[*EVALUATING POWER-TO-HEAT POTENTIAL OF CHP IN SOUTH KOREA: AN ENERGY SYSTEM MODELING APPROACH TO SURPLUS ELECTRICITY UTILIZATION*]

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Overview

Power-to-heat (P2H) technology has emerged as a crucial resource for achieving carbon neutrality goals in the heat production sector while serving as a flexibility resource in power systems. Despite South Korea's emphasis on power sector decarbonization, the heat production sector has received relatively limited attention. While P2H has been frequently discussed following South Korea's carbon neutrality announcement, specific implementation targets and strategies remain undefined, and comprehensive economic analyses are lacking. This study analyzes the potential utilization of P2H technology in combined heat and power (CHP) plants and evaluates its capacity as a mitigation technology and a flexibility resource, focusing on a sample CHP plant near the Seoul metropolitan area.

Methods

We developed an energy system model simulating a facility-level CHP plant to analyze P2H implementation levels and utilization under various scenarios. The model incorporates heat storage investment decisions, electricity prices, surplus power supply patterns, and carbon pricing scenarios. Key variables include: (1) new heat storage facility investment options, (2) electricity prices, (3) carbon pricing levels, and (4) surplus electricity quantity and temporal patterns. For this analysis, electricity prices were set between 0-100% of the hourly System Marginal Price (SMP). The amount of surplus electricity was calculated by downscaling the surplus electricity generation derived from Korea's power system model, using the ratio of regional electricity demand to national total demand. The analysis examines the interaction between heat storage investment, electricity price, surplus electricity availability, and carbon costs to determine optimal P2H deployment.

Results

The analysis evaluates P2H and heat storage investment volumes, P2H charging patterns, and emission levels across three scenario groups: (1) surplus electricity and electricity price scenarios without heat storage, (2) surplus electricity and electricity price scenarios with heat storage, and (3) integrated scenarios considering surplus electricity, electricity price, and carbon costs with heat storage. The results demonstrate varying levels of P2H adoption and effectiveness depending on the combination of these factors.

When surplus electricity was provided at no cost, Power-to-Heat (P2H) technology was utilized across all seasons except summer. However, when electricity prices were set at 20% of SMP, P2H utilization was limited to winter months only. Furthermore, when electricity prices exceeded 20% of SMP, P2H implementation was found to be nearly non-existent.

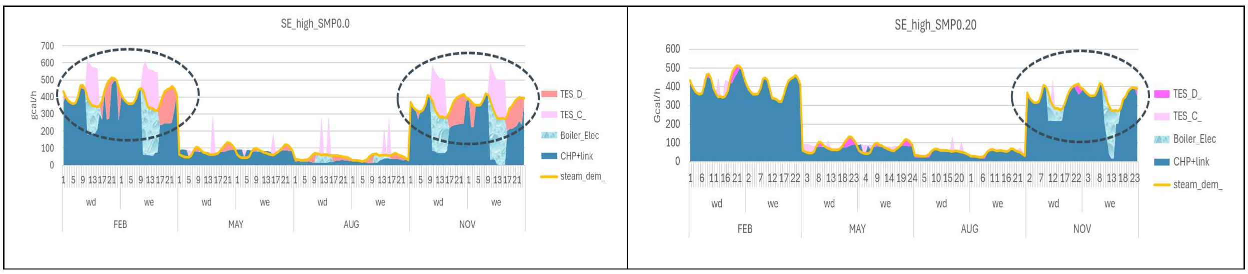

Figure 1 Hourly P2H utilization change based on electricity price change

The potential adoption capacity of electric boilers was found to vary significantly depending on the possibility of additional heat storage system implementation. In particular, as surplus electricity was concentrated during specific periods of high solar power generation, the availability of heat storage systems proved to be a crucial factor in expanding P2H adoption, especially in scenarios with higher surplus electricity generation.

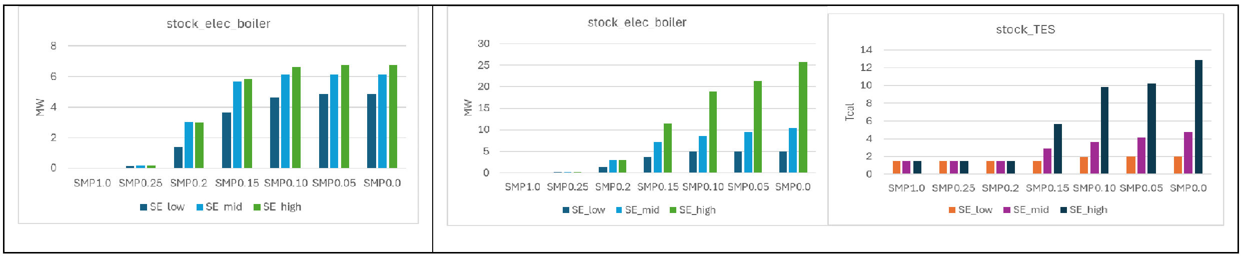

Figure 2 Electricity boiler stock change according to new thermal energy storage(TES) installation

As carbon prices increased, the deployment capacity of electric boilers expanded, contributing to emissions reduction in CHP plants. When carbon prices exceeded certain thresholds, P2H utilization levels remained relatively consistent at electricity prices below 10% of SMP. While higher carbon prices made P2H implementation favorable even at higher electricity prices, under current technological assumptions, P2H adoption still required significantly low electricity prices, specifically around one-quarter of SMP. Furthermore, the greenhouse gas reduction potential from P2H implementation was found to be relatively modest compared to other feasible reduction measures in CHP plants, such as hydrogen co-firing.

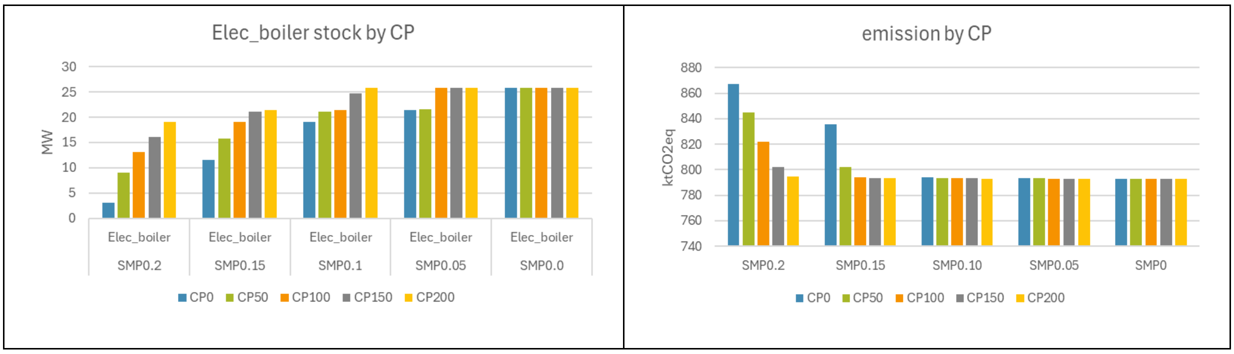

Figure 3 Electricity boiler stock and GHG emission by carbon price change

Conclusions

The study reveals that P2H technology lacks economic viability at current electricity price levels. The effectiveness of P2H implementation is heavily influenced by the duration of surplus electricity availability periods. P2H becomes economically viable only when electricity prices fall below 15% of current SMP levels. However, with increased carbon pricing, P2H maintains competitiveness even at 20% of current SMP levels. While P2H demonstrates potential to replace conventional CHP operations beyond peak load boiler levels, resulting in emissions reductions, the overall reduction impact remains modest under current conditions.

References

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