CHAPTER 6

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SUMMARY AND CONCLUSIONS

The focal theme of the present study was the development of a decision support system (DSS) for biomass gasification that would help in assessing the feasibility of the technology as a decentralized electricity generation source. The development of the DSS involved the identification of critical parameters of biomass gasification based electricity generation systems and development of biomass gasification models for integration into the DSS. The gasifier performance models were validated with experimental results before integration into the DSS. The DSS was utilized for planning a biomass gasification based electricity generation system for a representative rural village. The following sections summarizes the different analysis used in the study.

6.1 Assessment of biomass supply chain

Standard methodologies for assessment of biomass supply chain for use in gasification based DEG in respect of availability, characteristics, pre-processing requirements, cost and environmental impact were developed. In order to generate information aiming planning of biomass based energy generation for a local region viz. Sonitpur district of Assam, India, characterization of locally available biomasses was done. Biomass characteristics influencing the gasification process are moisture content (MC), volatile matter (VM), ash content, organic and inorganic constituents. The MC varied in the range of 8.59 – 82.63, ash content in the range of 1.63 – 26.11, VM in the range of 61.01 – 85.63, FC in the range of 7.05 – 28.06, C in the range of 27.22 – 55.76, H in the range of 4.11 – 7.01, N in the range 0.16 – 5.98, O in the range of 34.38 – 67.39 and CV in the range of 11.23 – 19.68. Taking into consideration the spatial and temporal variation in the biomass resources of a given region and dependency of the gasification process on the characteristics of the biomass feedstock, the results of the analysis are thought to be helpful in complementing a decision support system for biomass gasification based electricity generation regarding the choice of biomass feedstock.

6.2 Assessment of biomass gasification performance

Utilization of biomass gasification modelling is an established method in analyzing the performance of a biomass gasifier. Various techniques of modelling are available. Fixed bed downdraft gasifier which have high char conversion, lower ash and tar carry over, quick response to load change and simple construction were considered in the study. A two stage modeling approach based on ANN and Kinetic modeling were considered for study.

There are very few references of ANN based modeling of biomass gasification. An ANN based model could be successfully developed for downdraft fixed bed type of gasifier. Prediction of end gas composition using neural network with ten hidden neurons in the hidden layer and using backpropagation algorithm has been possible. ANNs show agreement with experimental data with absolute fraction of variance (R^2) greater than 0.99 in the cases of CH_4 and CO model and higher than 0.98 in the case of CO_2 and H_2 model along with small RMSE. All of the variables have a strong effect on the outputs for each of the ANNs. The variables accounting for biomass composition (C, H and O) represent between 8% and 29% of the importance on the end gas composition. Reduction temperature was the most important variable in CO and H_2 prediction while it was the second most important variable in CH_4 and CO_2 prediction. All the variables were found to have strong influence on the outputs with variations in the range of 8% to 31%.

However, addition of more experimental data pertaining to downdraft gasifiers will help in expanding the database to further improve the spectrum of applicability of the models. The proposed ANN based model can serve as a useful tool to optimize and control the process of biomass gasification in downdraft fixed bed gasifiers.

A Kinetic model of downdraft biomass gasification could be developed. The developed kinetic model was used for predicting dry gas composition using different feedstock. Values of air–fuel ratio or equivalence ratio, gas flow rate and moisture content of feedstock for different runs of the gasifiers were supplied to the model. The modelled values were then compared with the experimental results for five different feedstock viz. Willow, Cedar, Eucalyptus, Gul Mohar and Dhaincha. It was observed that the model under-predicted the CO, CO_2 and CH_4 composition in almost every case with a maximum error of nearly 6%, 7% and 3% respectively. However, in the case of H_2 prediction there is mixed variation with a maximum error of 7.6% in the case of Dhaincha.

The developed Kinetic model was also used in prediction of critical char bed length with variations in gasifier ratings and feedstock. The critical char bed length was found to increase with increase in gasifier rating and there were small variations in its value for change in feedstock.

A generalised platform to predict gasification performance for a range of feedstock was developed. The models are utilised in formulation of the framework of a decision support system (DSS) for biomass gasification based energy generation.

6.3 Decision support system for biomass gasification based electricity generation

A DSS was developed having the capability to predict the viability of using a biomass gasifier based electricity generation system for a range of energy demand and feedstock supply scenarios or to determine the optimum mix of different aspects (feedstock related parameters, gasifier operating conditions, electricity distribution) where energy demand and feedstock supply issues are known. The DSS architecture is based on the feedstock characteristics module, gasification performance module and economics' module. Determination of levelised cost of electricity (LCOE) was adopted as an estimate of the economic feasibility of biomass gasification based electricity generation system. This also allowed comparison with other technologies of electricity generation. A standard methodology for LCOE estimation was modified to accommodate for the uncertainties associated with the demand-supply chain of the system and used in the analysis. The developed methodology was integrated with the DSS. The user interface, gasification performance database and economic analysis relationships were amalgamated in the workbook as different sheets. The inputs, outputs and variables for each spreadsheet are carefully defined and an Excel macros was developed to transfer data between spreadsheets as required. This macro handles the user interface, the opening and closing of spreadsheets where necessary and stores the results. The interface allows the user to make choices regarding the electrical power requirement, the capacity factor, the type of feedstock, the type of gasifier (in terms of material of construction) and the type of power generation unit. The results in terms of feedstock type, feedstock pre-processing requirement, gas flow rate, feedstock consumption rate, feedstock availability and levelised cost of electricity are displayed in the user interface.

The developed DSS was used for investigating the scope of biomass gasifier as a rural energy option in a representative rural area. Jhawani village in the Bihaguri development block of Sonitpur district, Assam (India) was considered for investigation. The existing activity pattern of the villagers, potential agro-processing jobs and irrigation requirements at Jhawani village were considered for assessing the electricity demand. The village had a peak demand of 15 kW and cumulative annual demand of 61 MWh energy. The peak energy demand of the village was forecasted to be 40 kW based on an annual electricity demand increase rate of 6.5%.

GIS based biomass resource assessment of the study area was done. The agro-residue biomass was identified to be a major source of feedstock for gasification based electricity generation system for the area. Dhaincha was the predominant biomass of the region followed by Rice straw, Sugarcane bagasse, Mustard straw and Jute stalk. Also, 3 tonnes of bamboo was also available in the village. Biomass gasification based electricity generation using Dhaincha, Rice husk pellet, Bagasse pellet, Jute stalk pellet and Bamboo were considered for planning.

Use of stainless steel gasifiers resulted in higher LCOE values in all cases despite having higher useful life and lower maintenance cost than mild steel gasifiers. Also, variation in the type of electricity generation units (DFP or PGP) had significantly lower influence on the LCOE. In case of Rice husk pellet, lowest LCOE was observed in the MSG+DFP configuration whereas in case of the other four feedstock the lowest LCOE was observed in the MSG+PGP configuration. Also, use of pelletized feedstock resulted in a higher LCOE in comparison to semi-woody biomass.

LCOE in the MSG+PGP configuration was compared with LCOE of other energy generation systems viz. Local Grid Electricity, Solar PV-Rooftop Residential, Solar

PV-Community and Diesel reciprocating engine. Biomass gasification based electricity generation was identified to be a viable option in the area. Use of biomass feedstock in the MSG+PGP configuration could be suggested as an option for biomass gasification based power generation in the study area.

6.4 Conclusions and future work

A comprehensive tool is developed that allows the user to take into account the uncertainties associated with a biomass gasification based energy generation system and allows to take decisions regarding them. The DSS is expected to be a useful tool for planners and policy makers. However, the applicability of the DSS is limited to downdraft gasifiers up to 100 kW. Thus, future studies may be conducted to include more types of gasifiers in the DSS. Also, there is scope for extending the study to higher ratings of the gasifier. Experimental validation of predicted critical char bed length using the Kinetic model is required before generalising the results, in turn increasing the robustness of the model. The biomass supply chain can be investigated using optimization based tools like multi-objective optimization which in turn will give more insight into the planning of the supply chain. There is scope for utilizing dynamic biomass estimation methods to extend the applicability to plantation biomass thereby increasing the robustness of the DSS. Temporal variations in biomass availability considering events such as forest fires, hydro-geological conditions, private or public biomasses, terrain activity, different costs depending on slope can also be included. The study also shows the requirement of further research in respect of influence of materials of construction on useful life of gasifiers, performance enhancement of producer gas engines and dual fuel engines, optimization of economics of biomass palletisation and electricity distribution for decentralised electricity generation. The DSS framework may be developed in the form of an application software to extend its use in planning of biomass gasification based electricity generation.