Hybrid systems (part 1): Geothermal potential

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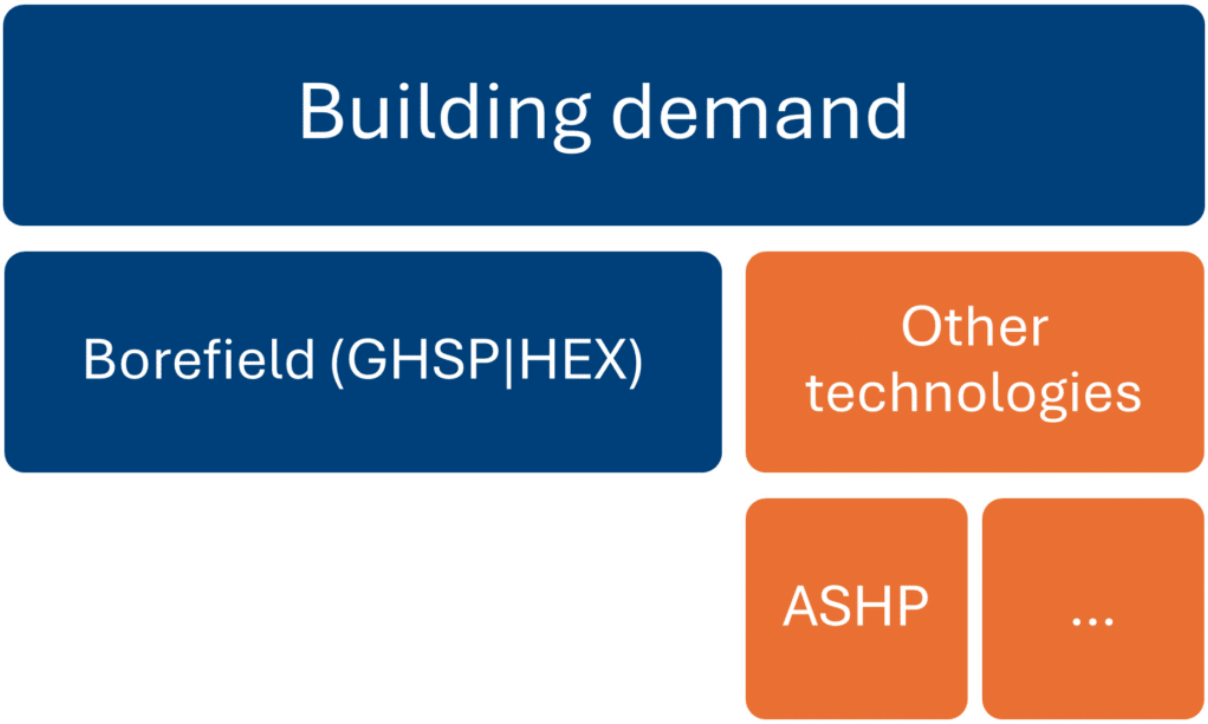
Hybrid systems offer a promising way to handle the growing challenges of geothermal projects. But what exactly are they? And how does this idea connect with geothermal potential? This article is the first in a series about hybrid geothermal system design, where we will explore the benefits and secrets of these systems. In this first article, we explain the basics of hybrid systems, their advantages, and how they relate to geothermal potential.

What are hybrid systems?

For large projects—such as multi-utility buildings or 5th generation district heating networks—the heating and cooling needs are often very high. To meet these demands using geothermal energy alone, you may need a large borefield. However, this raises important questions:

- Is there enough space to install the borefield?
- Can the budget cover the cost of so many boreholes?
- Is a fully geothermal solution the best option, or are there more cost-effective alternatives?



A hybrid geothermal system could be the solution. By adding other technologies—like an air source heat pump (ASHP)—to the borefield, you create a hybrid system where multiple technologies work together to provide heating and cooling. The combination of technologies depends on several factors: the building's heating and cooling needs, available space (e.g., for installing an ASHP on the roof), and existing systems (e.g., a gas boiler in renovation projects).

Advantages of a hybrid system

Hybrid systems are sometimes the only practical option—for instance, when space for a borefield is limited. However, they also bring other advantages.

Lower investment costs: Hybrid systems let you combine the strengths of different technologies to save money. Some technologies have lower upfront costs but higher operating costs, while borefields are often the most expensive part of the system. For example, reducing the borefield size by 10% with a hybrid design can significantly lower capital expenses (CAPEX) and make the project more affordable.

Increased system reliability: By using multiple technologies, hybrid systems provide a natural backup. If one part fails, the other can still handle the building's needs.

> ***!Note***
> *The design of backup systems is a separate design consideration. Typically, more than 100% of the required power to heat or cool your building is installed. This ensures that, if something goes wrong (or if heating and cooling needs have been underestimated), the system can still deliver the required load.*

Designing a hybrid system

A key decision in designing a hybrid geothermal system is figuring out how much of the heating and cooling load the borefield should handle. Should it be the main source, or should it share the load equally with another technology? The main question becomes: **What geothermal share can I achieve with a certain number of boreholes?**

This question is closely related to the concept of geothermal potential.

What is geothermal potential?

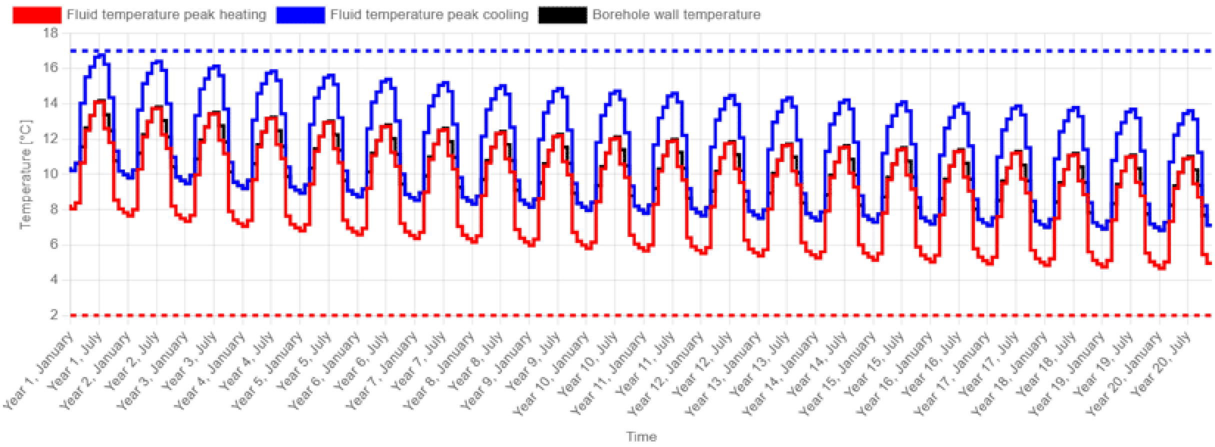
When it comes to geothermal potential of a borefield, we can make three distinctions:

1. **Potential for power:** The ability to provide more peak heating or cooling.
2. **Potential for energy:** The ability to exchange more energy with the ground over time, even if peak demands are already met.
3. **No geothermal potential:** When the borefield is already operating at its full capacity for both power and energy.

Geothermal potential for power

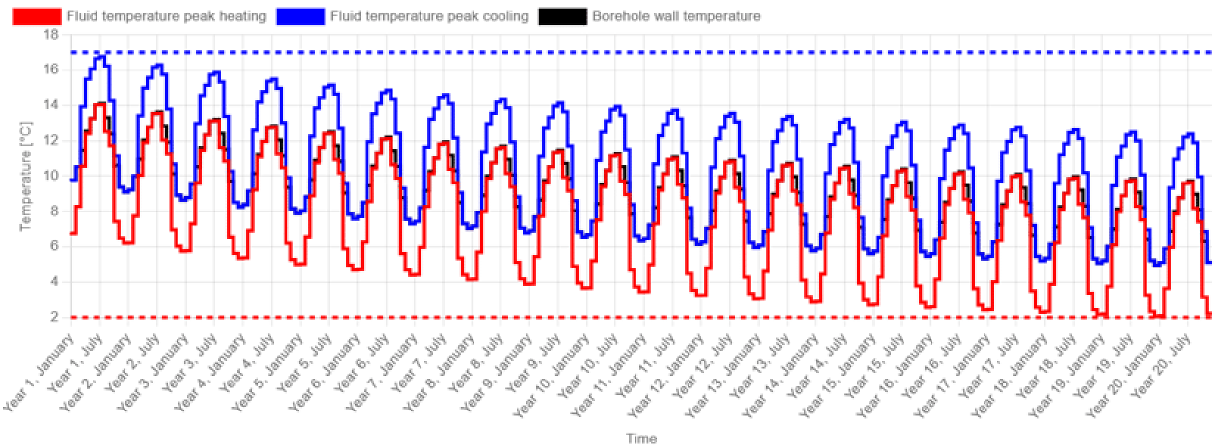
Imagine we have a borefield with a temperature profile like the figure below. As you can see, the borefield reaches its limitations in the first year of operation with the maximum average fluid temperature. It is not possible to inject more heat into the ground (i.e., cool your building further) at this point, as this would exceed the temperature boundaries. Looking at the minimum fluid temperature, we see that it does not come close to the minimum average fluid temperature. This means we can extract more heat from the ground and provide our building with additional heating power. Therefore, we can conclude that this borefield has **potential for power**.

> ***!Note***
> *If you're unfamiliar with temperature profiles, check out our detailed article on the topic here.*



Geothermal potential for energy

If we do so, we end up with a borefield like the one shown in the figure below. As you can see, we now reach both the maximum and minimum temperature thresholds, making it impossible to add more cooling or heating power onto the borefield. This is because we are already constrained by both the peak heating and cooling limits. However, this limitation only occurs in the first year for peak cooling and in the last year for peak heating. In the earlier years, there is still potential to extract more heat from the ground, while in the later years, there is potential to inject additional heat.



If we were to install additional geothermal power onto this borefield, we could exchange more energy with the ground, but we would not be able to extract more power during peak periods. This is why we say that this borefield has **potential for energy** but not for power, as the peak power already reaches the temperature limitations.

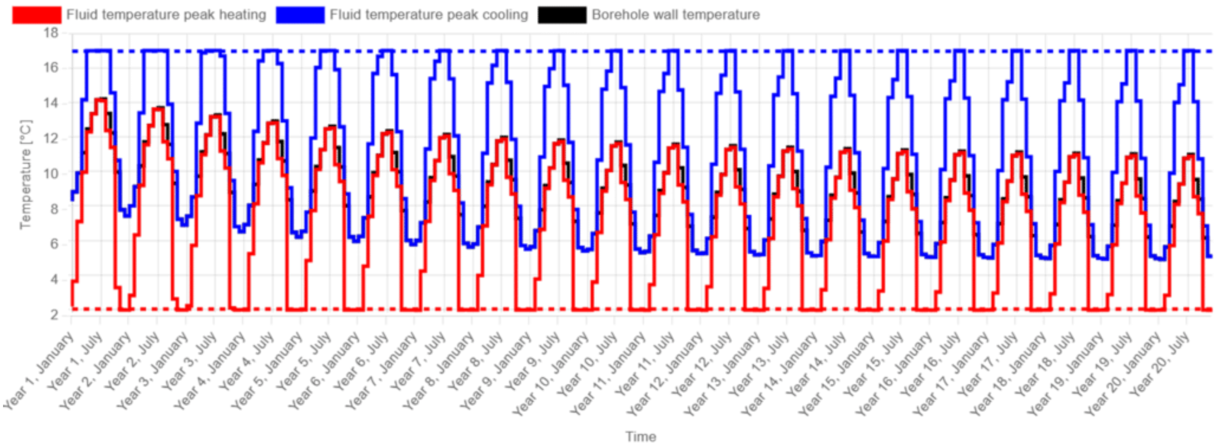
!Note

In some cases, as shown above, installing additional cooling power to inject extra heat into the borefield during later years could also increase the geothermal heating power. By injecting more heat into the ground, we correct the imbalance in the ground, thereby creating additional potential for heating. In such a scenario, the borefield would revert to the previous category, regaining some potential for heating power.

However, since this would be considered a "second-order" effect, it is typically neglected in the naming convention. As a result, we classify this borefield as having no potential for additional peak power but as having potential for extra energy exchange.

No geothermal potential

The last case we can have is the situation below. As you can see, we have installed some extra power for this borefield so we can provide our building with some more cooling in the later simulation years and some extra heating in the first years of operation. Since the borefield now reaches the temperature limits in every month, we conclude that **this borefield has no geothermal potential, not for energy not for power**.



!Note

Strictly speaking, one can argue that there is still some potential left for this borefield, since the maximum average fluid temperature threshold is not reached during winter and some spring months. In order to achieve this, you would have to change the building demand or connect another building to the borefield. This however falls outside the scope of this article.

Relation between hybrid systems and geothermal potential

How does this relate to hybrid systems? As mentioned earlier, the central question in hybrid geothermal design is: What share of the load can I cover with x boreholes? The answer is simple: it depends. It depends on your geothermal potential and how you choose to optimise your borefield.

Hybrid systems with some remaining geothermal potential for energy

One possibility is to design the borefield so that there is no potential for power left, but some potential for energy remains (the second situation described above). In this case, you know that a specific amount of power can be reliably extracted during every year of the simulation period. The hybrid system can then be designed to cover the remaining portion of the load. This approach ensures a system that covers 100% of the load with zero oversizing, minimising investment costs (CAPEX).

The drawback of this design is that it does not utilise the borefield's full energy potential. By installing additional power, more energy could be exchanged with the ground. Since the GSHP (and especially passive cooling) typically has the highest efficiency within the HVAC system, not leveraging its full potential results in suboptimal efficiency. Consequently, operational costs (OPEX) will be higher than necessary.

Hybrid systems with no geothermal potential remaining

The other possibility is to design the borefield so that no energy potential is left (the third situation described above). In this case, more power is installed than can be utilised in every year of the simulation period. This approach maximises the energy exchanged with the ground, fully utilising its potential and leaving no geothermal capacity unused. It ensures the highest share of geothermal energy in the system, leading to the best overall system performance and the lowest OPEX.

The downside of this approach is that the installed power cannot always be fully utilised, requiring compensation through the hybrid system. This results in a system with more installed power than the building actually needs, leading to higher investment costs due to oversizing.

> ***!Note***
> *Oversizing is not always a disadvantage. In some cases, additional backup power may be desirable, providing extra reliability for the system.*

Conclusion

In this article, we introduced the concepts of hybrid systems and geothermal potential. We demonstrated that borefields can have either geothermal potential for power, geothermal potential for energy, or no geothermal potential. These concepts were then linked to the design of hybrid geothermal systems, where the decision to design a system with remaining energy potential or no potential at all leads to different investment costs (CAPEX) and operational costs (OPEX).

In the next article, we will explore these two concepts further and discuss the methodology for designing a borefield to achieve one type of geothermal potential or the other.

References

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