# CHAPTER V
# CONCLUSIONS AND RECOMMENDATIONS

In this research, the sustainable process design of bioethanol production from cellulosic multi-feedstocks in Thailand. Feedstocks that used to produce bioethanol are cassava rhizome, corn stover and sugarcane bagasse as available agricultural residues. The procedure consists of four-part method to investigate and improve process designs. The first part deals with process simulation to evaluate different processes in term of process specification and performance. The second part deals with economic evaluation to calculate costs (total capital cost, total operating cost), profit (net revenue and NPV), rate of return and payback period. The third part deals with sustainability analysis to analyze three main factors in the process that are mass, energy and water and specify the process bottleneck. The fourth part deals with life cycle assessment part to analyze the environmental impacts focused on acidification, eutrophication and global warming potential. After finishing the four main parts, a sustainability metrics is generated to compare alternative cases design to find the best sustainable process design. Results from this research are divided into two sections that are one feedstock cases and multi-feedstock cases.

For one feedstock cases, they are analyzed to find the suitable process which is NREL 2011 and to test each feedstock which is the highest potential in term of process specification, performance and economic criteria for bioethanol production as sugarcane bagasse, cassava rhizome and corn stover respectively.

Another is multi-feedstocks cases, these cases are emphasized for study because they enhance long-term security and increase flexibility of feedstocks supply. A base case of multi-feedstocks is alternative D case in which of minimized feedstocks cost ratio. After investigation of sustainability analysis, there are three main ideas for improving the process design that are heat exchanger networks, water recycling by membrane treatment and solid waste combustion.

Focused on seven main factors in term of sustainability as shown in Figure 4.37 and 4.38 in multi-feedstocks cases, alternative F case (heat exchanger networks and water recycling) is the lowest net fresh water added to the process otherwise alternative G case (heat exchanger networks, water recycling and solid wastes combustion) is the best values of seven main sustainability factors; excepted, net fresh water usage because of more water used for produce steam in solid waste combustion. So this work give an importance of each factor at the same level, alternative G case is the best values which gave six out of seven main sustainability factors. Thus, the overall comparison of seven main sustainability factors, the best sustainable process design is alternative G case for bioethanol production.

Based on all of these results, alternative G case is the best process design in term of sustainability for bioethanol production.

According to the results, several recommendations can be offered:

1. Some data used for this work are primary data from people and actual sites as price of corn stover and its life cycle inventory in term of air emission from agricultural cultivation was not recorded in Thailand. The next work should be used average price and life cycle inventory of corn stover in Thailand.

2. For more easily adapt to actual plants, the process design should be added first agricultural generation such as cassava and sugarcane. It will make more flexibility for long-term security feedstocks supply and close to real plants.

3. Some of solid waste and wastewater from the process could be used to produce organic fertilizer in aerobic fermentation process because it can reduce environmental impacts instead of synthetic ones. Moreover, some wastewater could be used to produce biogas that can help the process in term of energy usage.

4. The optimum point in the best process design should be investigated by varying economic and environmental section.

5. For more sustainability, the safety of the process is another important parameter that should be taken into account in terms of chemical and process inherent safety index.