CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

In this research, the bioethanol conversion process using rice straw, a potential lignocellulosic material in Thailand, was first modeled by using the commercial simulator, PRO/II 9.1. A systematic sustainable design methodology was then applied through the use of several sustainability analysis tools, SustainPro, ECON program for economic evaluation, and lastly LCA technique in order to evaluate the environmental impacts of the design by using a commercial program called SimaPro 7.1 with the CML 2 baseline 2000 method. Aiming to develop the more sustainable process, the study used sustainability analysis to generate several new design alternatives having potential for improvements. These new alternative designs were then compared with the base case design in energy and water consumption, environmental aspects (mainly global warming potential or GWP as CO_2 equivalent), safety awareness and profitability of the designs. The capacity of these processes was assumed to be 200,000 L/day of bioethanol.

After performing the calculations for sustainability metrics, the indicators were calculated and used to identify points or streams in the process which have high potential for improvement which water and lignin were identified. Based on the analysis of the base case design, five main ideas with fifteen new design alternatives were generated. The first idea was heat integration to reduce energy. The second idea was wastewater exchange heat as utility. The third idea was wastewater recovery by evaporator. The fourth idea was wastewater recovery by membrane. Lastly, the fifth idea was the combustion of lignin as fuel.

In term of energy aspect, the sustainability metrics showed that alternatives 11 and 15 were the most energy saving processes compared with all of alternative. Alternatives 10 and 14 were the processes that consume lowest raw material. For water consumption, it was shown that alternative 11 and 15 were the most saving water quantity processes. Regarding to safety indices, all alternatives were considered as inherently safe. In term of profitability, alternatives 8 and alternative 15 have shown to have the highest profit. In other words, they were considered as the best designs for investment. In term of environmental aspect, alternatives 15 has

shown to be the most environment friendly when considering on global warming together with other impacts.

Based on these results, alternative 15 (wastewater recovery using membranes and lignin combustion with heat integration) was shown to be the best design for bioethanol production process from rice straw because this design had the most water and energy saving and highest profit while maintaining safety awareness and environmentally friendly. This plant should be placed in Suphanburi province which was indicated as the best location.

According to the results, several recommendations can be offered:

1. Rice straw is a good and abundant lignocellulosic material for bioethanol production compare to other biomasses. Further research in this area should be done to improve the yield and the process that will make the better profit, less environmental impact and reduce the petroleum consumption in Thailand.

2. For an economic point of view, the profit of this plant may be lower than the actual one. The reason comes from the price of raw materials and utilities information cannot gather from the real bioethanol plant because they are classified information for the company. Therefore, the price will come from literature, mainly is in laboratory scale, which is higher than the commercial price.

3. In the actual bioethanol plant, the wastewater treatment process should be the part of the plant because it can reduce the operating cost from the huge of water supply in the process. Even though, it may increase capital cost for the units. Therefore, the optimization of these factors should be used for the better process.

4. Some of the wastewater could be sent to biogas and cogeneration process to produce steam and electricity as by product. This can help reduce environmental impact within life cycle boundary because overall energy consumption can be reduced. However, similar to wastewater treatment process that one should consider both advantage and drawback in term of economic. In other words, the outsource process or invested process have to be determined which one is better.

5. In the future, membrane will be the importance unit for treat wastewater or purify ethanol. Therefore, the further study on this subject could improve the process and reduce the cost of the plant.