HSLU Hochschule Luzern

Technik & Architektur
Master of Science in Engineering
Energy and Environment

Master Thesis – Energy and Environment

Integration of Thermal Storage in Hybrid Utility System

Modelling of TES for Integration in Hybrid Utility Systems Model of New Zealand's Industry

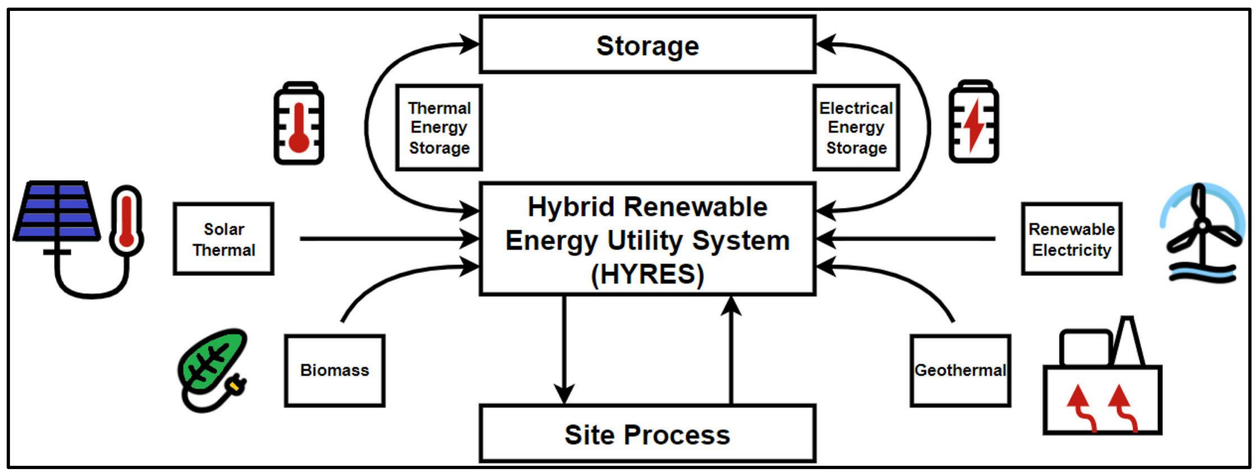

Figure 1: Schematic of a hybrid renewable energy system (HYRES) for an industrial site.

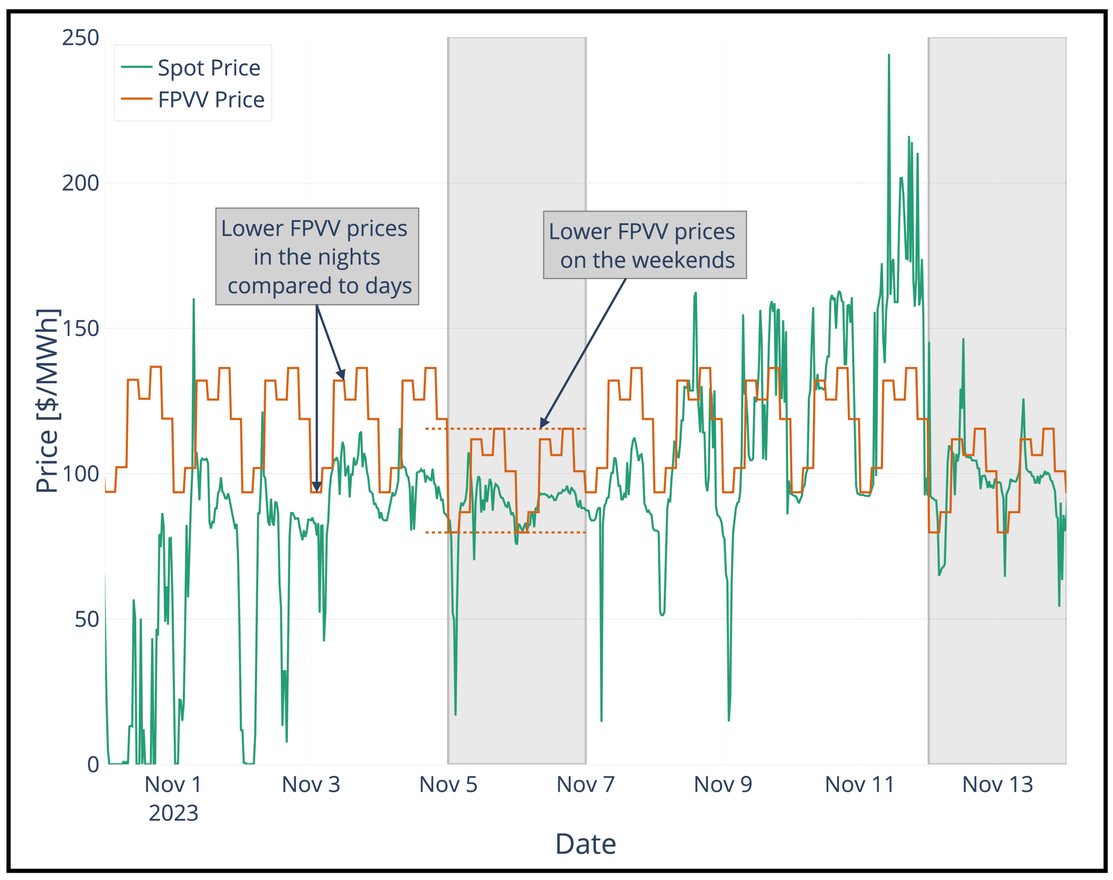

Figure 2: Comparison spot (green) and FPVV (orange) electricity prices. Gray area indicates the weekend.

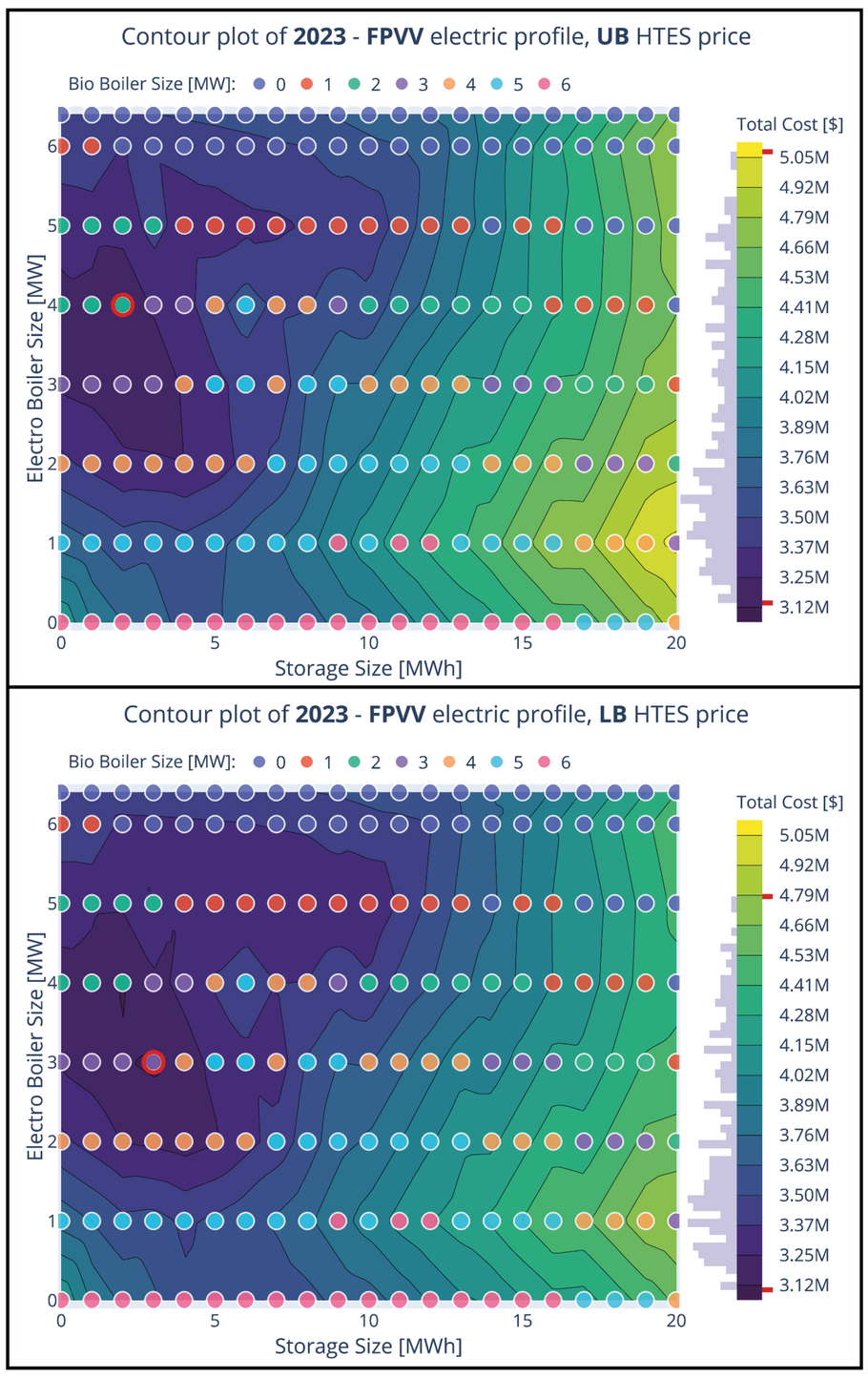

Figure 3: Contour plot of the total costs of the HYRES system with spot electricity price (top) and FPVV electricity price (bottom).

Introduction

In 2023, 55% of new Zealand's process heat was supplied using natural gas or coal. At the same time, electricity prices fluctuate with seasonal renewables supply, creating both financial risk and barriers to electrification. A reliable, flexible solution is needed to meet the country's 2050 net-zero target while keeping energy costs under control.
This thesis investigates how New Zealand (NZ) industry can be decarbonised using hybrid renewable energy systems (HYRES) with high-temperature energy storage (HTES) (see Figure 1).

Procedure

First, eight commercial HTES options (molten salt and packed media) were assessed based on technical, operational, and maturity criteria. Second, a modular Python model using implicit finite-difference and upwind schemes simulated heat transfer during charge/discharge cycles. Finally, a simplified HTES model was integrated in an existing HYRES optimisation model.

A parametric study was performed, to determine the total cost of various combination of biomass (BMB), electro boilers (EB) with HTES. The analysis was performed with different electricity price scenarios (spot price and fixed price varying volume (FPVV)). A comparison of two typical weeks can be found in Figure 2.

Result

The results demonstrate that an HTES size of between 2 and 10 MWh is optimal. The cost for a HYRES was calculated for all combinations in the parametric study. Figure 3 shows a contour plot of the cost for the two different electricity prices. The x-axis represents the HTES size, the y-axis the EB size, and the colour of the surface represents the cost. Information on the BMB size was added as a third dimension using different coloured scatter points. The red surrounded point marks the optimal HYRES with least cost. In addition, the maximum and minimal costs are indicated with red lines on the colour scale as well as the distribution of quantity (histogram) is projected on the colour scale.

As can be seen, the area of the lowest cost shifts to smaller HTES sizes for the FPVV price. This is due to the greater volatility of spot electricity prices compared to FPVV prices. This allows the HTES to be charged more economically, resulting in higher HTES sizes for the optimal point.
A sensitivity analysis showed that even doubling the CAPEX for HTES would only have a marginal effect on the optimal HTES size.

In conclusion, this thesis demonstrates the significant potential of HTES in increasing flexibility and reducing costs in HYRES systems in New Zealand.

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