Carbon Neutrality and the Role of Nuclear Power Generation in Korea

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1. Background

IPCC(Intergovernmental Panel on Climate Change) announced in its special report in 2018 that the global average temperature increase after industrialization should be limited to 1.5℃ in order to struggle against climate change and to preserve the ecosystem of the earth. In addition to that, it is recommended that carbon neutrality of net zero carbon emission is to be accomplished by 2050.

South Korea announced in Oct. 2020 the completion of carbon neutrality by 2050. In the meantime, Korean government has decided in Nationally Determined Contributions(NDC) to UNFCCC that it will fulfill the target for Korea's GHG emissions in 2030 to be decreased by 40% compared to that of 2018.

In special report "Net Zero by 2050" by IEA, a roadmap for global energy sector is presented for the accomplishment of global net zero emissions. In its report, Net-Zero Emissions(NZE) scenario was proposed which the following various situations are being assumed globally. Firstly, total (primary)energy supply falls by 7% between 2020 and 2030 in the NZE and remains at around this level to 2050. Secondly, solar PV and wind power become the leading sources of electricity globally before 2030 and together they provide nearly 70% of global generation in 2050. Thirdly, electricity demand grows rapidly in the NZE scenario, rising 40% from today to 2030 and more than two-and-a-half-times to 2050.

Based on the above situations we tried to analyze the impact of net zero emissions policy in electric sector in Korea through the indices like system operating costs, power mix (capacity, generation), and electricity tariff.

2. Basic Requirements for analysis

The NZE path involves a significant increase in electricity demand because of the results of an increase in economic activity, rapid electrification in the existing high energy consuming industries that have been using the fossil fuels, and hydrogen production by electrolysis.

In this study we focused on electric sector among the overall industrial sectors in searching the path to net-zero emission target considering the status of electricity. It is expected that global electricity demand climbs 23,230 TWh in 2020 to 60,000 TWh in 2050 in the NZE, with an average increase of 3.2% per year. Similarly, this study also applied some of the above global perspectives.

2.1 Analysis Model

MESSAGE(Model for Energy Supply Strategy Alternatives and their General Environmental Impact) which was developed in 1980s' by IIASA(International Institute for Applied System Analysis) was used for the analysis. The above model with linear program is known to be very useful in reflecting flexibly the characteristics of electric load from the viewpoint of load lengths and load amounts(heights).

The basic data needed to operate the model are somethings related to the long-term electricity demand (generations, electricity sales amounts, peak load, the hourly load patterns, etc.).

2.2 Korea's Reference Energy System(RES)

In this analysis, the basic diagram for Korea's energy system which is called as reference energy system(RES) should be envisaged. This includes the flows of import/domestic energy sources, power generation technologies and their relations with fuel sources, the network of power plants and transmission line.

The below picture briefly shows the Korea's RES.

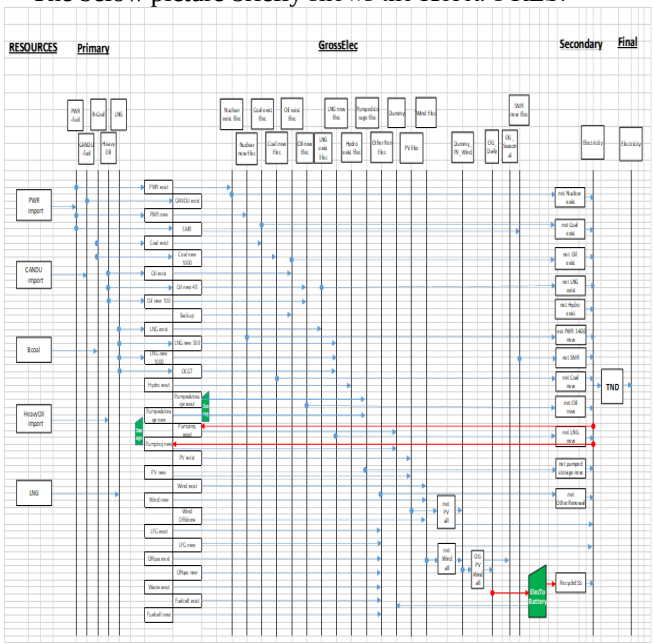

Fig. 1. Reference Energy System for Korea's electric system

2.3 Input data

The electricity demand perspective by 2050 is firstly needed. It is assumed that total electricity demand in 2050 will be increased to two and half times of that in 2020 considering the above IEA's special report and "a

draft scenario(1) of carbon neutrality in Korea" made by government side. In addition, annual peak demand and total power capacity required are to be provided using system load factor and system reserve margin.

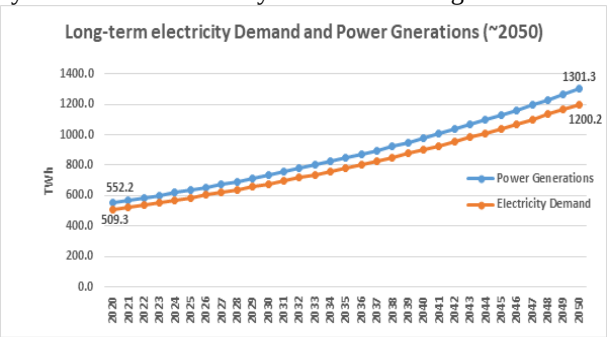

Fig. 2. Long-term Electricity Demand and Power Generations

On the supply side of power generation, renewable energy sources like photovoltaic and wind power firstly are expected to be the main power technologies in the era of carbon neutrality. Also non-carbon power technologies like nuclear power and fuel cell will be another important power sources. Perspectives of construction and O&M costs over the study period to 2050 are the key factors influencing on the power economics and optimal power mix. We calculated the future trend data on costs of the above power technologies referencing to the overseas materials published.

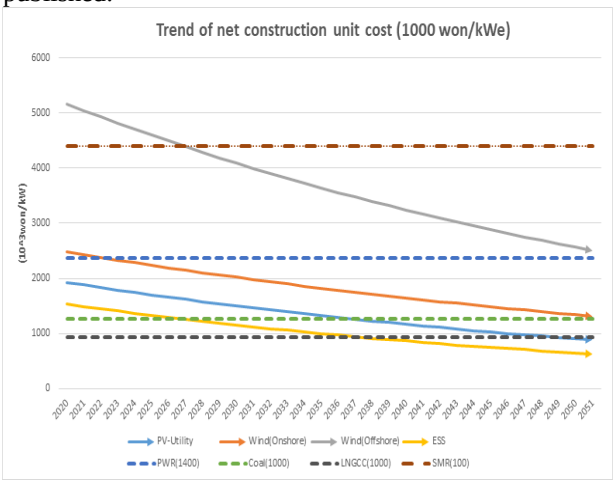

Fig. 3. Perspective for net construction costs by power source

2.3 Scenario Development

Depending on the share of renewable power generation and the commitment size of nuclear power technologies like SMR (Small Modular Reactor) and Large PWR, twelve scenarios in total are analyzed in this study. Among them four scenarios are discriminative and we make a comparison only for these four scenarios. First scenario(C5XX) is based on the nuclear power phase-out policy of Korean government. Second one(C5XO) is considering some of SMR into the electric system after 2030. Third one(C5OO) is in the affirmative position for nuclear powers and is considering some of SMR and Large PWR plants after 2030. Lastly fourth one(C333) is in the active position for nuclear power and is considering much more investment. for SMR and Large PWR plants after 2030

3. Results

Focused on the above four scenarios, the main results show the capacity mix and generation shares by power technology and the system costs or sales unit cost related to electricity tariff.

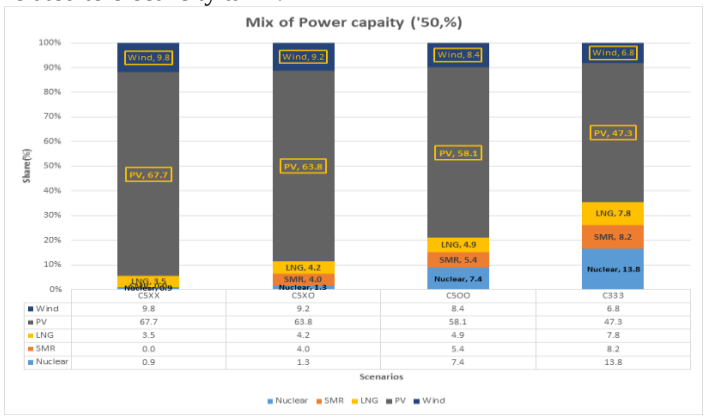

Fig. 4. Mix of power capacity by scenario ('50)

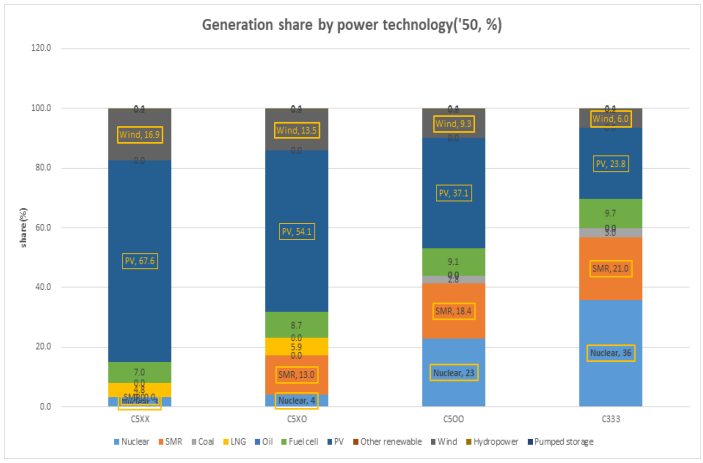

Fig. 5. Power Generation Mix by scenario ('50)

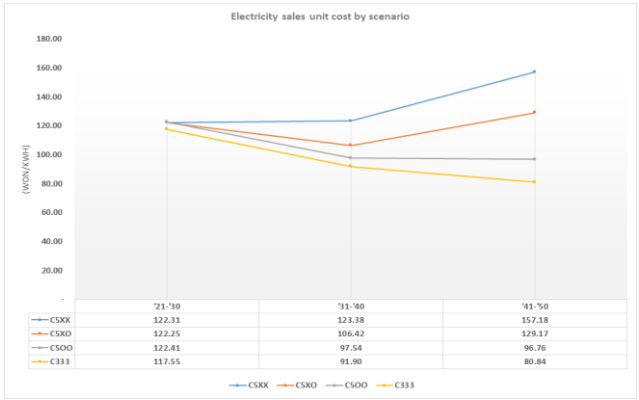

Fig. 6. Electricity sales unit cost by scenario (’50)

4. Conclusions

The role of power generation sector is very important in getting to the national goal of carbon neutrality. The rational path to this goal need the comprehensive consideration for the economic and environmental and technical aspects.

Especially considering the relative importance of power generation sector, the impact on economy through an electricity tariff is expected to be very large. Viewing from the results of scenario analysis, total electric system costs in case of the continuous non-nuclear power policy reaches to around 1,664 trillion won for ten years from 2041 to 2050, with an annual cost being 166 trillion won and it finally brings about an annual average electricity sales cost to be approximately 157 won per kWh. On the other hand, in case of including actively both new SMRs and Large PWRs into the grid, total system cost over ten years from 2041 to 2050 comes to around 856 trillion won which is decreased largely compared to non-nuclear power scenario, with an annual average electricity cost being about 81 won per kWh.

In conclusion, it is recommended that the parallel consideration of renewable energy sources and nuclear power in electric system is absolutely necessary in achieving effectively the goal of carbon neutrality in Korea.

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