Lucerne University of Applied Sciences and Arts

Engineering and Architecture
B.Sc.. Energy and Environmental Systems Engineering
Bachelor-Thesis

Techno-Economic Evaluation of PIT Storage for Flexible Power-to-Heat and Seasonal Energy Supply

Student: Mariana Ciriani

1. Introduction, Goals and Research Questions

This thesis, conducted in collaboration with CKW AG, investigates the techno-economic performance of Pit Thermal Energy Storage (PTES) integrated with a large scale heat pump (HP) and an electric boilers (EB) for seasonal heat supply and flexible Power-to-Heat (P2H) operation in Swiss district heating systems.

With increasing renewable electricity generation, balancing the mismatch between electricity supply and winter heat demand has become a critical challenge. PTES offers a cost-effective solution for long-term thermal storage while enabling short-term flexibility through P2H.

The aim is to evaluate how PTES can simultaneously support seasonal heat supply and grid flexibility, and how component sizing influences technical and economic performance.

Key research questions:

- How does PTES perform as a seasonal heat storage solution in Swiss district heating networks?
- Under which conditions does P2H improve economic performance?
- How do HP, EB, and PTES sizing affect heat cost and investment indicators?

2. Method Overview and Materials

Figure 1 presents the modeled district heating system with all the components. For modeling, a two-stage simulation framework was developed in Python. The technical model simulates hourly system operation and energy flows based on real heat demand and electricity price data for the years 2021 and 2023. The economic model post-processes these results to compute key performance indicators.

System operation follows a rule-based dispatch (see Figure 2): the HP supplies heat as a base-load unit, surplus heat charges the PTES, the PTES discharges during winter peaks, and the EB acts as backup and provides P2H flexibility by charging the PTES during negative electricity price hours. PTES is modeled as a simplified single-node reservoir and sized to cover 40% of winter heat demand in the reference case.

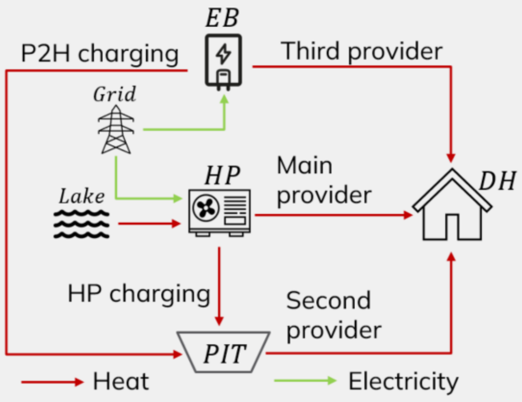

Figure 1: System's schematics

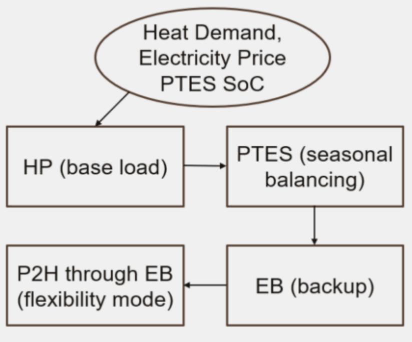

Figure 2: Dispatch logic

Sensitivity analysis were conducted by varying HP and EB capacities, PTES size, P2H activation, and reference year. Model outputs include hourly operation profiles and techno-economic indicators: Levelized Cost of Heat (LCOH), Internal Rate of Return (IRR), simple Payback Period (PP).

3. Results and Discussion

The results show that heat cost is primarily driven by HP sizing, with HP-dominated configurations consistently achieving the lowest LCOH (Figure 3).

Enabling P2H via the EB has only a marginal effect on LCOH, indicating that EB operation does not contribute to heat cost reduction under the investigated conditions.

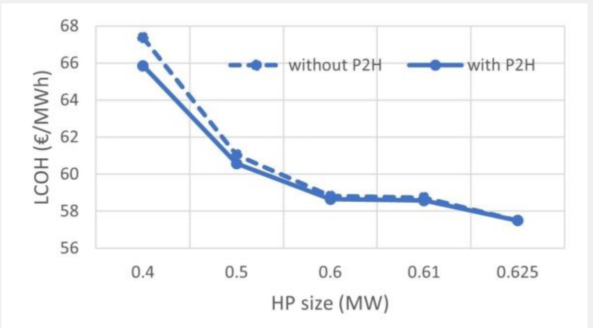

Figure 3: LCOH vs HP size

In contrast, investment performance is strongly influenced by P2H operation. As shown in Figure 4, the IRR increases when P2H is enabled, reflecting additional flexibility-related revenues rather than changes in heat production costs. The results therefore highlight a clear distinction between heat-cost optimization, governed by HP sizing, and economic optimization, driven by flexibility provision.

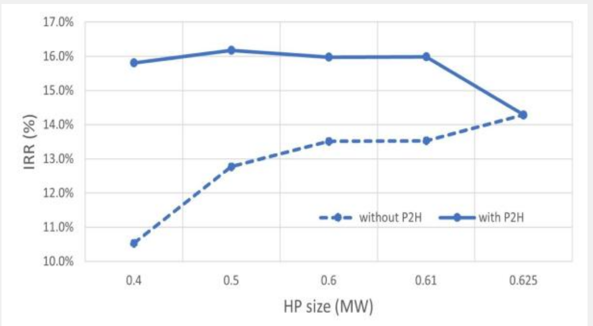

Figure 4: IRR vs HP size

Overall, the findings indicate that PTES combined with large HPs is effective for cost-efficient heat supply, while P2H enhances project profitability without altering the underlying heat-cost structure. The consistency of trends across system sizes confirms the robustness of the results for early-stage system assessment.

4. Conclusion and Recommendations

The study shows that P2H improves economic performance primarily through flexibility provision, rather than through heat cost reduction. System performance is strongly influenced by component sizing, with the HP determining heat cost and the EB affecting investment indicators. The results reveal a clear decoupling between heat-cost optimization and profitability, indicating that configurations minimizing LCOH are not necessarily those maximizing economic return when flexibility revenues are considered. Simplified storage modelling and rule-based dispatch limit realism, and future work should focus on stratified PTES representation and predictive control strategies.

References

Narula, K., de Oliveira Filho, F., Chambers, J., & Patel, M. K. (2020). Simulation and comparative assessment of heating systems with tank thermal energy storage: A Swiss case study. Journal of Energy Storage, 32, 101810. https://doi.org/10.1016/j.est.2020.101810

Industry Partner CKW. Axpo Group

Supervisor: Malin Siegwart
Expert: Kai Lieball
Semester: Autumn Semester, 2025-2026