CHAPTER VIII
CONCLUSIONS AND RECOMMENDATION

In this research, the methanol production from CO_2 with three different routes including hydrogenation, bi-reforming and tri-reforming was modeled and simulated through Aspen Plus 8.6 process simulator. A systematic sustainable design methodology was then applied through the usage of the sustainability analysis and ECON program for economic evaluation. To upgrade the processes more sustainably, the study used sustainability analysis to generate new alternative designs having potential for improvements. These alternative processes were then compared with the base case in terms of environmental aspects and profitability.

Regarding the hydrogenation of CO_2, the research pointed out that the methanol synthesis itself has the possibility of CO_2 reduction by obtaining the negative net CO_2 emission. However, the main problem that prevents CO_2 hydrogenation from practice comes from hydrogen supply. If the process uses hydrogen from steam reforming of natural gas, it could not be a practical alternative in environmental and economic aspects. If hydrogen is produced from renewable energy sources, the process could present an interesting alternative for CO_2 treatment despite that currently only hydrogen from hydropower with water electrolysis can bring out a considerable interest for investors. Nevertheless, the issue with hydroelectric is whether there is suitable place to build the plant as well as obvious effects on the environment when the plant is built. Even so, this technique is used in remote area either to meet regional demand or to supply to the grid during peak demand. In the near future, biomass could provide a low-cost hydrogen supply by using gasification or pyrolysis method. However, sufficient land to produce the amount of fuel and food needed is the problem with biomass. Therefore, biomass can play an important role in producing hydrogen if waste from agriculture, industry, municipal activities is utilized.

In contrast to hydrogenation route, bi-reforming of CO_2 will be an attractive route for investors in terms of economy. All scenarios from the bi-reforming route show the economic potential. In addition, the overall investment required for the process is paid off within three to six years of manufacture of the product by the profits of selling the product, methanol. However, the story is totally different with net CO_2

emission. The best scenario for the bi-reforming approach will emit around 428 $kgCO_2/tMeOH$ to the atmosphere. Although this value is lower than that from the conventional methanol plant which uses steam reforming of methane (around 540 $kgCO_2/tMeOH$), it is still far from our target which is a negative net CO_2 emission. Nevertheless, the bi-reforming technology can be considered as a transition process from traditional plants to alterative processes because this technology allows a reduction of greenhouse gas emissions but still keeps a strong attraction from investment.

The research showed that the tri-reforming of CO_2 plant is not a viable alternative for methanol production from flue gases of the coal-fired power plant with CO_2 capture. If the methane is employed to support heat for the reformer, the results pointed out that the combination of tri-reforming and methanol synthesis results in poor performances in both environmental and economic aspects. In fact, the tri-reforming process is proposed to use free heat sources from the power plant by Song (2001). However, even though utilizing waste heat from the coal power plant in the alternative case, the process is still economically infeasible. The primary reason is caused by the high concentration of inert nitrogen in flue gases, which leads to huge capital and production costs. Thus, how to get rid of nitrogen plays an important role to improve the economic potential of the process. In the future, when oxygen-enriched air or pure oxygen is fully exploited in the power plants, the tri-reforming technology can become more attractive due to much lower inert gas concentrations.

Though this is a thorough analysis of the CO_2 treatment processes, there is a possibility for the future work.

First of all, due to time limitations, the results for CO_2 capture was taken from literature regarding amine scrubbing. These numbers, for the simulations and the costs, can be validated through additional simulations.

Secondly, as discussed above, the tri-reforming process could become realistic if a high amount of nitrogen is removed from flue gases before feeding to the process. The further work can be conducted to ensure the applicability in industrial settings.