CHAPTER VII
COMPARISION AMONG DIFFERENT PROCESSES

7.1 Net CO_2 Emission Evaluation

In this section, alternatives from three processes are evaluated and compared mutually as presented in Table 7.1.

Table 7.1 Net CO_2 emission from alternatives of three conversion processes

Specification	Hydrogenation of CO_2 with Hydrogen from Hydropower	Bi-reforming of CO_2	Tri-reforming of CO_2
Net CO_2 emission ($kgCO_2/tMeOH$)	-555.6	1257.1	207.6

Obviously, only hydrogenation of CO_2 with hydrogen from hydropower has met the environmental target of negative net CO_2 emission. Both indirect methanol production from CO_2, i.e. reforming followed by hydrogenation, led to non-negligible emission of CO_2. Compared to the conventional·process which releases around 540 $kgCO_2/tMeOH$, the bi-reforming process is two times higher CO_2 emission while 2.6 times lower is seen in tri-reforming route. Clearly, the methanol process from hydrogenation of CO_2 with hydrogen from hydropower is the best candidate to achieve the near-zero emission.

7.2 Economic Evaluation

In this section, the economic aspects of three alternatives from different routes are evaluated and compared mutually. The results are shown in Table 7.2.

Table 7.2 Comparison of economic aspects among different scenarios

Specification	Hydrogenation of CO_2 with Hydrogen from Hydropower	Bi-reforming of CO_2	Tri-reforming of CO_2
Capital cost (MM$)	54.26	49.01	188.36
Production cost (MM$/year)	70.92	54.08	88.51
Product sales (MM$/year)	77.63	77.58	77.36

From Table 7.2, the bi-reforming witnesses the lowest values in both capital and production cost with 49.01 MM$ and 54.08 MM$/year, respectively. Both hydrogenation and tri-reforming process have higher the capital cost than bi-reforming route while the highest comes from the tri-reforming process, with 3.5 times higher than the hydrogenation pathways which is the next highest cost. A similar pattern is seen in the production cost, tri-reforming is the most costing process, followed by hydrogenation route with the difference of nearly 18 MM$/year and bi-reforming route with 1.6 times lower. Obviously, low capital and production cost allows bi-reforming process to have the feasibility in terms of economics as seen in Figure 5.11. Although the production cost for hydrogenation route is quite high, this process still has the economic potential because the product sales can fully compensate for the manufacturing cost. This helps bring the profit after 6-year operation as pointed out in Figure 4.17. In contrast to the hydrogenation process, the profit from selling methanol products from the tri-reforming process could not make up for the cost for operation, leading to infeasibility in terms of economics as illustrated in Figure 6.12.

As mentioned above, hydrogenation of CO_2 with hydrogen from hydropower can satisfy two research targests which are negative net CO_2 emission and no economic loss. Despite having the economic potential, bi-reforming has to be improved to reduce the amount of unreacted methane in the purge streams to achieve the negative net CO_2 emission target. Tri-reforming is still far from practical applications.