BIOMASS GASIFICATION FOR DECENTRALIZED ELECTRICITY GENERATION IN MALAWI

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EXECUTIVE SUMMARY

Inadequate access to energy poses a critical challenge to Malawi's economic development. Less than 13% of the population has access to electricity and those who do face insufficient and unreliable supply. Yet to date, renewable energy –both on-grid and off-grid has played a small role in electrification. The objective of this study was to design, develop and characterize rice husk gasification system as an alternative source of power for electricity generation. The biomass-based power project aimed to provide access to clean energy services, primarily focusing on productive load using locally available biomass feedstock. The study was carried out by collecting data in the paddy plantation area, paddy production, rice milling industry. It was decided based on the potential analysis of collected data to develop a rice husk gasifier power plant in Wowo Cluster Village, Nkhulambe Extension Planning Area (EPA), Phalombe District. The basic engineering design and detailed engineering for this plant were carried out after selecting the plant location. The plant was designed for 100 kWe electricity capacity using a fixed bed reactor equipped with a gas cleaning system. The design was made as simple as possible so that a local manufacturer can fabricate the reactor. In addition, the economic analysis has been carried out using the primary methods of NPV (Net Present Value), IRR (Internal Rate of Return) and PBP (Pay Back Period) assessment. The results showed that the economic viability of the proposed system is always acceptable with positive PBP and NPV values.

INTRODUCTION

Access to affordable and reliable electricity is a key challenge and policy priority in Malawi. Currently, 87% of the population still lacks access to electricity, with a disparity of 4% in rural areas compared to 58% in urban areas (NSO, 2018). With residential tariffs at $0.14/kWh and connection costs of $150, electricity is unaffordable for many even in the vicinity of the grid. Unsurprisingly, electricity consumption is low; in 2016, Malawi's per capita electric consumption stood at about 110 kWh, far lower than the African average of 153 kWh. Against this backdrop, the government sees renewable energy (RE) as a potential solution to low levels of access. Moreover, the government sees renewable energy as one way to reach rural populations who live beyond the national grid. The Government of Malawi has set an ambitious target to increase electricity access to 30% by 2040, primarily by increasing generation capacity and expanding the grid. The government has recently identified that off-grid technologies can be cost-effective in providing electricity to a dispersed rural population. Malawi's rural communities, which constitutes 85% of the country's population, are dispersed and demand insufficient electricity (at existing prices) to justify the cost of extending the grid. Going forward, despite aggressive grid targets, off-grid technologies are likely to play an increasing important role in bringing electricity to the rural poor. The overall goal of the project was to design, develop and characterize rice husk gasification system as an alternative source of power for electricity generation. The study intended to increase awareness on the benefits of utilizing biomass (agricultural waste) for useful products with several social and environmental benefits.

APPROACHES AND RESUTS

This study consisted of desk studies, primary data collection in field visits (February and March 2019), laboratory analysis in Malawi, and the integrated feasibility study assessment for Wowo Cluster Village

Community. The main tasks undertaken were:

A. Desk review and inception: feasibility analysis methodology adaptation (components, quantified criteria, protocols); and desk review of available information on gasifiers
B. Field work: preparation of field work- materials, logistics; and field visits to over 50 rice mills spread across the eight Agricultural Development Divisions (ADDs)
C. Feedstock characterization: proximate and ultimate analysis
D. Feasibility characterization and community ranking: (i) socio-economic component analysis (needs assessment, energy demand, income structures, prospects for business development, willingness to pay; (ii) technical and technological component analysis (supply chains, biomass resources, distribution); (iii) financial component analysis (cost-benefit analysis, cash flow projects, social NPV); and (iv) ranking of communities potentials and selection for detailed implementation preparation
E. System design: design theory, mathematical modeling, computational fluid dynamics; final design and manufacture of different parts and assembly.

The summary of the key findings are given below:

- Crop residues contribute significantly to the biomass sector in Malawi and can potentially be used as energy source for rural electrification. Rice straw, rice husks, maize straws[stalks], maize cobs are the major agricultural residues that can be used to meet the electricity needs of rural communities in the country.
- With the total agro-crops production of 2.45 million tons, and considering the amount of fraction of different types of crops, the total contribution of biomass residue potential is about 5.5 million tons.
- The baseline study found that rice husk is approximately 20% of rice production by weight, and rice straw is approximately 29%-130% of rice production by weight.
- Considering a combustion efficiency of 95%, with calorific of 13.3 GJ/ton and 15.65 GJ/ton, for rice husks and maize cobs, respectively, and at power plant efficiency of 25%, the amount of power generated is in the range of 0.013 – 0.544 MW. For gasification of maize cobs, the amount of power generated is in the range 2.0 – 20 MW.
- Results of the proximate and ultimate analyses showed that rice husks has high volatile matter contents (59.63 % dry basis) and low bulk density (120 kg/m^3), consequently, it is easier to ignite and to burn than coal because of the high volatile matter. The low density complicates its transportation, storage and processing. The ultimate analysis showed that

carbon content is 38 to 50%, hydrogen is around 6%, oxygen is 30 to 43%, and nitrogen is around 2% and traces amount of Sulphur.

- The study found that collection and transportation of agricultural residues especially rice husk, corn cobs and fuel wood are somehow established but it is purely in customary form in Malawi. Due to the nature of commodity, specialized storage and transport facilities are required.

IMPLICATIONS AND RECOMMENDATIONS

Biomass continues to play an important role for the energy sustainable development in Malawi, the potential of biomass is huge, however, its conversion to modern energy is still low. Biomass gasification can offer an attractive alternative renewable energy system especially in rural areas where biomass fuel is readily available. These resources could provide community based small-scale independent power plants. Rice husks and straw as well as maize stalks and maize cobs can be ranked the two top of the available biomass types in Malawi. This study has undertaken a baseline study as well as feedstock assessment. It has also conducted a detailed feasibility assessment; carried out system design and has fabricated and assembled a gasification system. To address the energy challenges facing rural areas in Malawi, by converting agricultural residues, the study proposes the following recommendations:

- Industrial Research Centre (IRC) through the Malawi University of Science should continue with one or more sites that have been analyzed in this feasibility study. If the aim is to contribute to integrated rural development using small-scale technology, biomass gasification should be pursued. In this case, Wowo Cluster Village could offer good starting site, albeit public-private partnerships should be pursued
- Financial support will be necessary to get biomass gasification started in Malawi. It is the task of IRC to formulate concrete projects resulting from this feasibility study and to develop framework for further research on biomass gasification.
- Research and Development institutions in the country should play an important role in accelerating biomass utilization and conversion to modern energy
- R&D collaboration among researchers in the country and SADC region should be developed and realized.
- Community based, decentralized electricity production from agricultural residues should be supported , e.g. local entrepreneurs could operate small-scale conversion systems (e.g. 50 kW) and the community could produce and provide the biomass feedstock and would receive energy services in return. This model-if successful-can be replicated in cooperation with micro-finance institutions, community extension organizations and energy producers.

CONCLUSIONS

Biomass is an emerging renewable resource for bioenergy production to meet the future energy demands in developing countries. Malawi as a developing country also need to put forth its efforts for potential production of bioenergy from biomass to tackle the energy crises. Biomass gasification can offer an attractive renewable energy system especially in rural areas where biomass fuel is readily available. These resources could provide community based small-scale

independent power plants. Rice husk and straw can be ranked the top of the available biomass types in Malawi and have power generation potential of around 87 Mwe. The power plant could be installed near the larger rice mills “cluster areas” in Karonga, Nkhata Bay, Nkhotakota, Salima, Zomba, and Phalombe with the surplus rice husk. However, establishment of rice husk based power plants in rice milling industry will lead to an enormous change in rice production and the rest of power will be supplied to national grid and to the local communities. However, other types of biomass such as maize cobs, maize stalks and rice straw should also be considered for gasification.

The research concludes that Malawi has a significant potential form of power generation from biomass gasification and has estimated around 87 MWe. Provision of government subsidies need to overcome the barriers for the installation of such gasification power plants. Government can seek funds from different foreign aids. Also carbon trade can be an option. Installation of biomass based power plants in rural areas will lead to an enormous change in the lifestyle of the local community by increasing the business hours in the market area, improving health conditions, and encouraging new business developments.

Additionally, biomass gasification for village electrification can be an option at those sites that do not have access to national electricity grid. The biomass can come from collected agricultural waste products. A relatively expensive grid has to be established, that will have to be financed using donor money. The most important variables are the demand electricity and the investment costs. The analysis shows that gasification is not viable given the current low demand and the high investment costs. However, a public-private funded village electrification project with a holistic approach to provide electricity as well as a concerted effort to build capacity and to encourage productive usage of electricity is a strategy worth pursuing.

Moreover, sites for residential and commercial applications can be interesting in the context of Malawi, whenever the electricity demand is high enough and when there is biomass available at a low price. Especially when diesel consumption can be replaced, a biomass gasifier has a very short payback rate. Unfortunately, bigger mills and factories that are not connected to the national grid are not very abundant in the country. However, even when a factory has access to grid electricity already, biomass gasification could still be an option.

This feasibility study has explored several options to implement biomass gasification in Malawi. The analysis shows that biomass gasification is not in all cases commercially viable, given the data collected for this study. However, taken the high potential for biomass resources and the lack of adequate energy provision in the country into account, the potential is unequivocably there. Some options mentioned in this study, such as village electrification, need clever social engineering and concerted effort of private and public organizations. Other options, like commercial application can safely be selected for a demonstration project in the near future. Yet another range of options, such as small scale gasifiers and irrigation projects deserve more attention, but have fallen outside the scope of this research.