Passive and active cooling for an office building

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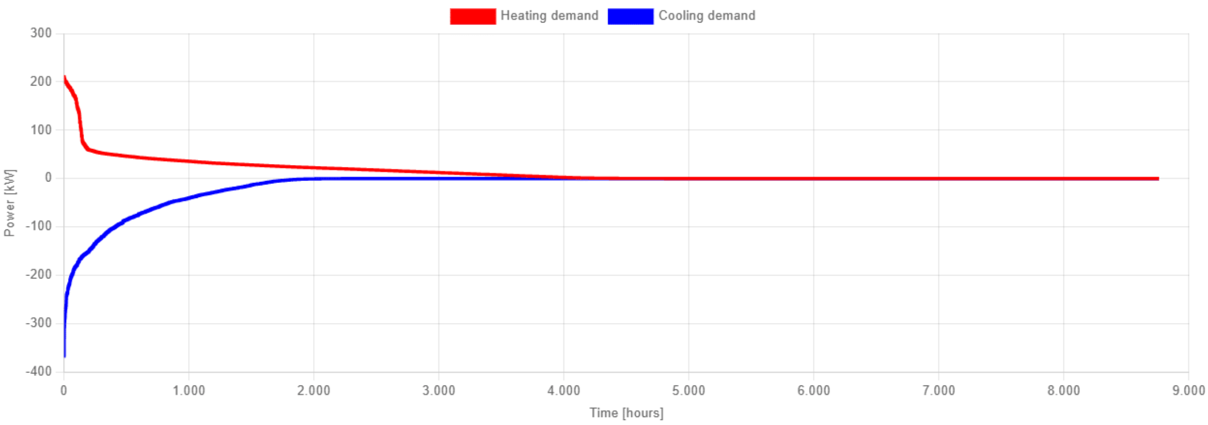
Combining passive and active cooling in your geothermal borefield allows you to take advantage of the best of both worlds. On the one hand, you can benefit from highly sustainable and efficient passive (or free) cooling, while on the other, you can reduce investment costs through an optimised active cooling design. This article demonstrates how you can use GHEtool to implement this intelligent combination!

> ***!Note***
> *This article builds on our previous article discussing the methodology of combining active and passive cooling. If you haven't read it yet, you can check it out here.*

Example: Office building

The figure below shows the load-duration curve of the office building we are going to study. As you can see, there is a significant cooling demand due to high internal gains, which are typical for office buildings (e.g. numerous computers, printers, network infrastructure, etc.). Additionally, the cooling demand exceeds the heating demand, resulting in an injection-dominated borefield.

> ***!Note***
> *If you are not familiar with injection- and extraction-dominated borefields and their implications, you can check out our article on borefield quadrants for a detailed explanation.*

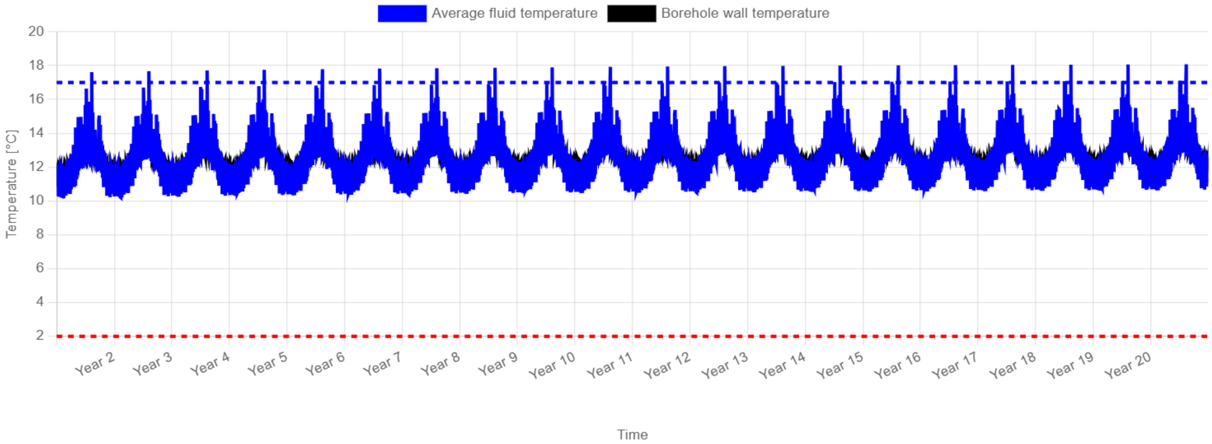


Load duration curve of the office building.

Sized for passive cooling

The first, let's say "ideal" situation from an efficiency perspective, is to size our borefield for 100% passive cooling. In this case, it looks like we need 130 boreholes with a borehole depth of 150 m to stay below our temperature limitation of 17°C for passive cooling. This gives us the temperature profile below.

> ***!Note***
> *The 17°C is a typical maximum average fluid temperature used for passive cooling. Since you lose 1–2°C across the passive heat exchanger, you cannot exceed this temperature if you want to provide the required cooling power for, for example, your floor cooling system. This, of course, depends on factors such as your emission system, required comfort level, condensation point of your air, and temperature differences in your hydraulic system.*



The hourly temperature profile when sizing the borefield for 100% passive cooling.

The temperature profile above does not always stay below the 17°C threshold we set. If we zoom in, it exceeds this limit for three hours per year. Given the inherent uncertainties of these types of profiles, one could argue that this is still a well-balanced design. Adding ten more boreholes just to cover this brief cooling peak would generally be economically undesirable in most situations.

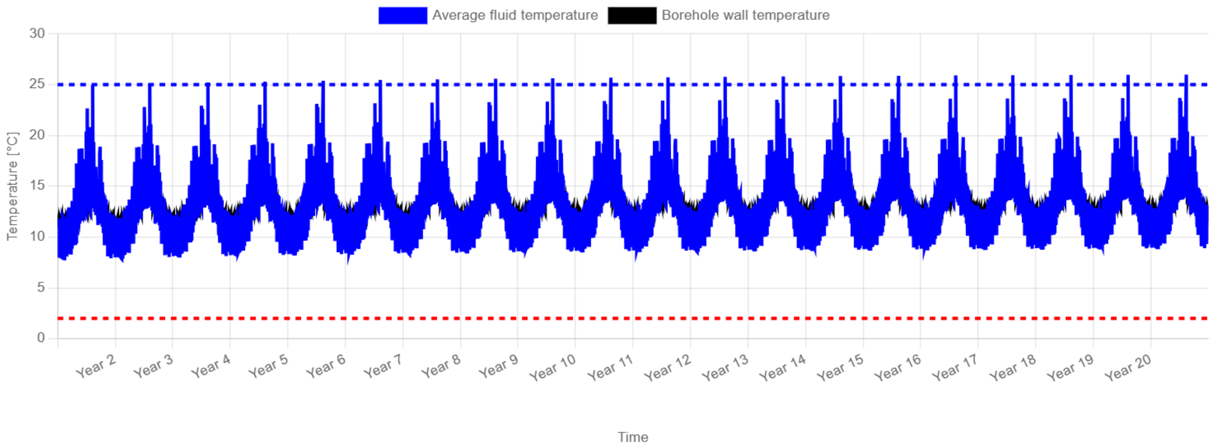
Another noticeable aspect is that the lowest average fluid temperature remains above 10°C, which is quite high for the climate region of Belgium. This indicates that the borefield is primarily sized to accommodate the cooling demand passively, resulting in significant oversizing from a heating demand perspective. We will therefore explore active sizing to reduce the required borefield size.

> ***!Note***
> *If you are unfamiliar with how to interpret such temperature profiles, you can visit our article on this topic here.*

Sized for active cooling

When we size the borefield for active cooling, the maximum average fluid temperature can increase, as we can now rely on the heat pump to provide the required cooling. By doing so, we can reduce the number of boreholes from 130 to 60, resulting in the temperature profile below.

> ***!Caution***
> *Although there is no technical limitation to the maximum average fluid temperature, it is advisable to keep it under control to prevent environmental harm. Please check local legislation for any restrictions regarding fluid temperatures.*



The hourly temperature profile when sizing the borefield for 100% active cooling.

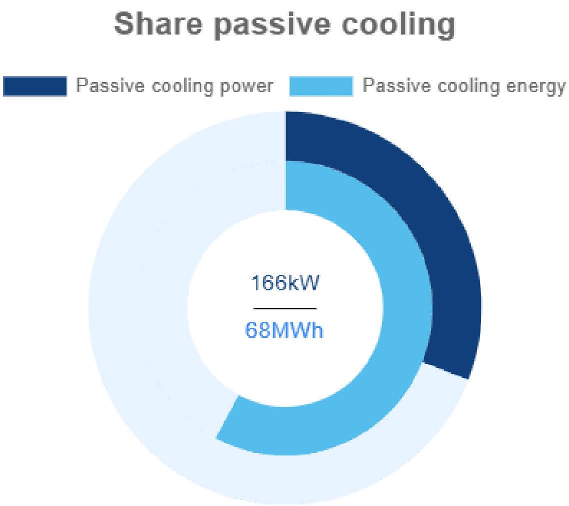
As one can see, the borefield now shows less geothermal potential in heating power. If you are not familiar with the concept of geothermal potential, you can read our article on the topic here. This results in a more efficient use of our investment.

Now that we have studied both extremes—100% passive and 100% active cooling—let us take a look at three designs that combine both approaches.

Threshold temperature with 60 boreholes

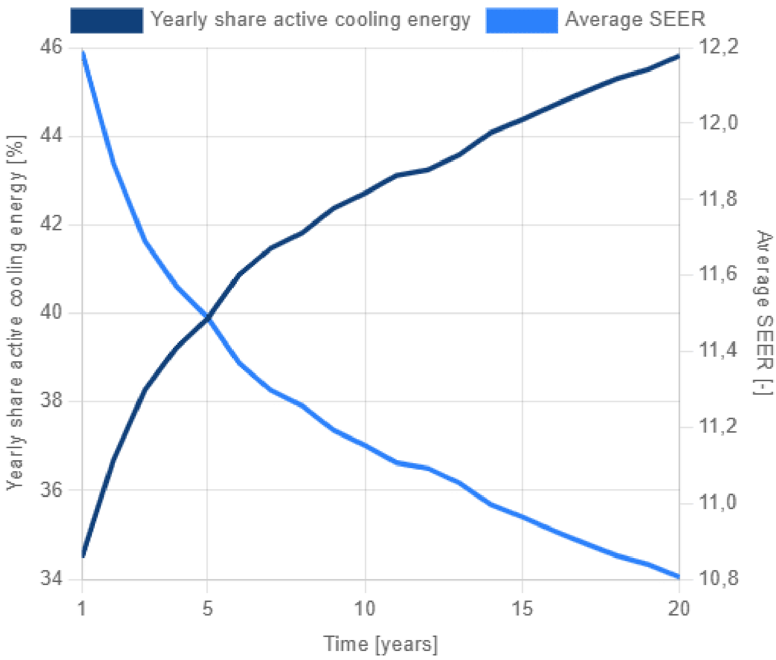
A good first step is to keep the same number of boreholes as in the 100% active design and check what percentage of the load can be met passively. To do this, we use the threshold temperature method (read the article here), setting it to 17°C. By applying this approach, we find that 58% of the cooling can be provided passively, resulting in an average SEER of 11.22.

> ***!Note***
> *This 58% is an average over the entire simulation period. In the first years, the share of passive cooling will be higher compared to the later years (see below).*



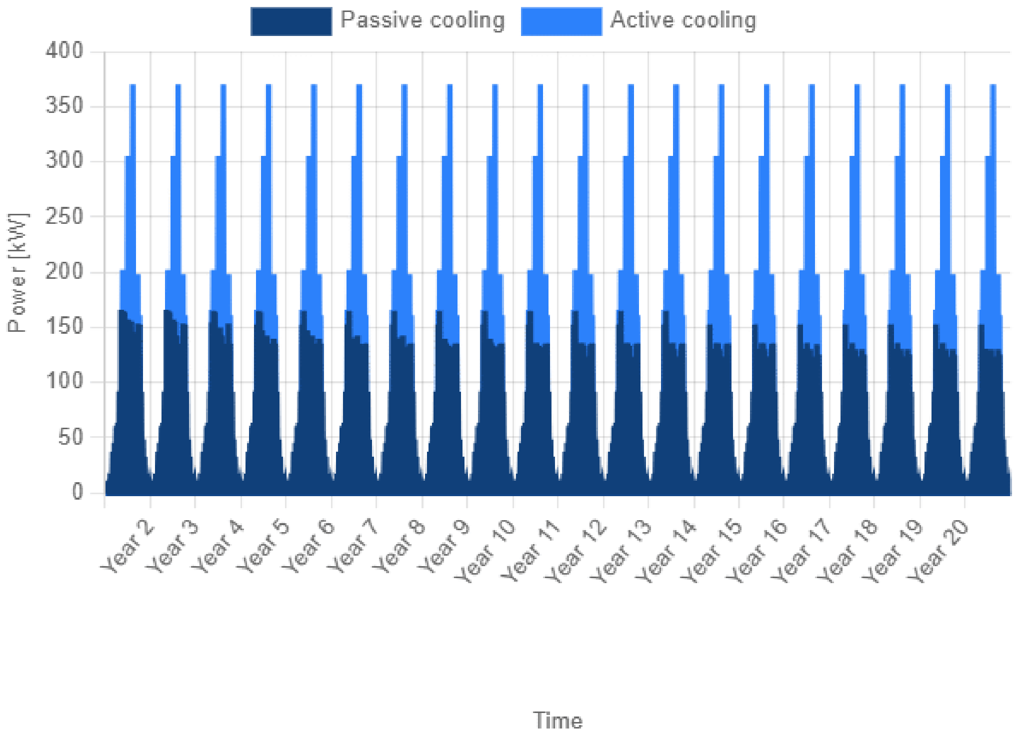
Share passive cooling for 60 boreholes. 58% of the cooling energy is passive.

If we take a closer look at the share of active cooling over the years, we can see in the figure below that it increases year after year. This is due to the imbalance. As mentioned before, this borefield is injection-dominated, meaning that it heats up over time, reducing the potential for passive cooling in the later years of the simulation period.



Evolution of the share in active cooling for 60 boreholes.

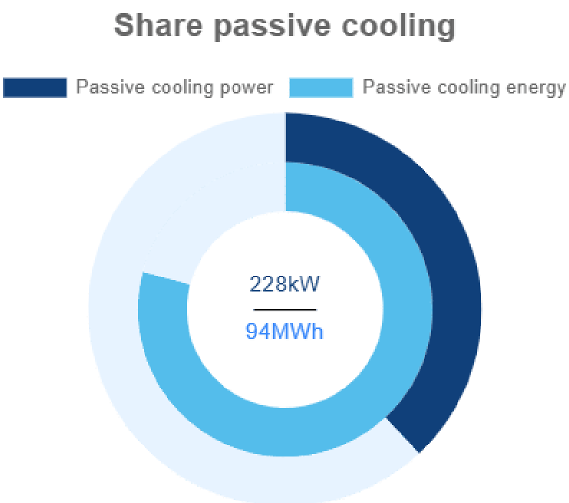
This effect can also be observed in the cooling demand profile below, where the share of passive cooling visibly decreases year after year.



Cooling profile for the 60 boreholes.

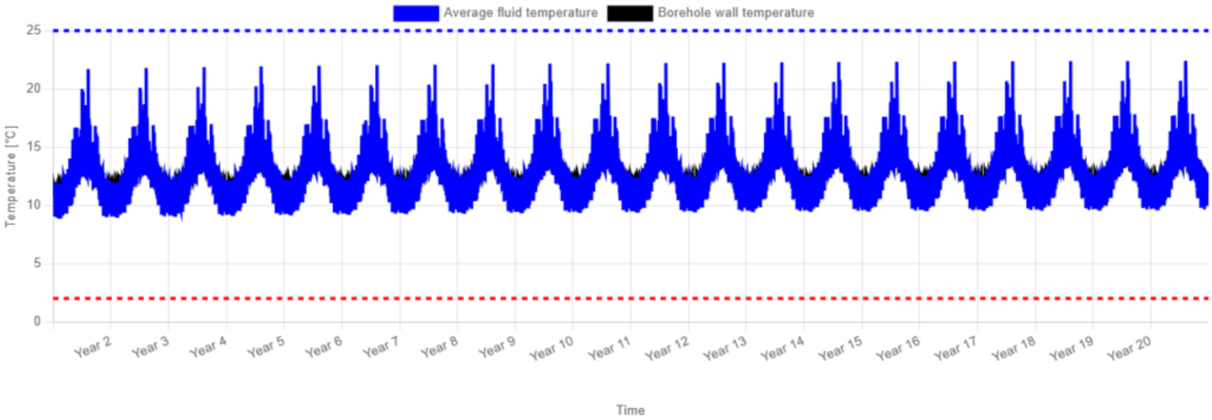
Threshold temperature with 80 boreholes

The 60 boreholes in the 100% active case provided 58% passive cooling. If we increase the number of boreholes to, for example, 80, we can observe the effect on the share of passive cooling. When we do so, we achieve 79% passive cooling and an average SEER of 14.41 over the entire simulation period. However, due to the geothermal imbalance, the share of active cooling will again increase year after year.



Share passive cooling for 80 boreholes. 79% of the cooling energy is passive.

When we take a closer look at the temperature profile below, we see that the average fluid temperature always remains below the 25°C limit set for active cooling. This is because we drilled 20 additional boreholes, which, from a strict design perspective, were not necessary since we are using both active and passive cooling. The fact that the average fluid temperature is lower than before explains why the share of passive cooling increases when more boreholes are installed.



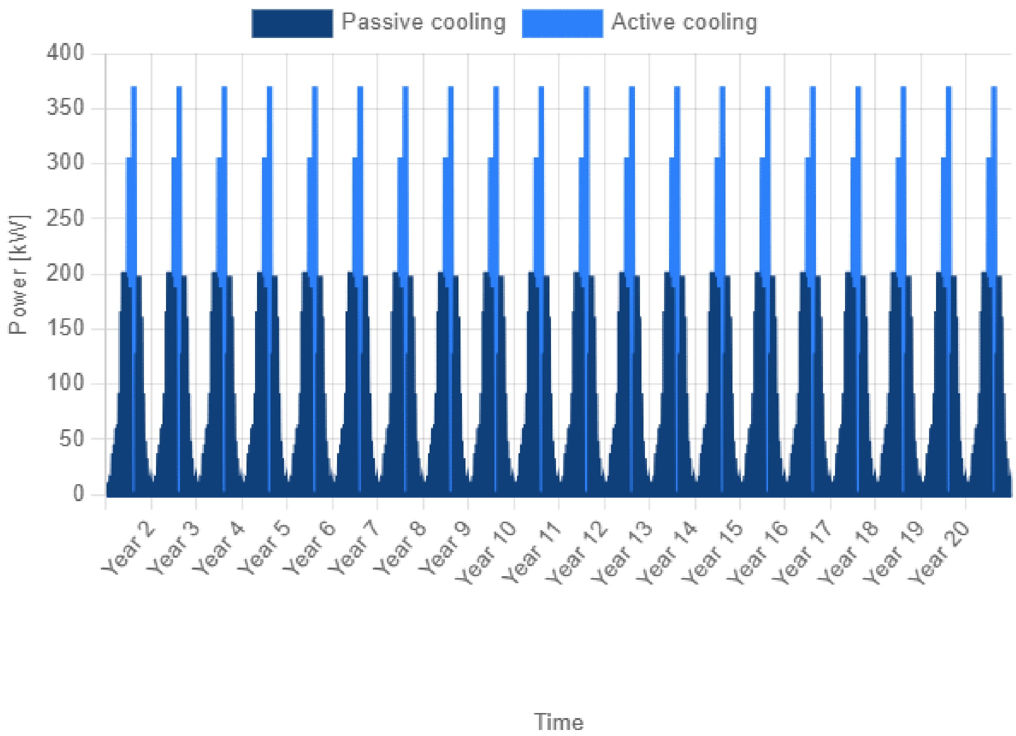
The hourly temperature profile for 80 boreholes when working with combined active and passive cooling.

Fixed months

An alternative to using a threshold temperature is to apply default active cooling during the summer months. Although this results in a lower passive share (as explained here), there can be valid reasons for choosing this approach, such as a simpler control strategy, a different cooling emission system, or the need for dehumidification.

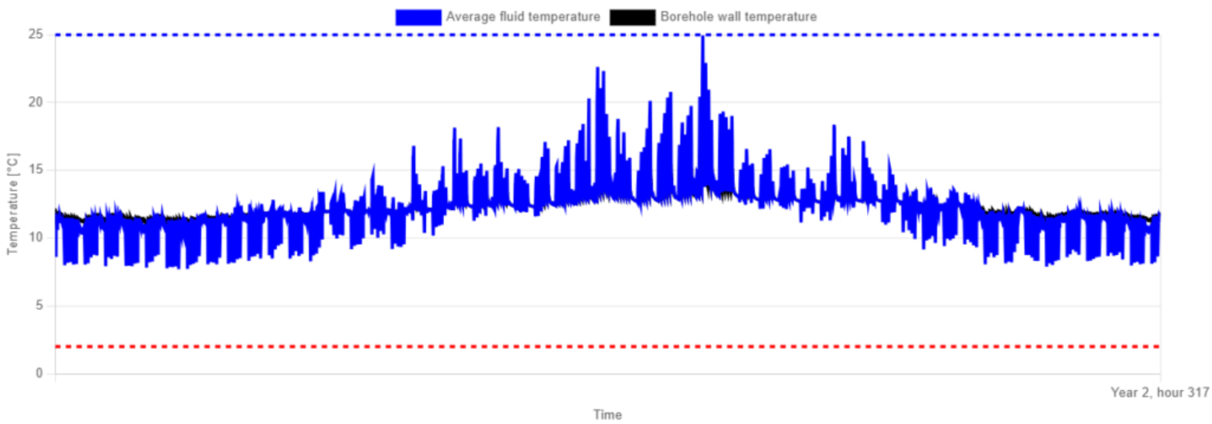
If we calculate the share of passive cooling using active cooling by default in July and August, we obtain a slightly lower average SEER of 10.53 and a passive cooling share of 52% for the same 60 boreholes (compared to an SEER of 11.22 and 58% when using the threshold temperature method).

The difference in geothermal share becomes evident when examining the cooling profile. Below, you can see that there is no passive cooling during the summer months, whereas in the threshold temperature case, some passive cooling was still present. This is an inherent inefficiency of the fixed-month method.



Cooling profile for the 60 boreholes using default active cooling in July and August.

One final note regarding this method is that you cannot be entirely certain that passive cooling in the non-default months (for example, June and September in this case) can actually be provided. When we take a close-up look at the temperature profile for the first year, we can already see a few fluid temperatures in May, June, and September exceeding the 17°C threshold. This suggests that the required cooling power at these moments may not be fully delivered, which is an important consideration to keep in mind.



Close-up of temperature profile for the first year.

Conclusion

This article discussed the design of a borefield for an office building using passive, active, and combined passive and active cooling. Switching from 100% passive to 100% active reduced the number of boreholes from 130 to 60, but it was found that around 58% of the cooling could still be provided passively. Increasing the number of boreholes to 80 resulted in a passive share of 79%. Using the fixed-month methodology led to slightly lower results than the threshold temperature method, with a passive share of 52%. Although simpler to implement in practice, this approach required extra caution in the non-active months.

References

- Watch our video explanation over on our YouTube page by clicking here.