THE STUDY OF LONG-TERM ASIA-PACIFIC ENERGY OUTLOOK BY IMPLEMENTATION OF CARBON CAPTURE AND STORAGE (CCS) TECHNOLOGY

47-106652 Muhammad Firdaus bin ANUAR
Shimada Laboratory, Department of Environment Systems, Graduate School of Frontier Sciences
Supervisor: Assoc. Prof. Sohei SHIMADA, Sub-supervisor: Prof. Ryuji MATSUHASHI

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1. Research Background

Asia-Pacific, the main regional focus for this study comprises of Central Asia, South Asia, Southeast Asia, North Asia and Oceania regions. According to data from International Monetary Fund (IMF) in 2010, Asia is the world's fastest growing economic region. And from the report of Netherlands Environmental Assessment Agency in 2007, China now has surpassed the US as the largest CO_2 emission country in the world with 7,031,916 thousand metric tonnes. This has make Asia region the largest CO_2 emitter from global share of CO_2 emission in 2008. Fast economic growth and increasing CO_2 emission have made the study towards Asia-Pacific important, especially towards energy supply and demand, which is directly related to the emission of CO_2.

Recent major important events and scenarios that related to energy that are given close attention by major international organization are the prospect of more discoverable shale gas reserves in North America and Fukushima-Daiichi nuclear power plant tragedy in Japan. According to energy outlook reports of major energy-related international organization, both events create the uncertain prospect for future energy landscape; a world that would increase it dependence towards natural gas, and intensive or restrictive usage of nuclear energy in electricity generation.

At the same time, the implementation of carbon capture and storage (CCS) technology and emission trading has been seen as the solution to regulate the hiking CO_2 emission level in Asia. The main barrier for large-scale CCS project deployment in Asia is the high capital and operational project expenditure, thus cost transfer option via emission trading mechanism could be good option to spark CCS deployment in Asia-Pacific region. By considering all these uncertainties, the study of long-term energy outlook for Asia-Pacific region by implementation of CCS is crucial.

2. Research Objective

Based on research background, this study aims at studying three main research objectives:

a) To predict and compare the energy supply and demand outlook in Asia-Pacific region with or without implementation of carbon capture and storage (CCS) under current energy landscape (business as usual), and also under uncertain future energy landscapes such as advanced gas scenario, intensive and restrictive use of nuclear power, and enforcement of emission trading scheme
b) To check the CO_2 emission of Asia-Pacific region with or without implementation of carbon capture and storage (CCS) under current energy landscape (business as usual), and also under uncertain future energy landscapes such as advanced gas scenario, intensive and restrictive use of nuclear power, and enforcement of emission trading scheme
c) To evaluate CO_2 storage potential in Asia-Pacific region

By using integrated non-linear optimization model, these three main objectives have been studied.

3. Simulation Model

This study utilizes DNE21 (Dynamic New Earth 21), a dynamic non-linear optimization energy model that combines energy system model, climate change model and macro-economic model. In DNE21, CCS system is included in energy supply side of the system.

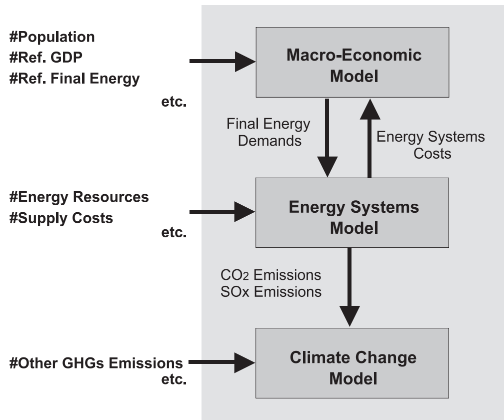

Figure 3.1: DNE21 model structure

3.1 Objective Function and Shadow Price

The objective function for this analysis is defined as the sum of sixteen regional energy system costs which involve fuel production costs, levelized plant construction costs, fuel transportation, electricity transmission costs and so forth. The objective function for DNE 21 is:

$$J = \sum_{n=1}^{N} C_n(u_n) \rightarrow \min.$$

which subject to these conditions:

$$A_n u_n = b_n \qquad (n = 1, 2, \ldots, N)$$

$$\sum_{n=1}^{N} T_n u_n = 0$$

$$u_n \geq 0 \quad (n = 1, 2, \ldots, N)$$

where

$C_n(u_n)$ = cost function of region n

u_n = variable vector for region n

A_n = coefficient matrix for the regional energy system of region n

b_n = constant vector of the right hand side for region n

T_n = trade matric for region n

By using objective function, the value of shadow price can be obtained. Shadow price is important to know the sensitivity of the scenario results to the model input parameters. For each constraint in optimization model, there is corresponding shadow price, which is the change in the value of the objective function accompanying a marginal unit displacement in the constraint.

3.2 Asia-Pacific Regional Segregation

DNE21 model also covers the time range up to the middle of 21st century, based on objective function of cost minimization for 150 years and disaggregates the world into ten main regions. However, for the purpose of reliability and to meet the objective of this study, the DNE21 has been further reformulated to simulate in the range of 50 years period from 2010 to 2050 and segregate the Asia-Pacific region to sixteen regions. Figure 3.2 shows the new regional segregation for Asia-Pacific region for this analysis.

4. Simulation Result

4.1 Case Scenario Simulation

In order to fully understand the energy supply and demand, CO_2 emission and CO_2 storage potential in Asia-Pacific region, three

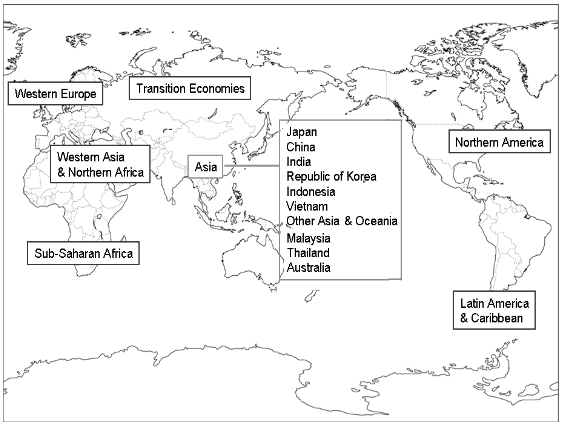

Figure 3.2: New regional segregation for Asia-Pacific region in DNE21

different energy scenarios have been considered for this analysis:

a) Reference Scenario (BAU and CCS)
   - *i) Business-as-usual without CO_2 geological storage (BAU)*
   - *ii) Business-as-usual with CO_2 geological storage (CCS)*

b) Uncertain Future Energy Landscape Scenario (GAS, NRS and NIS)
   - *i) Gas Advanced Scenario (GAS)*
     - higher estimates of natural gas and shale gas reserves, both conventional and unconventional
     - lower gas-fired thermal power plant construction cost
     - higher gas well storage (including for EGR) in North America, Western Europe, Australia, China, Middle East, Africa, Indonesia, Malaysia and Russia
     - lower CO_2 storage cost in gas well
   - *ii) Nuclear Intensive Scenario (NIS)*
     - intensive usage of nuclear power in electricity generation in existing nuclear country
     - nuclear proliferation to new emerging nuclear countries such as in Middle East and Vietnam
   - *iii) Nuclear Restrictive Scenario (NRS)*
     - restrictive future use of nuclear energy in all nuclear countries post-Fukushima
     - countries like Germany and Switzerland are assumed to slowly phasing out their nuclear power share in electricity generation

c) Emission Trading Scenario (ETS)
   - implementation of carbon trading and emission market by setting up emission regulation based on latest UNFCCC data in COP17:

- USA - 17% reduction from 2005 level in 2020, 50% reduction from 1990 level in 2050
- EU - 20% reduction from 1990 level in 2020, 50% reduction from 1990 level in 2050
- Japan - 25% reduction from 2005 level in 2020, 50% reduction from 1990 level in 2050
- China - 40-45% reduction of emission per unit of GDP from 2005 level in 2020
- India - 20-25% reduction of emission per unit of GDP from 2005 level in 2020
- Australia - 15% reduction from 2000 level in 2020, 50% reduction from 1990 level in 2050
- Russia - 20% reduction from 1990 level in 2020, 50% reduction from 1990 level in 2050
- South Korea - 30% reduction from business as usual level in 2020
- Developing countries - No emission regulation in 2020, but same with 1990 emission level in 2050

As a reference scenario, BAU and CCS is the basis of simulation case. BAU considers current energy data and project the energy supply and demand until 2050 without considering any CCS or CO_2 geological storage (CGS). CCS, on the other hand, considers CCS and CGS as part of cost minimization. The uncertain future energy landscape scenario represents the uncertainty in future energy situation, such as higher prospect of discoverable shale gas in GAS, intensive usage of nuclear energy in electricity generation in NIS and restrictive usage of nuclear energy in electricity generation post-Fukushima Daiichi in NRS.

4.2 Simulation Results

The simulation results are represented into five main findings:

a) Energy supply and electricity balance
b) CO_2 emission
c) CO_2 storage capacity
d) Amount of CO_2 reduction contribution
e) Shadow price for emission trading

Figure 4.1 to 4.3 shows the energy supply balance, electricity balance and CO_2 emission for Asia-Pacific region.

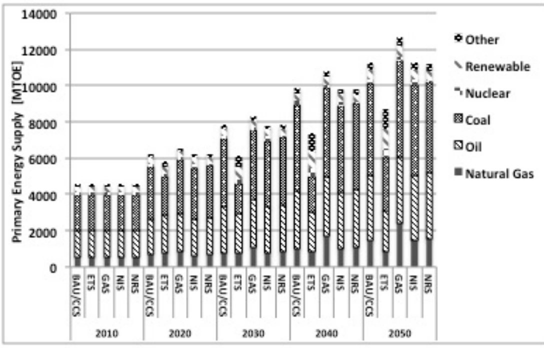

Figure 4.1: Energy supply balance of Asia-Pacific region by case comparison

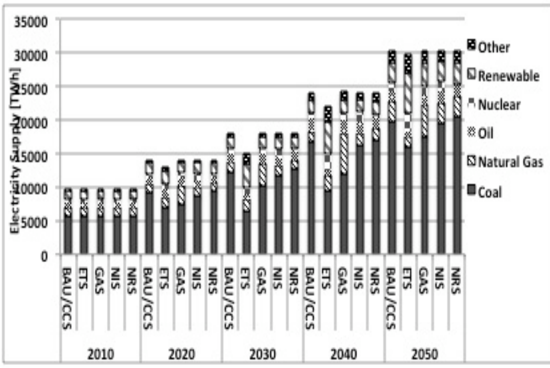

Figure 4.2: Electricity supply balance of Asia-Pacific region by case comparison

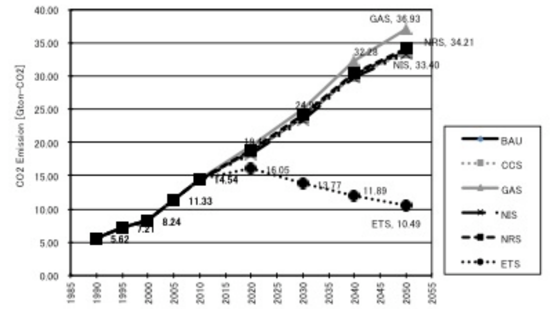

Figure 4.3: CO_2 Emission of Asia-Pacific region by case comparison

Figure 4.4 shows the comparison for CO_2 storage capacity in all simulation cases. The significance of ETS case to spark the start of CCS deployment in Asia-Pacific has been observed.

Figure 4.5 shows the potential for CO_2 storage as CO_2 reduction contribution in Asia-Pacific under ETS case and Figure 4.6 shows the optimized shadow price for CO_2 in ETS case.

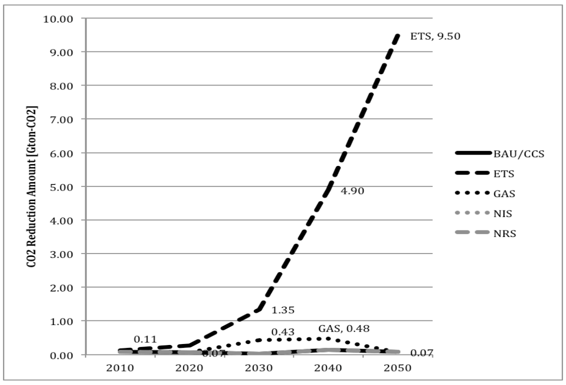

Figure 4.4: Comparison for CO_2 storage capacity in all simulation case

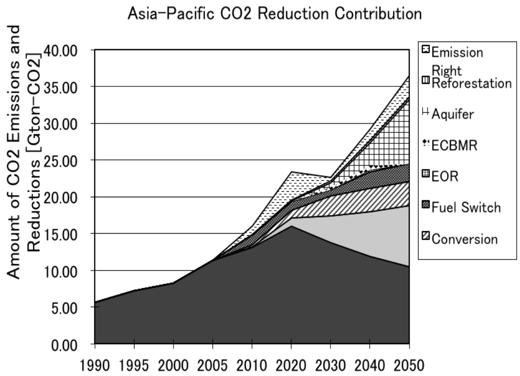

Figure 4.5: CO_2 Reduction Contribution for Asia-Pacific in ETS case

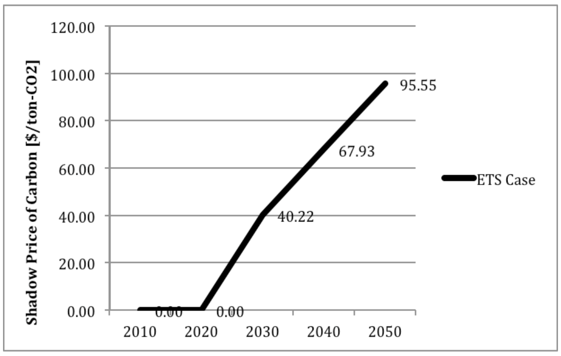

Figure 4.6: World's shadow price for CO_2 in ETS case

5. Conclusion

Based on the simulation results, these general conclusions could be drawn:

5.1 Energy Supply, Electricity Supply and CO_2 Emission

a) Coal continue to be the main energy resources for Asia-Pacific
b) The implementation of CCS and CGS in Asia-Pacific countries will increase the fossil fuel energy supply and fossil-fuel based electricity generation to the region
c) In GAS case, higher prospect of recoverable shale gas reserves would increase the natural gas supply, and also other type of fossil fuel. Highest CO_2 emission level has been observed in GAS case compared to all cases.
d) In NIS case, intensive usage of nuclear energy in existing and emerging nuclear countries would reduce the dependency of that country towards fossil fuel. In contrast, there will be significant increase of fossil fuel supply to non-nuclear region
e) In NRS case, lesser nuclear usage would increase the fossil fuel share in energy supply and electricity supply
f) In ETS case, the emission trading will allow carbon to be traded and thus will increase the variety in energy mix in most Asia-Pacific countries, and also increase the share of renewables and other type of cleaner fuel in long term perspective. CO_2 emission level is expected to be reduced gradually by implementation of carbon trading

5.3 CO_2 Storage Capacities and Shadow Price of CO_2

a) In CCS case, CO_2 storage potential is significant in North America, Asia-Pacific and Russia and East Europe
b) In GAS case, higher prospect of shale does not increase the CO_2 storage amount but will spark the CCS deployment to Asia Pacific
c) Intensive usage of nuclear in NIS case however, would keep the CO_2 storage potential to focus in North America region
d) Highest CO_2 storage potential would be in ETS case where the cost of CO_2 storage has potential to be compensated by traded carbon cost
e) In ETS case, the shadow price for CO_2 starts at USD 40.22 in 2030 and will reach USD 95.55 in 2050 and potential type of CGS to be utilized in Asia is aquifer, ECBMR and EOR

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