# Case Study for Energy Transition Policy in South Korea -Using Energy Planning Model 'MESSAGSE'

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## 1. Introduction

The elected South Korean government declared to reconsider all plans for new nuclear power plants and to cancel long term operation (LTO) of existing nuclear power plants in last year [1]. Since this declaration, South Korea's energy transition policy has been implemented. As a first step, the government made public committee which had debated to cancel construction proposal of two nuclear reactors (Shin Kori No.5 and No. 6) [2]. As the results, the public committee recommended proceeding with construction [3]. However, to response these public pressure, the research which related to evaluate the social and economic impact of energy transition policy is highly needed.

It is noted that this study had been conducted before the 8th national electricity plan was published. Also, the further study has been conducted followed as 8th national electricity plan.

The objective of this study is to compare an existing plan and the alternative plans of newly energy transition policy in South Korea. This study looks into options for future electricity supply in Korea and evaluates three energy cases in terms of economic competitiveness, energy security, environmental protection and climate change mitigation.

## 2. Methodology

IAEA's energy planning model MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impacts) is used for constructing and analyzing alternative scenarios. MESSAGE allows determining the least-cost expansion plan that fulfills the future electricity demand with an optimal mix of generation taking into account technical, economic and environmental considerations [4].

Simulation continues along an energy chain from supply to demand. Stages of the energy chain have inputs making up the reference energy system. The reference energy system (RES) is shown in Figure 1.

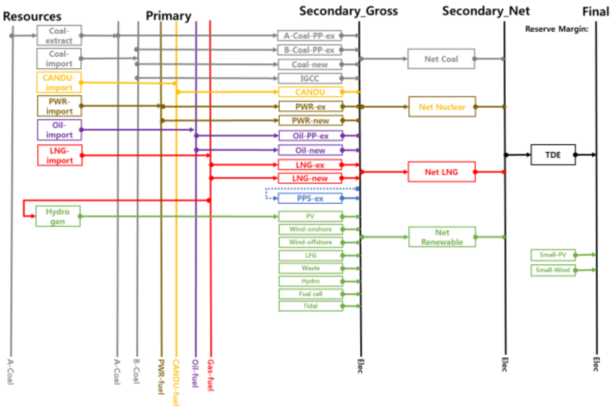


Fig. 1. MESSAGE reference energy system

## 3. Definition of Cases

In this study, three cases are set up to be compared. The first case called 'BAU (Business-as--usual)' is based on the 7th national electricity plan [5]. The next is 'New Energy Policy (NEP) 1'. It is described as the replacement of major energy resources from nuclear and coal to renewables. And the last, NEP 2, is the combined BAU and NEP 1. In other words, NEP 2 case means that nuclear power plants is a major component to generate electricity in Korea, and also the portion of renewable energy to 20 percent by 2030. Table 1 gives the description of these cases.

Table 1: Description of cases

| Tech. | BAU | NEP 1 | NEP 2 |
|---|---|---|---|
| **Nuclear** | - 15.8 GW of new capacity is committed to be added by 2030<br>- LTO is allowed for all NPPs except Kori-1 | - Only 7 GW of new capacity is committed to be added by 2030<br>- LTO is not allowed for all NPPs | - Same as BAU |
| **Coal** | - 11 GW of new capacity to be added by 2030 | - Only 2.6 GW of new capacity allowed by 2030 | - Up to 7.7 GW of new capacity allowed by 2030 |
| **LNG** | - 8 GW of new capacity is committed to be added by 2020 and | - No restriction | - No restriction |

| | | | |
|---|---|---|---|
| | continuous construction is allowed after 2020 | | |
| **Renewable** | - 11.7% of total electricity production by 2030 | - 20% of total electricity production by 2030 | - 20% of total electricity production by 2030 |

## 4. Input Data

MESSAGE requires various inputs such as (i) projected energy demands, (ii) load regions, (iii) technologies and (iv) economic data on existing and new power options.

It is assumed that the analysis period is from 2016 to 2030, and base year is 2015. Discount rate is 5.5% per year.

### *4.1 Electricity demand projection*

The ongoing national electricity plan has projected demand for electricity to grow at 1.1% annually up to 2030. At the same time, the plan has projected peak electricity demand to grow at 1.19% annually for the same period.

### *4.2 load regions*

Electricity demand changes from time to time in a year. At the same time, production load from renewables is intermittent, being subject to the metrological conditions. To take into account the pattern of the variations of both electricity demand and of production load from renewables, a year is divided into 140 load regions. The yearly load division includes 12 seasons, 2 peaks (winter & summer) and 2 bases (national holiday: *SEOL & CHU-SEOK*). The weekly load is divided between working days, Saturday and Sunday. The day types are divided into 5 parts. Figure 2 shows the comparison between the load curve in this study and the historical load curves based on the hourly load region. It turns out that the simulated values from the model match the historical values relatively.

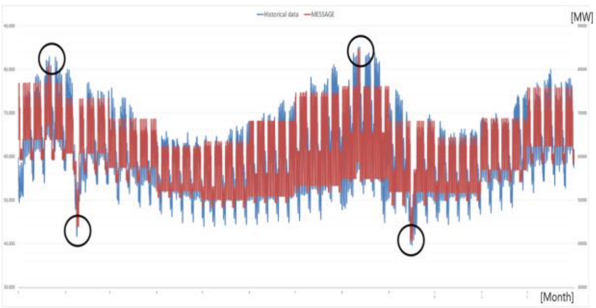


Fig. 2. Comparison between historical electricity demand load (blue) and load curves defined in this study (red).

### *4.3 Technologies*

Explanations of the existing and new technologies in the model are given in table 2.

Table 2: Existing and new technologies

| Technologies | Exist | New |
|---|---|---|
| **Nuclear** | 12 units of PWRs, Kori-1/2/3/4, Hanbit-1/2, Hanul-1/2, PHWR-1/2/3/4 | New-1400MW |
| **Conventional and thermal power plant** | Coal, D(domestic)-coal, LNG, OCGT, Oil | Coal(New-500MW, 1000MW) LNG(New-500MW, 700MW) |
| **Renewables** | PV, Wind(Onshore, Offshore), Off-gas, LFG, Fuel-cell, Tidal, Small-hydro | |
| **Others** | Hydro, PPS(Pumped Storage), CHP, IGCC | PPS |

Table 3 gives the data about lifetimes and capacity factors for the major power technologies in this study. In order to model the impacts of the metrological condition on the production performances of renewables, typical sites for PV(*Yeong-am*) and wind(*Han-kyung*) plant were surveyed.

Table 3: Lifetimes and capacity factor for each technology

| Technologies | Lifetimes | Capacity factors |
|---|---|---|
| **Nuclear** | 60 years | 0.85 |
| **Coal** | 30 years | 0.80 |
| **LNG** | 30 years | 0.85 |
| **Wind and PV** | 25 years | Wind(0.278) *, PV(0.158)* |
| **Hydro** | 80 years | 0.28 |

*: Capacity factors of wind and PV are annual average values

### *4.4 Economic data*

The data related with renewables are obtained from the IEA/NEA publication titled 'Projected costs of generating electricity'[6] and economic data are partly from the latest conference[7], and the other data, which are not available in the public, are constructed by applying extrapolation of the past data reflecting changes in the general price level.

In the alternatives scenarios, refurbishment for LTO (Long term operation) will be considered for the NPPs. It is assumed that refurbishment expenditures be \$520/kWe, based on the information surveyed in the literature in the field.

## 5. Results and discussion

### *5.1 Electricity generation mix*

As BAU case, South Korea will be generated 654 TWh of electricity in 2030. NEP-1 is less 18 TWh and NEP-2 less 7 TWh than BAU cases. Fig 3 shows the results of electricity generation mix for each case. Nuclear generated 23.9% and LNG 26.9% in NEP, 2030. The other cases displayed nuclear generated around 44% and LNG 4~7% in 2030. It means that nuclear power plant could be replaced by LNG as major power options.

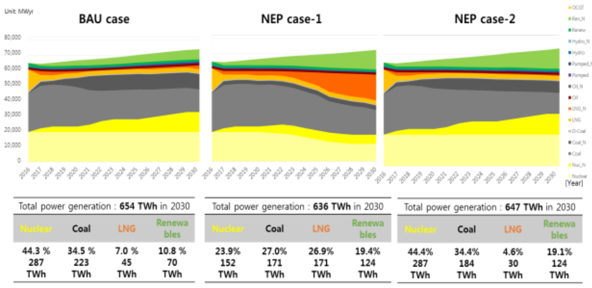


Fig. 3. Electricity generation mix

### *5.2 Total installed capacity*

Fig 4 shows the total installed capacity for each scenario. Total installed capacity of BAU is 160 GW in 2030 and around ~180 GW in NEP-1, 2. The share of renewables is 34% for NEP 1, 2 cases in 2030. As generation mix, capacity of nuclear also be replaced by LNG.

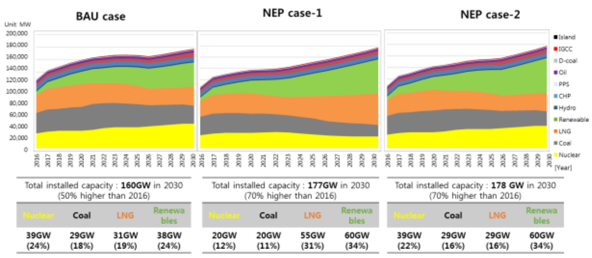


Fig. 4. Total installed capacity

In 2030, total installed capacity of renewables will increase from BAU case (38 GW) to NEP-1, 2 (60 GW). Fig 5 presents increasing capacity of renewables, including PV and wind over the study period. In all cases, PV is the most dominant renewable energy. It accounts for 71.9% and wind 17.1% in BAU cases. And, PV accounts for 51.5% and wind 40.4% in the other cases.

There are remarkable additions in off-shore wind. It's because there are annual upper limitations to construct new capacities of PV and on-shore wind. However, upper limit was not imposed on the off-shore wind.

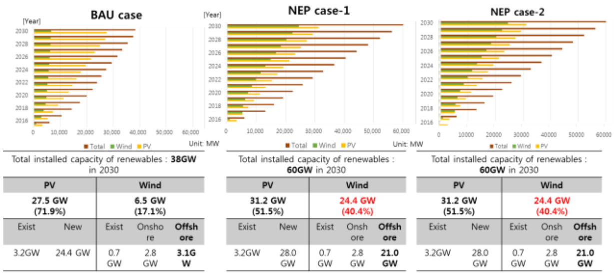


Fig. 5. Total installed capacity for renewables

### *5.3 Economic competitiveness*

As followed this model, the total system cost is around 500~700 trillion KRW over the study period. Table 4 gives the total system cost for each cases in detail.

The total system cost of NEP 1 is 35% and 12.3% higher, respectively, compared with BAU and NEP 2 by 2030. Since new capacities of most nuclear power plants are replaced by LNG. Nuclear is generally known as an economical power plants to generate electricity in South Korea, with Coal second [2].

Table 4: Total system cost over the study period

| Case | Total Cost [Trillion KRW] | Capital Cost [Trillion KRW] | Running Cost [Trillion KRW] |
|---|---|---|---|
| **BAU** | **506** | 114 | 392 |
| **NEP-1** | **683** | 245 | 438 |
| **NEP-2** | **608** | 131 | 378 |

### *5.4 Energy security*

Energy security is the important problem in most of country. In 2016, overseas dependence of Korea reached 95%. Except domestic coal (A-coal), most of energy resources is imported from abroad. This study investigated power generation in 2030 base on imported fuel, especially B-coal, LNG and Oil power plants for each case. Table 5 gives the power generation based on imported fuels. Energy security is considered as amounts of imported fuel in this study.

Although the share of renewables for NEP1 and 2 cases might be 20% in 2030, energy security of two cases is a starkly different. The share of NEP 1 is 53.9% and NEP 2 33%. Two cases of NEP are different with accounting for LNG options. Also, NEP 2 is less dependent than BAU case in terms of imported fuel, because NEP 2 has a goal to reach share of renewables by 20% in 2030. It is noted that nuclear power and renewables are dominant role of energy security.

Table 5: Power generation based on imported fuels

| | Imported Coal | | LNG | | Total base on Imported fuels | |
|---|---|---|---|---|---|---|
| | TWh | % of total electricity | TWh | % of total electricity | TWh | % of total electricity |
| **2016** | 226 | 39.6 % | 126 | 22.2% | 359 | **63.0 %** |
| **BAU 2030** | 219 | 33.8 % | 45 | 7.0 % | 269 | **41.5 %** |
| **NEP1 2030** | 167 | 26.3 % | 171 | 26.9 % | 342 | **53.9 %** |
| **NEP2 2030** | 179 | 27.7 % | 30 | 4.6 % | 214 | **33.0 %** |

### *5.5 Carbon dioxide emission*

The environmental protection and climate change mitigation explained the amounts of carbon dioxide emissions such as greenhouse gas. An illustrated in Fig. 6, NEP 2 is the most eco-friendly cases to decrease greenhouse gas. The 2030 carbon dioxide emissions decrease to 19.1% in BAU, 17.4% in NEP-1 and 33.4% in NEP-2, based on year of 2016. There is no remarkable difference between BAU and NEP-1.

In general, greenhouse gas emissions of LNG (470 g CO2e kWh−1 for life-cycle emissions and 64.2 t CO2 TJ−1 during generation) and Coal (970 g CO2e kWh−1 for life-cycle emissions and 98.3–107.0 t CO2 TJ−1 during generation) are higher than nuclear power (40 g CO2e kWh−1 for life-cycle emissions and 0 t CO2 TJ−1 during generation) and renewable energy [2].

Replacing nuclear with LNG, NEP 2, is the most profitable options to reduce greenhouse gas emission.

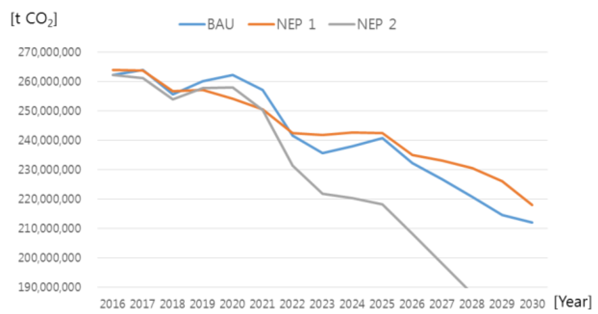


Fig. 6. Amount of carbon dioxide emission by 2030

## 5. Conclusions

The two alternative cases, NEP-1, 2 are developed and analyzed for the revision of energy policy and these cases are compared with BAU, which is based on 7th national plan, in terms of economics, energy security, and environment/climate change.

It is found that (i) nuclear power will continue to play a critical role for ensuring and reliable electricity supply ; (ii) renewable energy sources can contribute up to 20% of the electricity supply, but because of their variability and intermittence back-up capacity will be needed for maintaining reliability of supply ; (iii) the total system cost in NEP-1, 2 is higher than BAU because of a larger back-up capacity needed for renewable ; (iv) In both cases, energy security will be improved but in NEP 1 case the improvement is minimal because nuclear power is restricted severely, whereas in NEP 2 case the energy security significantly improved (a reduction of imported fuel from 63% in 2016 to 33% in 2030) ; (v) NEP-2 is attractive in terms of climate change mitigation as the carbon dioxide emission reduction is twice as compared to NEP-1.

From this study, it can be concluded that nuclear needs to play a critical role in providing competitive and emission-free electricity in Korea which will also continue in the future.

At the current stage of national electricity plan, the '8th national electricity plan' is published. Hence, this study has been updated based on the new plan. The further study be developed based on various scenarios, in particular, focused on projection of electricity demands. Also, additional economic data will be reviewed, discussed and updated.

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