CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

In this research, the bioethanol conversion process using potential lignocellulosic material in Thailand, sugarcane bagasse, was modeled by using the commercial simulator PRO/II. A systematic design methodology was applied through a sustainability analysis tool, SustainPro, in the analysis of indicators, sustainability metrics, and safety indices. LCA technique was employed to evaluate the environmental impacts of the design using SimaPro 7.0 with the CML 2 baseline 2000 and Eco-indicator method. In order to develop the process to be more sustainable, the sustainability indicator results from sustainability analysis and environmental impact from LCA were analyzed to provide directions for improvements. The new design alternatives were then generated by process simulation based on suggestion from the analysis, both in the process aspect (Alternative 1, 2, 3, and 4) and the energy efficiency aspect (Alternative-5). The comparison of energy consumption, indicators and impact assessment between base case and new design alternatives was conducted to indicate the improvement for sustainability.

The results obtained from the LCA study on the base case showed that the major environmental impacts—the global warming, acidification, and eutrophication, and energy resources potential—resulted mainly from energy consumption (heating duty) supplied in the recovery stage. Particularly for the global warming potential, the impact resulted from the greenhouse gases emission came from the recovery stage which accounted for 41% of total emission, followed by the pretreatment stage (39%).

The indicator results obtained from SustainPro suggested that the open and close paths pass through recovery area and had high potential for improvement, especially in the quadruple effect evaporator. The new design alternatives were then generated by focusing on minimization of the energy consumption on the recovery stage.

The energy consumptions for Alternative-1, Alternative-2, Alternative-4, and Alternative-5 were reduced compared to the base case design, especially in Alternative-5, having the lowest heating duty with 40% reduction. Changing

quadruple effect evaporator to a beer distillation column can save lots of energy, thereby also effecting the EWC indicator and thus improving the environmental impact.

The indicator results also showed that the total value added in almost all alternatives was reduced because the EWC was diminished, which means that the new design is more sustainable than the base case. The sustainability metrics for the new design, especially in Alternative-5, improved significantly, when compared to the base case in all groups of metrics. In term of safety, the safety indices results of Alternativs-1, Alternative-2, and Alternatives-3 did make safety issue neither better nor worse, while Alternative-4 and Alternative-5 made it better when compared to the base case. The WAR algorithm results proved that the impact generated between the base case and alternatives are nearly the same, which can be concluded that the new designs are able to reduce the energy consumption without harming the environment more than the base case.

In term of energy efficiency, the results showed that except Alternative-3, the new design alternatives are more energy effective with the higher NER than the base case, and Alternative-5 is the most energy effective design with the value of NER is 62% higher than the base case design. When comparing the environmental impact among the base case and alternatives, Alternative-5 also showed improvement and achieving a reduction of 32% in both global warming and acidification, 37% in energy resources, 45% in eutrophication, thereby making the process the most environmental friendly. The next below belong to Alternativs-4, Alternative-2 and Alternative-1, respectively. On the contrary, Alternative-3 is less environmental friendly compared to the base case. In the case of comparing alternatives between two aspects, the energy efficiency released the emission less than those of process aspect. In process aspect particularly, the new design on distillation platform is much lower than those of evaporator platform.

Based on the results, several recommendations can be offered as follow:

1. The use of a beer distillation column instead of quadruple effect evaporator is suggested to improve the environmental performance in order to decrease the greenhouse effect generated and energy cost spent.

2. The economic evaluation should be considered for the new investment in case of changing from the base case to alternatives.

3. The pretreatment stage could be the next hot spot to further improve according to its high heating duty.

4. Finding the future technology in recovery and pretreatment stage can be applied to reduce the energy consumption.