Economic Feasibility of Renewable Energy-Integrated P2H(Power-to-Heat) Systems in Jeju Island

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Overview

This study investigates the economic feasibility of P2H systems in Jeju Island and explores the impact of policy interventions for their implementation. The transition to sustainable energy systems necessitates innovative solutions to effectively utilize renewable energy sources. The 11th Basic Plan for Electricity Supply and Demand projects that by 2038, Korea's renewable energy share will grow to 238 TWh, representing 33% of the energy mix. P2H technology, which converts excess renewable electricity into heat for storage, is essential in Korea, where 58.9% of energy in the manufacturing sector and 78% in the building sector is consumed as heat(Ministry of Trade, Industry and Energy (2024)). In countries such as Germany and Europe, models for introducing P2H systems have already been set up and economic feasibility assessments have been conducted, but in Korea, the focus is still on technology development. Ensuring the economic viability of energy prices and new technologies is an important factor for a sustainable transition. In the case of Korea, electricity and heat rates are very low, making it difficult to secure the economic feasibility of new technologies. However, Jeju Island has favorable conditions for the introduction of P2H. First, Jeju Island has the highest penetration rate of renewable energy in Korea. While the average renewable energy generation in South Korea is 9%, the figure for Jeju Island is 19.2%. As a result, the number of cuttailments in Jeju last year also increased rapidly to 200 times. An alternative is needed to properly utilize surplus renewable energy. Second, most areas in Korea use district heating or natural gas for heating, which results in low average heating costs. However, Jeju Island is an island and the residents are dispersed, so they use LPG or kerosene as their main heating source. While the average heating cost per household on the mainland is around 100USD, the average cost per household in Jeju is 410 to 500 USD(Korea Institute of Machinery and Materials, 2024). This means that the relatively high heating costs make it possible to secure economic feasibility when introducing P2H. This study investigates the economic feasibility of integrating renewable energy with residential Power-to-Heat (P2H) systems in South Korea, focusing on a representative household model in Jeju Island. The analysis aims to provide insights into the cost-effectiveness of such systems and the potential impact of policy interventions to promote their adoption.

Methods

We developed a representative business model focusing on a household in Jeju Island equipped with a 10 kW rooftop photovoltaic (PV) system, a 19.8 kW heat pump, and a 237 kWh thermal storage unit. Fig 1 illustrates the integration of renewable energy and P2H systems. The analysis compared two scenarios:

1. **Baseline Scenario:** The household relies solely on liquefied petroleum gas (LPG) for heating.
2. **Alternative Scenario:** The household utilizes the integrated renewable energy-linked P2H system.

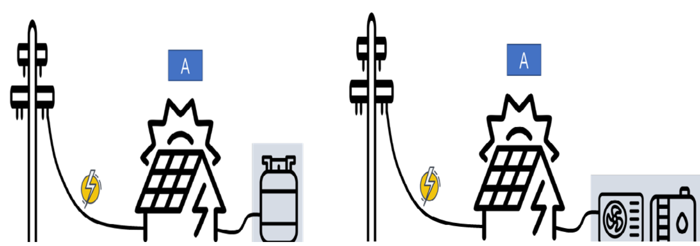

Fig 1. Schematic representation of P2H system integration with renewable energy in Jeju Island

The analysis utilized key economic indicators, including Benefit-Cost Ratio (B/C), Net Present Value (NPV), and Internal Rate of Return (IRR), to assess feasibility. Additionally, the study examined the effects of various policy measures, such as installation subsidies ranging from 0% to 100% and electricity pricing incentives, on the system's economic performance.

Results

The economic analysis of the baseline scenario reveals that the Internal Rate of Return (IRR) is -0.8%, indicating that the expected return on investment falls below the required threshold. The Net Present Value (NPV) is calculated to be −13,075USD, demonstrating a projected financial loss when assessed in present value terms. Furthermore, the Benefit-Cost Ratio (B/C Ratio) is 0.82, falling below 1, which implies that the benefits do not outweigh the costs. These results collectively suggest that the baseline scenario is not a financially viable business model under current conditions.

However, the introduction of policy interventions significantly enhances economic feasibility. Fig 2 illustrates economic feasibility simulation results under different policy scenarios for P2H system:

Installation Subsidies: A subsidy covering approximately 30% of the total installation cost results in a B/C ratio exceeding 1, indicating economic viability.

Electricity Pricing Incentives: Implementing reduced electricity tariffs for excess consumption, particularly during periods of surplus renewable energy generation, improves the system's economic attractiveness.

Combined Policy Measures: A combination of a 20% installation subsidy and a moderate reduction in electricity tariffs yields a B/C ratio greater than 1, suggesting that a mix of policy tools can effectively promote system adoption.

NPV(USD)	Installation grant					
Electricity Price (¢/kWh)	0%	20%	40%	60%	80%	100%
Base line	-13,075	- 5,658	1,759	9,177	16,594	24,012
7.17	- 9,144	- 1,726	5,691	13,108	20,526	27,943
5.59	- 5,132	2,286	9,703	17,120	24,538	31,955
0	- 1,120	6,297	13,715	21,132	28,550	35,967
1.43	485	7,902	15,320	22,737	30,154	37,572
2.87	2,090	9,507	16,924	24,342	31,759	39,177
4.3	3,694	11,112	18,529	25,947	33,364	40,781

B/C	Installation grant					
Electricity Price (¢/kWh)	0%	20%	40%	60%	80%	100%
Base line	0.82	0.93	1.09	1.30	1.62	2.16
7.17	0.88	1.01	1.18	1.41	1.76	2.34
5.59	0.96	1.09	1.27	1.52	1.90	2.53
0	1.03	1.17	1.37	1.64	2.04	2.71
1.43	1.05	1.20	1.40	1.68	2.10	2.79
2.87	1.08	1.24	1.44	1.73	2.15	2.86
4.3	1.11	1.27	1.48	1.77	2.21	2.94

Fig 2. Simulation results showcasing economic feasibility under various policy scenarios

Conclusions

The integration of renewable energy with residential P2H systems presents a promising avenue for enhancing energy efficiency and sustainability in South Korea. However, without supportive policy measures, such systems currently lack economic viability. Strategic policy interventions, including installation subsidies and electricity pricing incentives, are essential to improve cost-effectiveness and encourage widespread adoption. Further studies should assess the long-term environmental and economic benefits of large-scale P2H deployment, particularly its impact on grid stability.

References

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