to above-mentioned three cases.

Biomass that has been harvested should have a stem diameter in the range of 50mm to 60mm and a length of 50mm to 100mm. Biomass should be conditioned before being used as the useful energy source. This would require 2-3 weeks of processing time [4].

Fuel wood that has been collected from dedicated plantation is conditioned under the supervision of the skilled labour. Voluntary plantation belongs to the consumers. Thus, they should be conditioned the biomass before supplying to storage.

Considering the operation time and smoothness of operation a storage that has a capacity of 10 tones should be built.

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.

Ankur Scientific (Ltd.) India [9], will supply the gasifier units. The 40kW option 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 these are induction generators used in the system, synchronization problem will not occur.

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 [9].

There is no point of converting the three-phase output into a single-phase system by using C-2C method [16]. Hence for the optimum use of the generated energy, three-phase distribution system should be incorporated in to the site.

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.

Greenhouse environmental effects are minimized in this technology, because the tree absorbs the output CO_2 gas when it is growing. i.e. CO_2 neutral. Also the tree increases the nitrogen content of the soil as well as it prevents the soil erosion. Produced ash and removed leaves can be used as an organic fertilizer, which is rich of Nitrogen [4][20][2].

III. Financial Analysis

Project cost diversifies according to several cases. 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

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

Funding to this project available through Global Environment Fund (GEF), Village Consumer Society, Bank Loan and balance from NGOs & Local Government Agencies.

Operation & maintenance and other costs related to the power generation are taken as fixed tariff from each and every household. Figure 4 & figure 5 shows the relevant tariff schemes and composition of energy charge for Base Case of 40kW option and 27kW option.

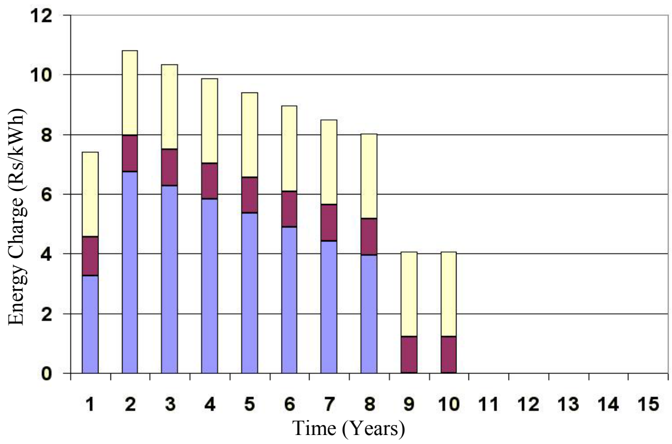

Fig 4: Composition of Energy Charge for Base Case of 40kW Option

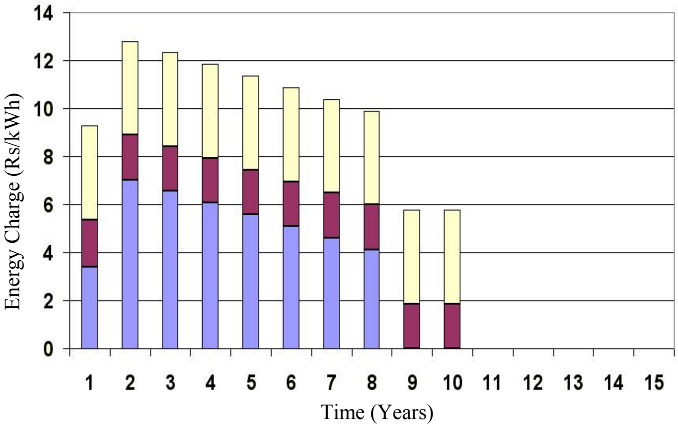

Fig 5: Composition of Energy Charge for Base Case of 27kW Option

Blue portion represents the capital repayment, Red portion represents the fixed O & M costs and Yellow portion represents Variable costs.

In this analysis 70% of the total project cost has been funded by a loan with the interest rate of 12.5%. That is why the capital repayment portion of the energy charge constitutes a higher contribution.

After the end of the repayment period, the energy charge will be around 3-4 rupees; hence monthly payment of a consumer should be around 250-300 rupees per month. (This is calculated assuming that the number of units used by a consumer is 72 units)

IV. SUSTAINABILITY AND RISK

Sustainability of the entire project depends on the efficiency of the supply chain. Thus, main consideration has been given to Plantation and Fuel Wood supply from the villagers. This is the main reason for incorporate three cases in to this study.

If Best Case has been adopted the risk involved in the implementation of the power plant will be minimum, has the highest sustainability and highest project cost. Conversely the selection of Worst-case will inherent the highest risk to the implementation of the power plant, has the minimum sustainability and lowest project cost. Base Case compromises the above-mentioned two cases and recommended for implementation. This case compromises between the project cost and sustainability/risk.

The village consumer society must have a prominent authority and commitment over the villagers to make this power scheme a success.

V. CONCLUSION

This kind of power project is most suited for isolated off-gird villages in dry/intermediate zones of SL. Thus, select a suitable village, from relevant zone with the aid of Distribution Expansion Planning Branch of Ceylon Electricity Board (CEB), which is not prioritized to electrify within the next 15 years.

Any selected village social feasibility is the first step. If it is acceptable, above mentioned model is easily applied. Only stake comes from the supply chain. Village Consumer Society should play a major role in controlling the supply chain. This model is developed to apply for any village as a Renewable Energy Generating Technology in SL.

VI. ACKNOWLEDGMENT

We are eternally indebted to Dr. Nishantha Nanayakkara and Prof. Priyantha Wijetunge, without whom this exercise would have been a mere pipe dream. We also extend our sincere gratitude to Dr Thilak Siyambalapitiya, Dr Kennedy Gunawardena and Mr. Sunith Fernando for their technical assistance.

The critical juncture of this project is undoubtedly the selection of an appropriate location, we remember with fondness, all who helped in this regard, particularly Mr. Lalith Fernando and Mr.Ajith Alwis.

Finally, we would like to thank the staff of the Department of Electrical Engineering and all others, whose corporation and inspiration went a long way in the successful completion of the project.

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