CHAPTER III
METHODOLOGY

3.1 Materials and Equipment

3.1.1 Equipment

- Desktop computer (Intel Inside Core i7, RAM 4 GB, Windows 7 and Microsoft Office 2013)

3.1.2 Software

- SimaPro version 7.1

3.2 Experimental Procedures

3.2.1 Goal, Scope, Functional Unit, and System Boundary

The goal of this study was to conduct life cycle assessment of utilization of compressed biomethane gas (CBG) generated from pig manure and napier grass in both energy and environmental aspects. Then, it can suggest the improvement of the production of biofuels to be more environmental friendly.

Relevant data required for the analysis were extracted from literatures and were also collected at an actual CBG plant in Mae Taeng district, Chiangmai province, Thailand. The data were analyzed by using commercial LCA software, SimaPro 7.1. The functional unit for this study was set to be 1 MJ of CBG which can be converted into 1 kilometer of vehicle driven distance. The resulting CBG from the processes was evaluated in terms of global warming potential (GWP based on greenhouse gas emissions) and net energy ratio (NER). The results were also compared with conventional fuels such as CNG and gasohol 95.

The system boundary of the whole life cycle (from Well-to-Wheel) of CBG in this study covers in the acquisition of raw materials, biogas production, upgrading, compression, transportation, refueling, and the usage of CBG biofuel (combustion) as shown in Figure 3.1.

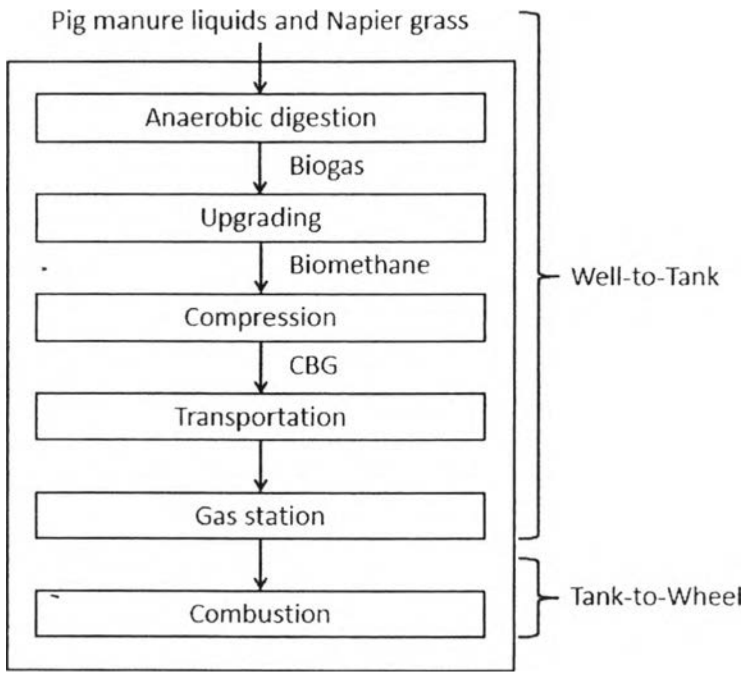

Figure 3.1 The system boundary of this study.

3.2.2 Inventory Analysis (LCI)

i) Collect both numerical and qualitative data for all activities based on the system boundary concerning about all energy inputs, raw materials, chemicals, utilities, and emissions in each process.

Table 3.1 Example of the data template for collecting data

Unit process: Biogas production							
Input inventory				Output inventory			
Description	Unit	Amount	Remark	Description	Unit	Amount	Remark
Resources				*Products*			
Pig liquids	kg			Biogas	m^3		
Napier grass	kg			...			
...							
Utilities				*Emissions*			
Electricity	kWh			CO_2	ppm		
...				...			

ii) Quantify the flow of material and energy as well as environmental load attributable to each stage of CBG's life cycle based on the functional unit.

The data sources of inventory data used in this study are indicated in Table 3.2.

Table 3.2 Data sources of this study

Stage	Key parameter	Type of data	Source
Napier grass cultivation	Fertilizers	Secondary data (adapted)	[1],[9]
	Diesel	Secondary data	[1],[9]
Biogas production	Electricity	Secondary data	[1]
	Methane losses	Secondary data	[1]
Biogas upgrading	Electricity	Secondary data	[2],[4],[6],[8]
	Methane losses	Secondary data	Onsite, [3],[4],[5],[6],[8]
Compression and Gas station	Electricity	Secondary data (adapted)	[1]
Transportation for napier grass	Distance	Primary data	Onsite
	Diesel truck	Primary data	Onsite
Transportation for CBG	Distance	Primary data	Onsite
	Diesel truck	Primary data	Onsite
Combustion	Fuel economy	Secondary data	[7]

[1] Previous reports and studies by National Metal and Materials Technology Center (MTEC).
[2] Scholz M. et al. (2012). Transforming biogas into biomethane using membrane technology. Renewable and Sustainable Energy Reviews. 17, 199-212.
[3] Sternovem. Committee for Green Gas. From biogas to green gas. Upgrading techniques and suppliers. 2ETPNG0840
[4] Jonsson S. and Westman J. (2011). Cryogenic biogas upgrading using plate heat exchangers. Master's thesis within the Sustainable Energy System Master's programme. Chalmers University of Technology. Sweden.
[5] Allegue L.B. and Hinge J. (2012). Biogas and bio-syngas upgrading report, Danish Technological Institute.
[6] UOP LLC.
[7] Emission and fuel consumption test results from PTT Public Company Limited.
[8] Deng L. and Hägg M. (2010). Techno-economic evaluation of biogas upgrading process using CO_2 facilitated transport membrane. International Journal of Greenhouse Gas Control, 4(4), 638–646.
[9] Bureau of Animal Nutrition Development, Department of Livestock Development. (2011). หญ้าเนเปียร์ปากช่อง 1.

3.2.3 Impact Assessment (LCIA)

Impact potentials of the CBG system were computed based on the LCI results by compiling data in the LCA commercial program named—SimaPro version 7.1—with Eco-indicator 95 and CML 2 baseline 2000 methods and then analyzing the overall processes in both energy and environmental aspects.

Energy efficiency was expressed in terms of NER which is a ratio of energy output to total energy input for the life cycle of CBG. The life-cycle energy analysis of biogas system was conducted by evaluating direct energy input; electricity and diesel, and indirect energy input; energy accumulated in chemical production, excluding the equipment and machinery used in the processes. The environmental impact category considered in this study was GWP as g CO_2 equivalent. LUC impact in this study was evaluated by using methodology developed by intergovernmental panel on climate change (IPCC). The calculation of GHG emissions from LUC made use of “the Commission Decision of 10 June 2010 on guidelines for the calculation of land use carbon stocks for the purpose of Annex V of Directive 2009/28/EC”.

3.2.4 Interpretation and Reporting

This step involves the combination and interpretation of the results of the inventory and impact assessment to provide conclusions and recommendations consistent with the goal and scope of this study.

i) Compare the life cycle energy and environmental potential impacts of CBG with other different upgrading technologies by NER and GWP.

ii) Evaluate opportunities to reduce energy, material inputs, or environmental impacts for each stage of the CBG’s life cycle.

iii) Analyze the improvement, in which recommendations are made based on the results of the inventory analysis and impact assessment stages.