# *UNPACKING THE DRIVING FORCES OF HISTORICAL ELECTICITY GENERATION COST CHANGE IN KOREA – MARKET FORCES VS TECHNOLOGICAL LEARNING*

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## Overview

In accordance with worldwide energy transition trends, the Korean government is promoting low-carbon and renewable power generation technologies. Nevertheless, dependency on three conventional primary power generation sources (coal, nuclear power, and natural gas combined cycle) will remain dominant, accounting for 78.8% of the expected total electricity generation in 2030 according to the 8$^{th}$ Basic Plan for Long-term Electricity Supply and Demand. Hence, understanding the cost drivers of electricity generation using primary sources is crucial in capacity planning, market design, and climate policy.

In this study, we collect empirical data on the variables commonly used in calculating the levelized cost of electricity (LCOE) and analyze the changes over the years to identify the cost drivers of electricity generation. Then, we decompose and reshuffle the variables into market factors and technical factors. Based on this classification, we propose ways to separate learning and non-learning components in the LCOE to provide a robust prediction for technological change and to draw implications for policy-makers and modelers.

## Methods

There have been several attempts to analyze LCOE trends and identify the cost drivers of power generation technologies. McNerney et al. (2011) analyzed the cost trend of generating electricity from coal power plants, while Koomey and Hultman (2007) analyzed that of nuclear power plants in the U.S. In line with these studies, we collect detailed market, cost, and engineering data to calculate and track LCOE changes in Korea from 1991 to 2018. Unlike previous studies, we perform both time-series and cross-technology analysis to draw general conclusions on cost drivers and technological change. Of the 256 operating conventional power plants in 2018, we cover data on 227 power plants (57 coal power plants, 148 NGCCs, and 22 nuclear power plants), equivalent to 88.7%.

We first analyze the changes in each of the variables that compose the levelized fuel, O&M, and capital costs to identify the cost drivers and calculate the LCOE. The variables are then reclassified into market factors (e.g., fuel price, capacity factor) or technological change factors (e.g., specific construction cost, efficiency). To measure how each variable affects the LCOE, we decompose LCOE change with the partial derivatives used in McNerney et al. (2011). With this data, we measure the technological learning with various dependent variables, namely conventional specific construction cost (Learning #1), the LCOE with a fixed non-learning factor (Learning #2), and the LCOE itself (Learning #3). By comparing the different learning models, we attempt to capture various learning processes that are not limited at the construction stage of electricity generation technologies.

## Results

The LCOEs of coal power plants fluctuated between 38.87 and 76.66 KRW/kWh, of NGCCs between 57.90 and 147.14 KRW/kWh, and of nuclear power plants between 35.38 and 48.13 KRW/kWh. The large variations in fossil-fuel based power plants were attributed to the large share and randomness of the fuel cost. The fuel cost of coal power plants ranges from 38.5% to 78.3% and that of NGCC plants ranges from 35.2% to 88.0% in terms of the LCOE. In contrast, the capital cost (47.74% ~ 59.00%) of nuclear power was the largest component of its LCOE, followed by the O&M cost (30.18% ~ 43.12%). The LCOE of coal and nuclear power plants increased by 9.1% and 18.5%, respectively, while that of NGCC plants decreased by 13.6% during our research period.

The decomposition shows that the LCOE of coal power plants increased by market factors (+11.47) surpasses the cost reductions due to technological advancement (-6.66). Meanwhile, market factors (-1.65), such as the capacity factor and capital recovery factor, and technology factors (-0.79), such as thermal efficiency improvement, contribute to the cost reduction of NGCC. In contrast, the decreased capacity factor, increased specific O&M, and construction

cost increases the LCOE of nuclear power. The comparison of different learning models shows that coal power plants and NGCC have a tradeoff between increased specific construction costs and improved thermal efficiency. Similar to Grubler (2010), nuclear power plants show negative learning for all learning models.

## Conclusions

Market factors were the cost driver for coal power plants and NGCC, which implies that the cost of electricity is highly vulnerable to the fuel import price and capacity factor. Since Korea have low energy independency, importing more than 90% of fossil fuels use, fuel import price is mostly exogenous. Capacity factor is affected not only by the market but also by government capacity planning. Considering that coal power and NGCC technologies are mature, the LCOE volatility of fossil-fuel based power plants incurred by market factors will be sustained and the controllable variable will be the capacity factor.

The cost driver of nuclear power plants was capital cost until 2010, but O&M cost has driven the LCOE of nuclear power plants in recent years. These trends were due to the realized decommissioning cost, as the first-generation nuclear power plants have been undergoing decommissioning since 2017. The comparison of various learning models shows the importance of a holistic approach in understanding the cost of electricity generation: Additional capital cost investment leads to more efficient operations, or incurred by the environmental and safety regulations such as installation of scrubbers and enhanced building codes. A deeper understanding of such dynamics in the learning process will benefit both modelers and policy-makers.

*Acknowledgment: This research is supported by the Ministry of Environment of Korea through its Climate Change Correspondence Program (2014001300002). This views and opinions expressed in this study are those of the authors alone.

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