CHAPTER III
EXPERIMENTAL SECTION

3.1 Material and Equipment

Equipment:

1. A Desktop Computer (Pentium IV, RAM 1GB, WinXP and MS Office 2003).
2. SimaPro 7.0 Software

3.2 Experimental

1. Goal and Scope Definition

1.1 Objective of this research work

1.1.1 To conduct LCI on natural gas production/separation in Thailand in order to evaluate the environmental impact using "gate-to-gate" concept.

1.1.2 To evaluate environmental effect of natural gas production / separation using SimaPro 7.0 Software with Eco-Indicator 95 and Eco-Indicator 99.

1.1.3 To identify the hot spots in natural gas production/separation and make suggestions for improvement.

1.2 Functional Unit

In this research, the functional unit is 1 kg of each product from gas separation plant

1.3 Scope and System boundary

This research studies life cycle of natural gas production. This includes raw materials acquisition, separation processes, transportation, utilities, energy, and utilization of waste emission in the natural gas separation in Thailand. Data collection will be done at three of the separation gas units at PTT Public Company Limited. The boundaries of gas separation plants 1, 2 and 3 are shown in Figures 3.1, 3.2 and 3.3, respectively. The production capacities are 390, 290, and 390 for GSP 1, 2 and 3, respectively

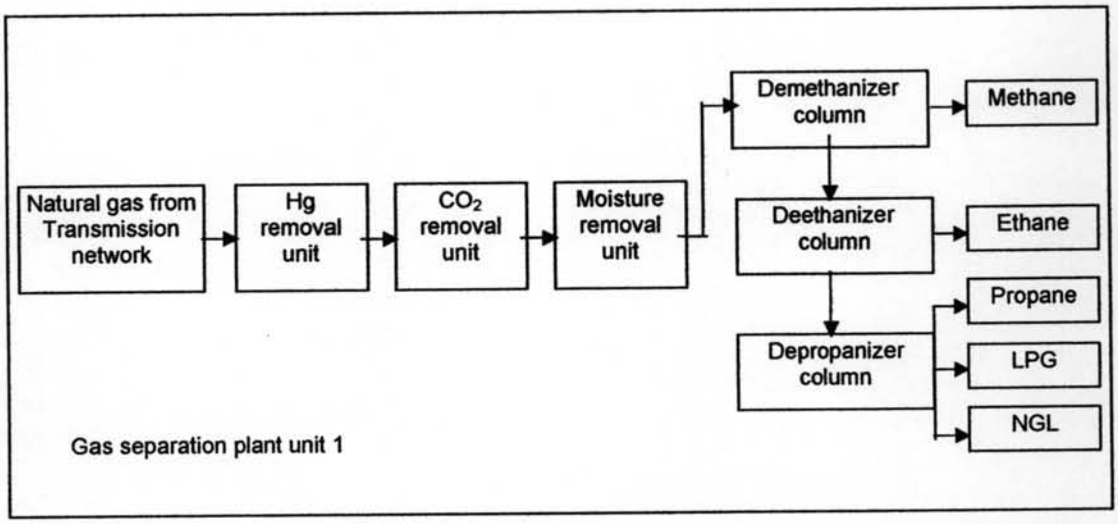

Figure 3.1 Boundary of gas separation plant unit 1 (GSP 1)

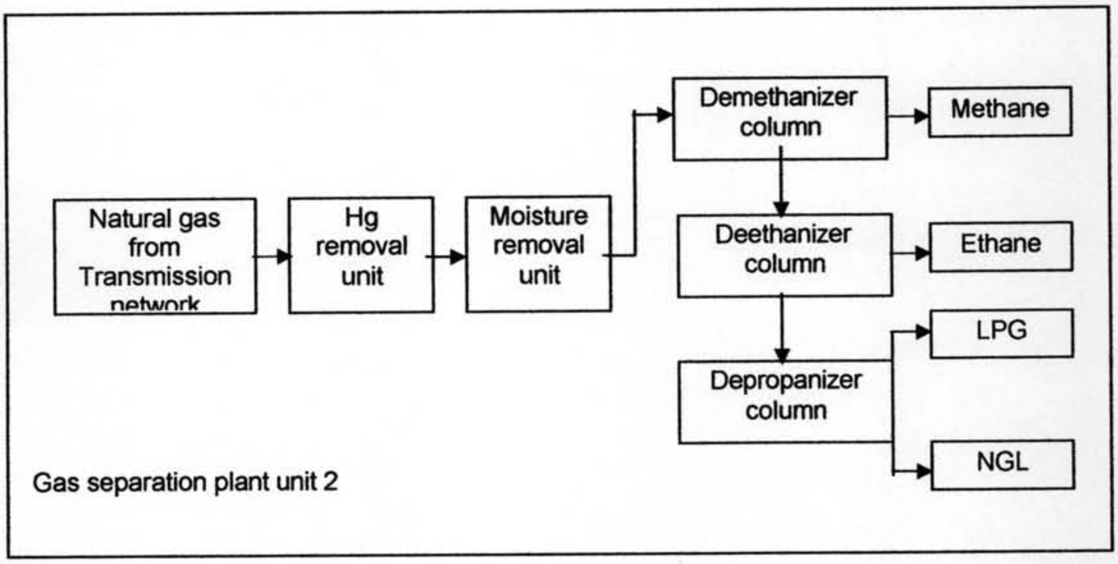

Figure 3.2 Boundary of gas separation plant unit 2 (GSP 2)

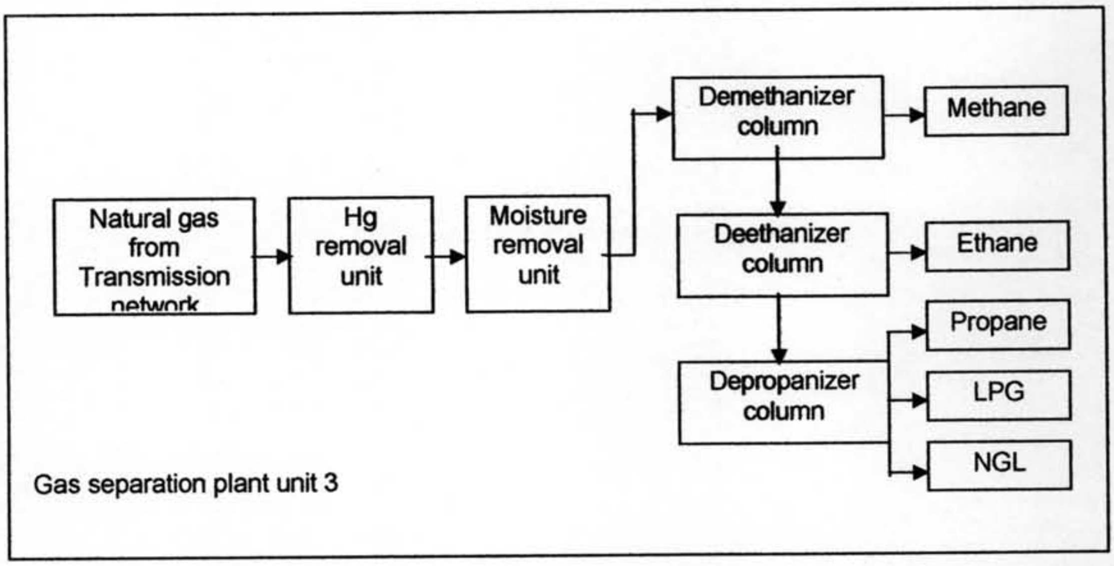

Figure 3.3 Boundary of gas separation plant unit 3 (GSP3)

1.4 Limitation and Assumptions

1.4.1 Electricity consumption of in-house gas turbine power plant is relative to Thai energy system.

1.4.2 Composition of sale gas from every plant is the same.

1.4.3 Using cut off rule for catalyst.

1.4.4 Fuel gas is Sale gas that come from its GSP

1.4.5 Density of air emission is equal of air which is 1.2 kg/m^3

1.4.6 Combustions in process are complete combustions.

1.4.7 Some materials e.g. steel, cement, etc. data is derived from SimaPro 7.0 database.

2. Life Cycle Inventory

2.1 Data Collection

The inventory analysis includes collection data to be used in preparation of a material consumption, energy, waste, and emission profile for all the phases in the boundary of this study. Raw data of GSPs are shown in APPENDIX A

2.1.1 Raw materials: all materials used in the process are collected from PTT Public Company Limited.

2.1.2 Energy: There are 3 types of energy consumption in separation plant which are heat and two electricity sources.

2.1.3 Wastes: They consist of air emission, emission to water, and solid waste in separation plant. The data was obtained from PTT Public Company Limited.

2.2 Calculations

2.2.1 Emission to water: In this study emission to water was collected in term of flow rate (m^3/hr) and wastewater parameter (g/ m^3) from mixing point from every separation plant in PTT Public Company Limited at Rayong. Water emission was allocated to each plant by production capacity. The calculation of emission can be obtained from:

$$\frac{Waste\ parameter(g/m^3)\times Flow\ rate(m^3/hr)\times Operating\ hour(hr/year)\times Capacity(MMscfd)}{Total\ Capacity(MMscfd)}$$

$$= Emission\ to\ water(g/y)$$

Example of waste water calculation is shown in APPENDIX B.

2.2.2 Emission to air: All emissions were collected in term of flow rate (m^3/sec) and emission to air parameter (ppm) except carbon dioxide which calculated from fuel gas.

The example of carbon dioxide is shown in APPENDIX C and carbon dioxide can be calculated by:

$$Fuel(MMscf/y)\times Convert\ to\ mole(mole/MMscf)\times\sum\frac{No.C\times Composition(\%)}{100}\times MW\ of\ CO_2(g/mole)$$

$$= CO_2\ emission(g/y)$$

Other air emission can be obtained from:

$$Flow\ rate(m^3/\sec)\times Operating\ time(\sec/year)\times Density\ of\ air(kg/m^3)\times\frac{Air\ emission\ parameter(ppm)}{10^6}$$

$$= Emission\ to\ air(kg/y)$$

The example of emission to air is shown in APPENDIX D.

2.2.3 Density of sale gas: Sale gas was collected in volume unit but other products were collected in mass unit. Sale gas needs to convert to mass for mass allocation. Density can calculated from composition of sale gas as:

$$\frac{\sum(Molecular\ weight\ of\ X_i\times Composition\ of\ X_i\ in\ Sale\ gas(\%)/100)}{Volume\ per\ mole(m^3/mole)} = Density(g/m^3)$$

The calculation of density is shown in APPENDIX E.

2.2.4 Allocation: The amount of quantity of all input-output data has to be converted to functional unit which is 1 kg of product from gas separation plant. The input-output can allocated as:

$$\frac{Emission(kg / year)}{Total\ product(kg / year)} = Emission(kg / 1\,kg\ product)$$

3. Life Cycle Impact Assessment

The Impact Assessment of this study uses SimaPro 7.0 with Eco-indicator 95 and Eco-indicator 99 methods. Both methods can calculate numbers that express the environmental load of products or processes. Eco-indicator 99 is developed from Eco-indicator 95 and types of impact categories are relatively similar. The important differences between these 2 programs are:

- Eco-indicator 99 can identify and show damage categories as graph and quantity which are derived from impact categories in characterization. (Damage categories relate to human health, ecosystem quality, and resources)

- Characterization unit of Eco-indicator 95 is kg equivalent but Eco-indicator 99 is in DALYs (Disability Adjusted Life Years).

- Eco-indicator 99 is more concern in resource depletion effect than Eco-indicator 95. So, the processes which require oil or gas or certain minerals will obtain a higher value in resource depletion impact.

- Land-use is included in Eco-indicator 99. Agricultural production processes will have a higher indicator than Eco-indicator 95. Also in the landfill of products with a large volume this is noticeable

- The dispersion and degradation of substances is included in Eco-indicator 99, substances with a short lifetime will contribute much less to the Eco-indicator 95.

In this research, Eco-indicator 99 is used for identify damage categories and it is also used for considering the resource depletion effect. For Eco-indicator 95, it is focus on characterization which gives the result of impact categories in kg Equivalent unit. Kg Equivalent unit is widely use in many countries. So, the result in this research can easily be compared with other countries results which carry out LCA on the same products or processes.

3.1 Structure of methods in SimaPro

The basic structure of impact assessment methods in SimaPro is:

1. Characterization
2. Damage assessment
3. Normalization
4. Weighting

The last three steps of the impact assessment method mentioned above are optional according to ISO standards. This means that they are not always available in all methods (Pre' Consultants, 2004)

3.1.1 Characterization

Classification is the step which computed from

$$\text{Characterization} = \text{Substances that contribute to an impact categories} \times \text{Characterization factor}$$

For example, the characterization factor for CO_2 in impact category climate change can be equal to 1, while the characterization factor of methane can be 21. This means that the release of 1 kg methane causes the same amount of climate change as 21 kg CO_2. The total result is expressed as impact category indicators (formerly characterization result)

3.1.2 Damage assessment

Damage assessment is a relatively new additional step in impact assessment. It is added to make use of the end point method as in Eco-indicator 99. The purpose of damage assessment is to combine a number of impact category indicators into a damage category. Damage of impact categories result is expressed in three types of damages:

- Damage to Human Health, expressed as number of year life lost and the number of years lived disabled. These are combined as Disability Adjusted Life Years (DALYs), an index that is also used by the World Bank and The World Health Organization (WHO)

- Damage to Ecosystem Quality, express as the loss of species over a certain area, during a certain time.

- Damage to Resources, expressed as the surplus energy needed for future extractions of minerals and fossil fuel.

3.1.3 Normalization

Many methods allow the impact category indicator results to be compared by reference (or Normal) value. This means

Normalization = Impact category / Reference value

And,

Reference Value = The average yearly environment load in a country or continent / The number of inhabitants

3.1.4 Weighting

Some methods allow weighting across impact categories. This means

Weighting = Impact (or Damage) category indicator results × Weighting factor

Weighting value can be added to create a total or single score. Weighting can be applied on normalized or non normalized scores, as some method like EPS do not have normalization step. In SimaPro, there are often alternative weighting sets available, always in combination with normalization set.

3.2 Factors used in Eco-Indicator 95 and Eco-Indicator 99 analysis

3.2.1 Eco-Indicator 95

The structure of this method consists of characterization, normalization, and weighting. All factors in this method are obtained from data of SimaPro 7.0 software shown in APPENDIX F. For damage category, it can be referred to each impact category as also shown in APPENDIX F.

3.2.2 Eco-Indicator 99

Eco-Indicator 99 is the successor of Eco-Indicator 95. Both methods use the damage-oriented approach. The development of the Eco-Indicator 99 methodology started with design of the weighting procedure. Characterization, normalization, weighting, and damage factor are shown in APPENDIX G.