CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. World and national situations cause increasing demand for additional power generation and increasing global concern over environmental impacts of fossil fuel utilization. There are major factors driving the country to promote and develop clean technology to generate electricity from RE sources. At present, governmental policy supports and encourages projects that used RE technology such as new subsidy adder for renewable VSPP. The Thailand's strategic plan about the use of RE sources is becoming increasing and it has strong underlying intention to implement policy. Moreover, Thailand offers well structured and managed energy sectors. The suitable RE technology for community power generation system in Thailand is biomass gasification technology owing to 1) the agriculture sector as the base of Thailand's economy and accounts for over a half of the labour force. Therefore, biomass is considered to be the most potential RE sources that can be reached, harvested and managed everywhere in Thailand. In addition, community, especially in rural areas, do not have many activities, thus, people have enough time to manage their energy sources. It can be said that Thailand offers human resources with traditional skills in agricultural production and availability of land for the establishment of dedicated plantation on area with demand for reforestation to secure the main fuel source; and 2) Biomass gasification technology as the most suitable technology compared to other RE technologies at this time because the necessary investments are cheaper because internal combustion engines can be economically operated with small loads. They are available in most countries, the know-how for operation and maintenance are available in any regions. Technology is mature and it is not characterized by daily fluctuation of energy supply unlike the regenerative sources of energy. Biomass gasifiers are available in different capacities for decentralized applications from 5, 20, 50, and 100 to 500 kW and biomass gasifiers can be installed and operated in any community

where biomass is available or can grow. Such a flexibility does not exist for other RE such as wind, solar, and micro-hydro system.

2. However, development of BGPGS will be sustained for community in Thailand, it has to develop the main factors together which are related and affect each other. The main factors of SBGPGS are technical performance, biomass supplying system, economic condition impacts and community.

3. Biomass supplying system is the main problem of biomass utilization because in general, most biomass is unfortunately low in heating value and/or is widespread over the country. Collection and transportation costs, as well as high investment costs with regard to the biomass gas engine technology would have a negative economical effect for such an enterprise. For long time and sustainable biomass utilization, it is necessary to first consider plantation for supply fuel of BGPGS and logistic. Moreover, community is necessary for management of biomass supplied system, BGPGS and community power.

4. Management model was supported by the most appropriate alternatives for SBGPGS and based on basic science. This model will offer the most advantages, if inputs are accurate.

5. Technical performance evaluation of BGPGS at SERT, Naresuan University, Phitsanulok, Thailand by using Eucalyptus residuals demonstrated that the system could be operated for several weeks. The operation was successful. The average biomass consumption rate was about 50 kg h^{-1} and the input power was 255 kW. The system was operated at an average gas flow of 135 Nm^3 h^{-1}. The average calorific value of producer gas was 4.5 MJ m^{-3} and cold gas efficiency was about 66%. The engine was operated on producer gas. The engine was started up fuelled by LPG and switched over to producer gas. The power was reduced compared to LPG operation by a power factor of 0.8. The output power was about 45 kW_e on LPG, while the maximum output power at full load was 25 kW_e on producer gas only. The oxygen (O_2) and carbon monoxide (CO) contents in the exhaust gas from the engine varied from 9% to 10% and 3% to 5%, respectively. The efficiency of the system was about 10% from wood to electricity. The gas engine-generator efficiency was about 15%. The engine operated well on the producer gas, but some deposits were seen in

the engine afterwards. The engine-generator system was reduced to about 44% compared to LPG operation by a power factor of 0.8.

The power loss was higher than expected. It was about 35% as a result of the lower heating value of a producer gas/air mixture. Concerning the efficiency of system, there are some problems that need to be improved, such as optimization of supplied air flow rate for high gasification efficiency and concern about the efficiency of engine.

6. Biomass supplied system of BGPGS at SERT

6.1 Biomass plantation area was classified into two groups, namely tropical hardwood plants and fast growing plants (E. camaldulensis, A. mangium and L. leucocephala). Biomass productivity of tropical hardwood plant at dry basis was 12,800 kg $Rai^{-1}year^{-1}$ and the average lower heating value of tropical hardwood plant in Thailand was of 4,908 kcal kg^{-1}. Therefore, biomass plantation area requirement of tropical hardwood plant for BGPGS was about 80 Rai, if harvesting biomass by means of cutting branches. E. camaldulensis and L. leucocephala are appropriate for most of the country, except areas in southern and eastern Thailand. On the other hand, A. mangium is appropriate for southern and eastern areas during periods of heavy rainfall in these regions. The growing interval for three characteristics of fast growing plants that is appropriate was 1×1 m^2 because it offered the most biomass production to other growing intervals. The rotation of SRF was 2 years. Lower heating values of E. camaldulensis, A. mangium and L. leucocephala were 4,381, 4,528 and 4,309 kcal kg^{-1}, respectively. An average biomass productivity referring to E. camaldulensis, A. mangium and L. leucocephala was 2,549, 3,231 and 3,469, respectively, at dry basis. At a full load plant, operation time of 7,008 h $year^{-1}$ (80% power plant capacity). Therefore, plantation area requirement of E. camaldulensis, A. mangium and L. leucocephala were 289, 212 and 222 Rai, respectively, for BGPGS. Thus, lower heating value of biomass fuel and overall thermal conversion efficiency were the main factors affecting biomass consumption rate and biomass plantation area.

6.2 Logistic of BGPGS was classified to the specific vehicles and specific characteristics of plants. The specific vehicles consisted of tricycle, motor tricycle, pickup truck and truck and specific characteristics of plants consisted of tropical hardwood plants and fast growing plants (E. camaldulensis, A. mangium and L.

leucocephala). The important parameter was vehicle costs (baht $year^{-1}$) and it was assumed the plantation area was a square area around biomass power plant. The vehicle costs (baht $year^{-1}$) of tropical hardwood plants that were classified to tricycle, motor tricycle, pickup truck and truck were 29,046, 1,651, 973 and 1,025, respectively, E. camaldulensis were 13,777, 783, 462 and 486, respectively, A. mangium were 10,959, 623, 367 and 387, respectively and the last one, L. leucocephala were 12,613, 717, 423 and 446, respectively. The vehicle cost of tricycle was the most expensive cost when compared to other vehicles. Nevertheless, economic evaluation not only considered the vehicle cost but also considered the transportation personnel costs (baht $unit^{-1}$) because the biomass transportation costs (baht $year^{-1}$) was the combination of both the vehicle costs and the transportation personnel costs which vehicle cost of tricycle had already included the transportation personnel cost. Therefore, the biomass transport costs of tricycle, motor tricycle, pickup truck and truck were 13,777, 60,783, 60,462 and 60,486, respectively, for which the lowest cost of biomass transportation was tricycle; thus, tricycle was the most appropriate vehicle for small enterprises range from 5 kW to 50 kW.

6.3 Biomass storage would be considered from biomass consumption at 50% moisture content, $M_{50\%\ wet\ basis}$ (t $year^{-1}$) because normally when biomass is cut, it can have a moisture content of 50% or more. However, biomass storage should be expanded to cover in rainy season and be collected from near the power plant for continuous running processes. In this study, the warehouse containing wood chips considered bulk density of Eucalyptus wood chips that ranged from $2\times2\times5$ cm^3 to $4\times4\times7$ cm^3 of 284 kg m^{-3} at the 80% capacity factor following the 25 kw_e of BGPGS. Therefore, the biomass storage, S_b (t $year^{-1}$), and warehouse (m^3) were 217 and 765 respectively, in addition, warehouse should be constructed at the size of 10 m. × 10 m. × 10 m.

7. The parameters of economic condition consisted of COE, NPV, PB and IRR. In addition, specific vehicles for logistic were classified to tricycle, motor tricycle pick-up truck and truck. The economic values presented COE, NPV and PB range from 7.20, to 8.09, -770,114 to -2,856,879 and 21.98 to 24.70, respectively, but IRR of all specific vehicles cannot be determined.

In summary, the 25 kW_e BG and gas engine system generated about 175,200 kWh electricity production per year. This project could reduce oil consumption of diesel power plant by about 50,057 liters (1,433,637 baht) per year and could reduced CO_2 emission by about 43,800 kg CO_2 per year.

8. Environmental impacts evaluation of BGPGS were classified into three parts, namely: 1) Consideration of the physical properties of waste water, namely pH, conductivity, Total Dissolved Solid (TDS), Suspended Solid (SS), and temperature (T). The measured values of pH, Conductivity, TDS, SS and T were 4.21, 1,486 microsiemenscm^{-1}, 767 mg L^{-1}, 26 mg L^{-1} and 35 °C, respectively. All parameters values of waste water could be accepted when compared to industrial effluent standard values; 2) Air pollutions, the emissions of gas engine into the air were measured in this study, and consisted of CO and HC for which the measured values were 3.84 %v/v and 1,482 ppm, respectively. The CO values that were released from the engine could be accepted when compared to air quality and noise standard values presented by the 4th Edition Law of the Office of Prime Minister, Thailand (1995) about government cars. However, the measured HC value was more than the standard level. It maybe because the producer gas, before intake to engine, contained more organic volatile matters which the engine could not converted to energy; 3) Noise level measured at 0.5 m from the engine was of 93.2 dB. (A). It could be accepted by air quality and noise standard values announced by the 4th Edition Law of the Office of Prime Minister, Thailand of government cars.

9. Normally, cold gas efficiency of gasifier should not be less than 70% and overall efficiency for commercial should not be less than 20%.

10. The overall conversion efficiency of 20% that could be accepted for commercial standard, the economic values presented COE, NPV PB and IRR range from 3.60 to 4.04, 11,948,185 to 9,861,420, 10.99 to 12.35 and 27% to 16%, respectively, which could be accepted for management model of SBGPGS. Economic condition of SBGPGS are reduction of imported fuel, achievement of power price stability and independence on international fuel price changes, job creation with secure income, community power sustenance, development of RE knowledge to community and decrease of government budget.

11. The most appropriate organization is the local administrative organization because the leader of community is accepted by people in the community. He knows everything in his community and has potential to manage it. Community model consisted of three main parts, namely, biomass supplying system, BGPGS and community power.

12. Community power will be managed by the local administrative organization about power purchased agreement and connection to PEA. Further grid of community in the form of a load flow has to be undertaken in co-operation with PEA. PEA may support local administrative organization in the procedure of acquiring the rights of way.

Recommendations

1. Management model of SBGPGS will offer the most advantages, if inputs are accurate. Nevertheless, implementation of the management model should consider not only technology but also education to community.

2. Overall technical efficiency was lower than the accepted level about 50%, if the overall system efficiency can be improved to an acceptable level, the biomass consumption and plantation area will be reduced. On the other hand, the power output will be increased to 50 kW. It means that the operating costs will be decreased and the BGPGS will be sustainable. Considering the gasification efficiency, it is a little less than the commercial level with, therefore, the gasifier should not be the main problem of the whole system; the main problem of system efficiency should be the engine because it was the second hand engine that was modified and the engine efficiency was not exactly known.

3. Total tar and particulates of this system were higher than the standard level, which meant that improvement of the cleaning and cooling system should be considered. Moreover, the air emission from engine contains high level of HC. It might contain more volatile organic matters (tar). In addition, when the system ran more than three hours the temperature of gas increased; therefore, the cooling system might be a problem.

4. Optimization of economic scale should be evaluated in the future.