CHAPTER III

EXPERIMENTAL

3.1 Materials and Equipment

3.1.1 Equipment:

Desktop computer (Dell, Vostro 3450 Intel(R) Core i3-2330, 2.20 GHz RAM 8 GB, Microsoft Office 2007) and Notebook (Asus, Intel(R) Core(TM)2 Duo CPU T8100, 2.10GHz, RAM 2 GB)

3.1.2 Software:

a. PRO/II version 9.1

b. ECON excel program

c. SustainPro program

d. SimaPro version 7.0

e. ICAS version 12.0

3.2 Experimental Procedures:

3.2.1 Literature Survey

a. Study and review the background of bioethanol production including their environmental impact through LCA technique.

b. Study the feasibility of the potential of raw materials (Cellulosic materials) in Thailand and select the best material for the process.

c. Do research on the selected raw materials (In this case cassava rhizome, corn stover and sugarcane bagasse)

3.2.2 Process Simulation

a. Simulate the base case process design from process flow diagrams by using selected materials and using PRO/II 9.1 simulation program as simulator.

b. Gather all of the necessary data available.

c. Collect the property data from ICAS version 15.0 program.

d. Make assumptions based on the goal definition.

3.2.3 Economic evaluation

a. Select a location suitable for bio-ethanol plant in Thailand

b. Collect stream, unit operations and utilities data from process simulation.

c. Determine the indicators for the economic analysis by ECON software.

d. Analyze and compare the cost requirements of each part of the process based on raw materials, equipment and utilities.

3.2.4 Sustainability analysis

Use software named SustainPro to generate new design alternatives which are divided into five steps as follows:

a. Collection of Steady-state Data

This step involves the collection of mass and energy balance data from simulation results with PRO/II 9.1

b. Flowsheet Analysis

The objective of this step is to identify all the mass and energy flow-paths in the process by separation into open-paths and close-paths for each compound in the process. An open-path consists of an entrance and an exit of a specific compound in the process. The closed-paths are the process recycles with respect to each compound in the process.

c. Calculation of Indicator Sensitivity Analysis

The objective of this step is to determine the parameters (indicators) for the sensitivity analysis.

d. Calculation of Sustainability Metric

The use of the sustainability metrics follows the simple rule that the lower the value of the metric the more effective (sustainable) the process. A lower value of the metric indicates that either the impact of the process is less or the output of the process is more. The metric calculated in this analysis are shown in Table 3.1, divided into different groups. The results report the energy used, raw material used, water consumption, and value added to this process. After new design alternative is performed in SustainPro, this work would compare these new values with those of the base case design. Then, results are shown in terms of how much improvement is achieved by the new design.

e. Generation of New Designs

Alternatives are created based on operability, energy consumption, waste reduction, environmental impact, safety and cost. The new design is simulated with PRO/II 9.1.

Table 3.1 The sustainability metrics of process design

Process Specification	Feedstock type
	Feedstock usage (kg/day)
	Chemical usage (kg/day)
	Ethanol production (liters/day)
	Net fresh water added to the system (kg/day)
Performance Criteria	Raw material usage (kg RM/kg EtOH produced)
	Net fresh water added to the system/product (kg/kg EtOH produced)
	Total energy usage (GJ/kg EtOH produced)
	Total wastes production (kg/kg of EtOH produced)
	Hazardous raw material/kg of product (kg/kg EtOH produced)
Economic Criteria	Revenue ethanol selling without cost ($x10^6$\$/year)
	Total utility cost ($x10^6$\$/year)
	Total capital investment ($x10^6$\$)
	Capital cost per year ($x10^6$\$/year)
	Total operating cost ($x10^6$\$/year)
	Minimum ethanol selling price (\$/kg EtOH produced)
	Net Revenue per year ($x10^6$\$/year)
Life Cycle Impact Assessment	Abiotic depletion (kg Sb eq.)
	Global warming (GWP100) (kg CO_2 eq.)
	Ozone layer depletion (ODP) (kg CFC-11 eq.)
	Human toxicity (kg 1,4-DB eq.)
	Fresh water aquatic ecotox. (kg 1,4-DB eq.)
	Marine aquatic ecotoxicity (kg 1,4-DB eq.)
	Terrestrial ecotoxicity (kg 1,4-DB eq.)
	Photochemical oxidation (kg C_2H_4)
	Acidification (kg SO_2 eq.)
	Eutrophication (kg PO_4 eq.)

3.3 Life Cycle Assessment (LCA)

3.3.1 Goal and Scope

In this research, thee functional unit was used: 1 kilograms of bioethanol 99.5wt% purity.

3.3.2 Inventory Analysis

a. Collect data related to environment and technical quantities for all relevant and within study boundaries unit processes.

b. Quantify how much energy and raw materials are used, and how much solid, liquid and gaseous waste is generated, at each stage of the product's life.

3.3.3 Life Cycle Impact Assessment (LCIA)

a. Calculate impact potentials based on the LCI results by using software SimaPro version 7.0.

b. Analyze and compare the impacts on human health and the environment burdens associated with raw material and energy inputs and environmental releases quantified by the inventory.

3.3.4 Interpretation

a. Evaluate opportunities to reduce energy, material inputs, or environmental impacts at each stage of the product life-cycle.

b. Analyze an improvement, in which recommendations are made based on the results of the inventory and impact stages. So the overall methodology of this work is shown in Figure 3.1.

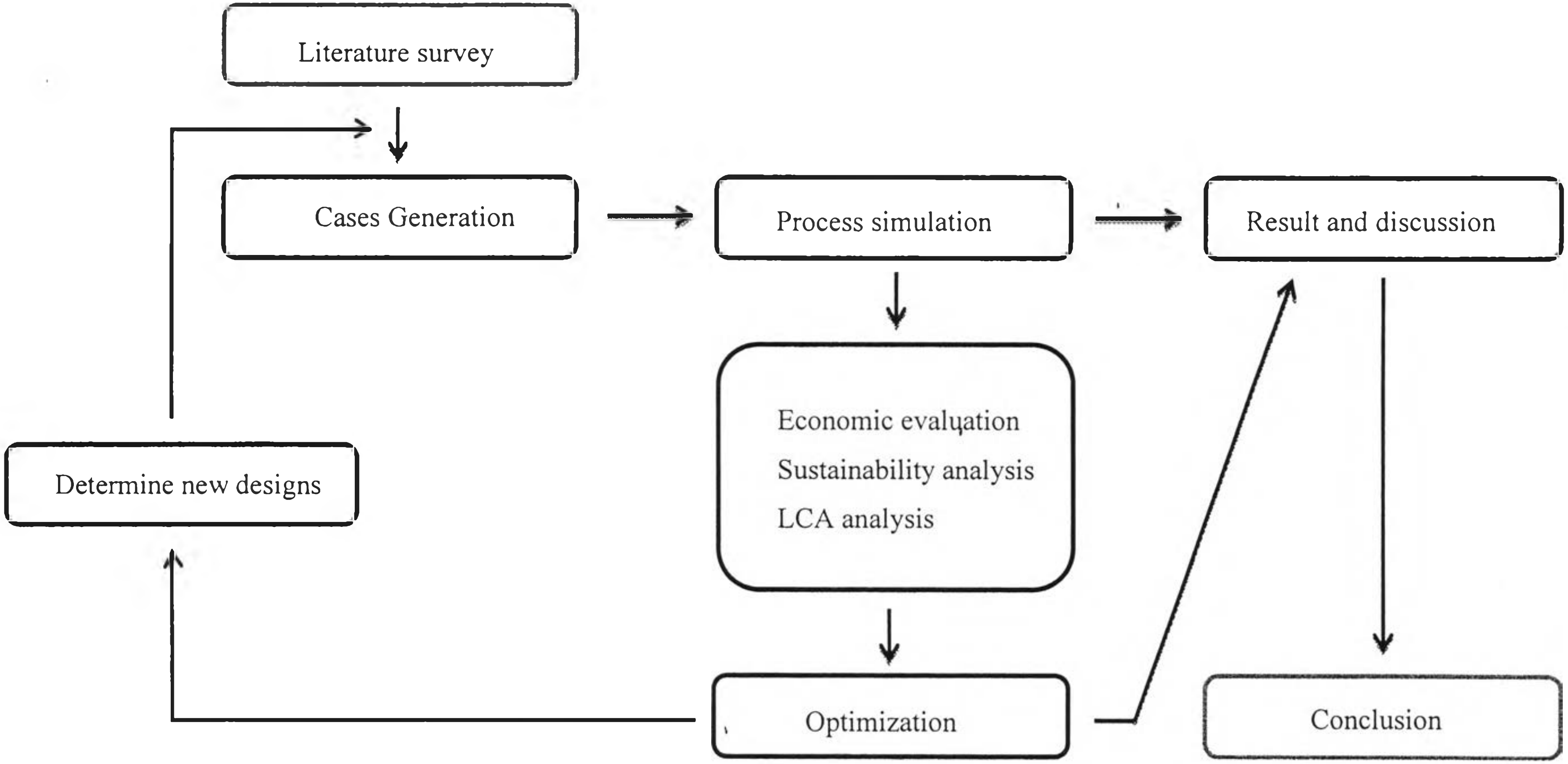

Figure 3.1 The block flow diagram shows the methodology of this work to get the best sustainable process design of biofuels.