

Integrating Temperature and Part-Load dependent COP in Shallow Geothermal Borefield Design

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THE CASE

For this research, a multi-utility building in Belgium was taken as a case study. This building has a peak demand for heating and cooling of 536 kW and 676 kW respectively, with a yearly energy demand of 643 MWh and 268 MWh. There is hence a strong imbalance in heat extraction.

The yearly values were upscaled to an hourly profile using the weather data of Kleine Brogel in Belgium.

The borefield layout was taken to be rectangular (10 × 12 boreholes) with a spacing of 6 m.

Each borehole has a double DN32 U-tube with a mixture of monopropylene glycol (25 v/v%) and a flow rate of 0.25 kg/s per borehole. The SV62 heat pump of Alpha Innotec was used.

The simulations were carried out using GHEtool.

HIGHLIGHTS

The goal of this case study was to investigate how the design of the borefield would change when including both temperature and part-load dependent COPs in the design. In addition, the expected SCOP for the optimal design was calculated and compared with the traditional B0/W35 value that is typically used in design.

- ✔ Including only temperature dependency has a negligible effect on the SCOP.
- ✔ Including both dependencies resulted in a 29% increase in SCOP.
- ✔ An additional 5% of borehole length was required.

REFERENCE

Peere, W., Blanke, T. (2022). GHEtool: An open-source tool for borefield sizing in Python. *Journal of Open Source Software*, 7(76), 4406

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INTRODUCTION

In conventional shallow geothermal borefield design, the seasonal coefficient of performance (SCOP) of the heat pump is an input to the simulation. Typically, the official B0/W35 or B0/W55 values are used for this.

However, the efficiency of a heat pump is not constant since it varies with temperature and part-load operation. Besides that, the borefield temperature is (almost) always higher than the B0 mark. Are we underestimating the efficiency of the heat pump in our designs?

RESEARCH PROBLEM

The SCOP serves to convert building loads into ground loads. However, this method introduces two key inaccuracies:

1. Both peak power and total energy demand are scaled equally, often leading to an overestimation of peak extraction power
2. The SCOP is typically based on standard conditions (B0/W35), whereas actual system temperatures are often higher, resulting in an underestimation of seasonal imbalance and an oversized borefield.

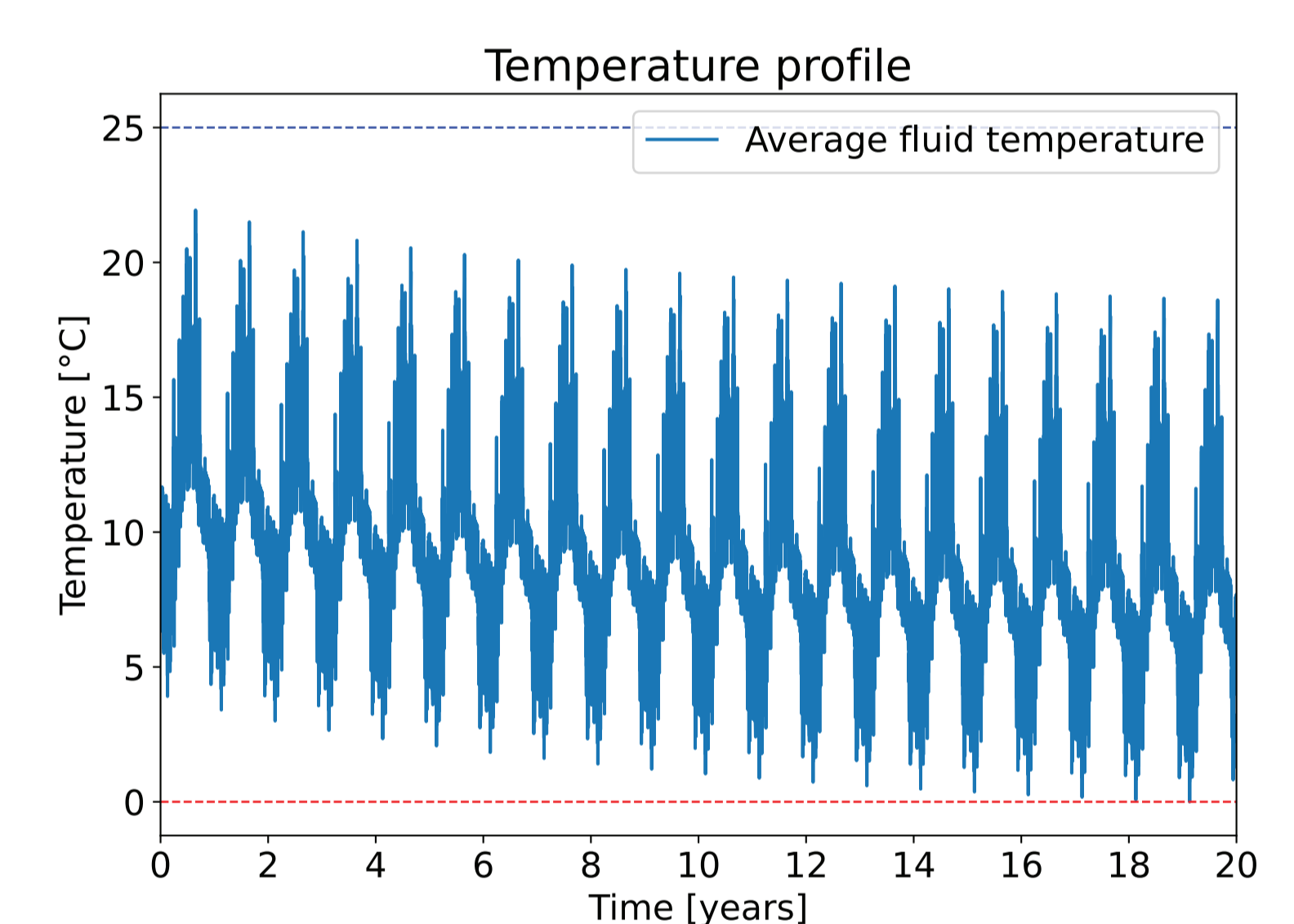
The goal of this research is to quantify the effect of designing with a variable COP (both temperature and part-load dependency) on both the required borefield size and the real efficiency of the heat pump.

BOREFIELD SIZING

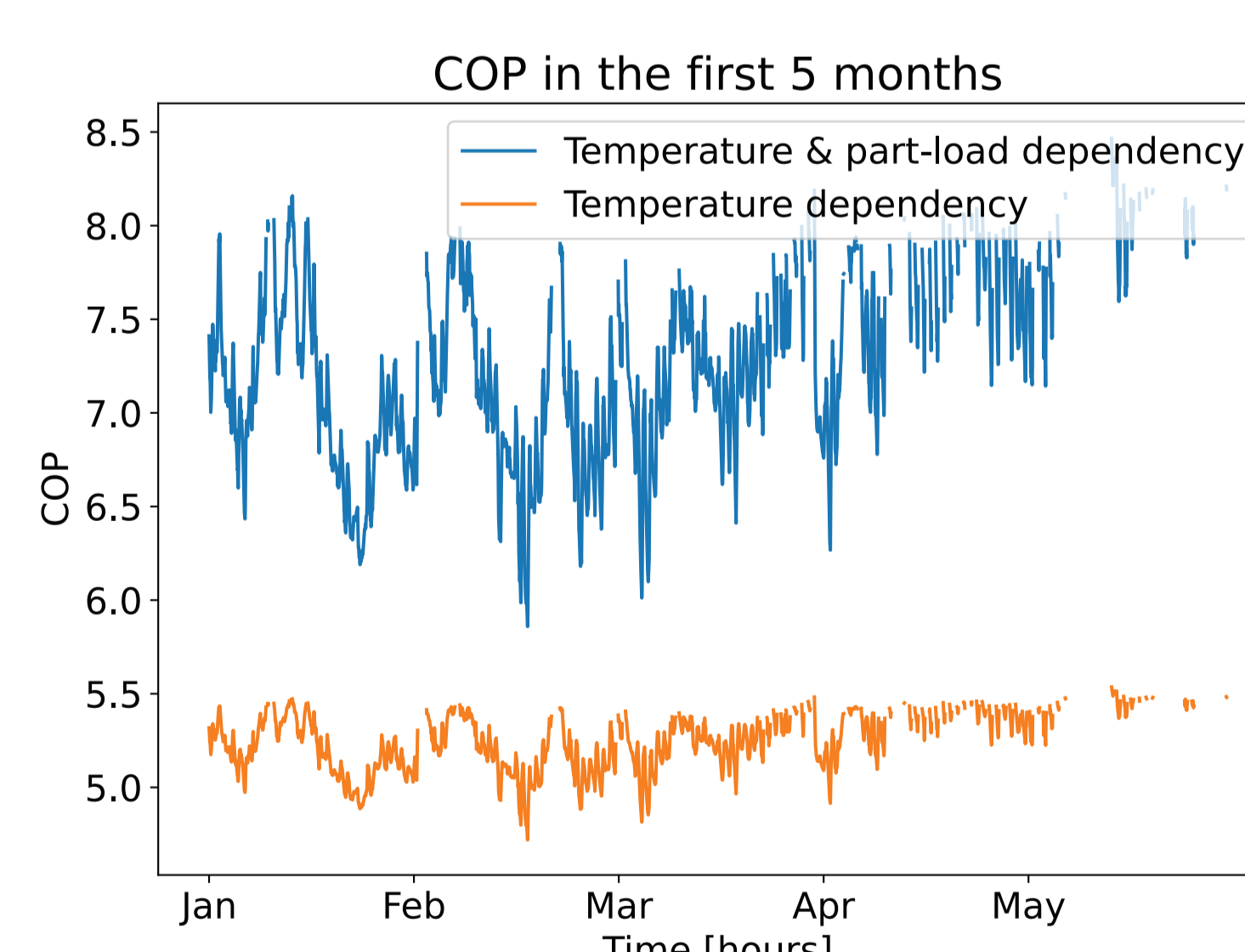
When the borefield is sized using the standard SCOP at B0/W35 of 4.86, the required borehole length to stay within the 0-25°C temperature range is 136 m.

When only the temperature dependency is taken into account, the required borehole length is 133 m, which is slightly less because the peak powers are no longer overestimated.

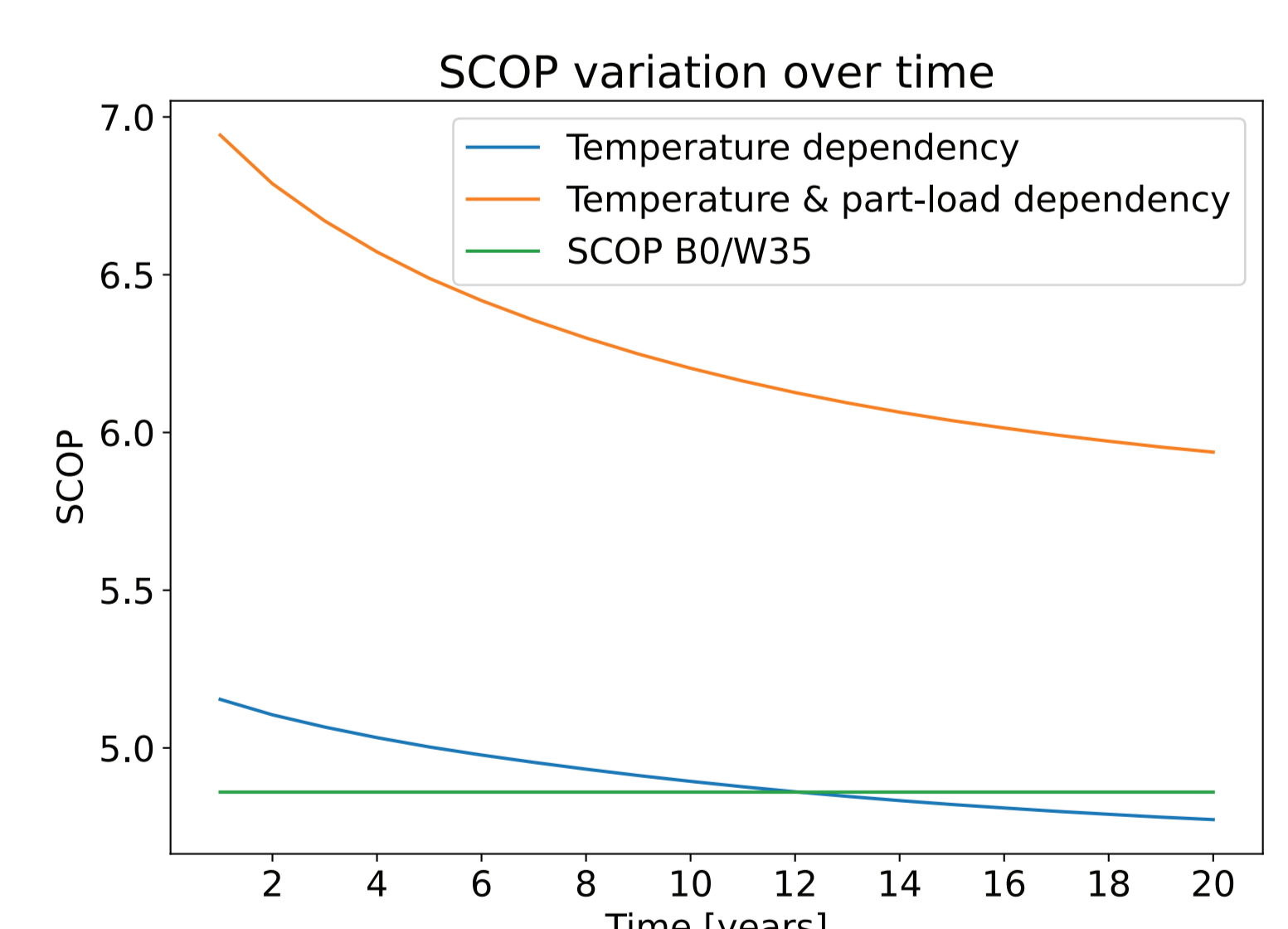
When the part-load dependency is also included, the required borehole length becomes 143 m, since the imbalance is now much more pronounced due to the higher SCOP.



EFFICIENCY OVER TIME



In the graph above, a zoom of the first five months of the simulation is shown. It is clear that the simulation which also includes the part-load efficiency has, on average, a higher value (since the heat pump often operates in part-load). Besides that, when you include the part-load dependency in your simulation, there is much more variation in the efficiency.



The graph above shows the SCOP evolution of the heat pump over the years (for the design with 143 m borehole length). When only the temperature dependency is included, the average SCOP is 4.9, almost the same as the B0/W35 value. With both temperature and part-load dependency, the average SCOP rises to 6.25, 29% higher than the official B0/W35. Both lines show a downward trend due to the imbalance.



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