Hybrid systems (part 2): Design methodology

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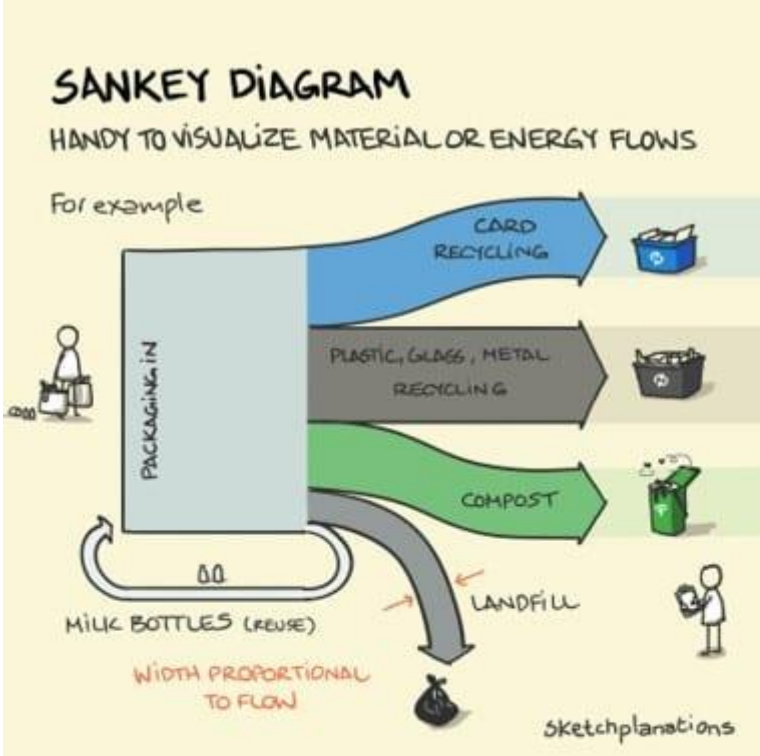
Sankey diagrams are ideal for visualising how things flow through a system—whether it's money, materials, or energy. That's why we've added them by default as a result in every GHEtool Cloud simulation. Read the article to learn more about the insights you can gain from these diagrams.

What is a Sankey diagram?

Sankey diagrams were originally developed to explain the efficiency of steam engines. They illustrate how the inputs of a system are connected to its outputs and can therefore be used to visualise interesting dynamics within the system. Although they were developed in the context of thermodynamics—where they are still frequently used—they have since found their way into economics, international collaboration and trade, and now, as of today, into geothermal engineering as well! Below is a sketch of a Sankey diagram for material use.



Sketch of a Sankey diagram (source: https://sketchplanations.com/sankey-diagram)

Every Sankey diagram should be read from left to right, moving from input to output. In the example above, all the packaging materials are inputs to the diagram and can be separated into multiple streams: cardboard, plastic, compost, and landfill.

!Note
The example above also includes a return flow of 'milk bottles'. This creates a cycle in the graph, which is typically avoided (although not strictly forbidden). In GHEtool Cloud, all Sankey diagrams are Directed Acyclic Graphs (DAGs), meaning they strictly flow in one direction.

An important aspect of any Sankey diagram is that the total input must always equal the total output. This ensures that no material, energy, or other quantity is lost or created within the diagram itself.

Before we take a closer look at how these diagrams are represented in GHEtool Cloud, we first need to introduce the concept of Seasonal Thermal Energy Storage (STES).

Seasonal thermal energy storage (STES)

When we talk about shallow geothermal borefields, we refer to using the ground as a heat battery rather than as a source. Unlike deep geothermal applications—where heat is harvested for industrial processes, electricity generation or district heating—borefields are typically used in scenarios where there is both a heating and cooling demand.

In summer, heat is stored in the ground, to be used later by the ground source heat pump (GSHP) during winter to heat the building. This extraction cools down the ground, making it suitable for (passive) cooling.

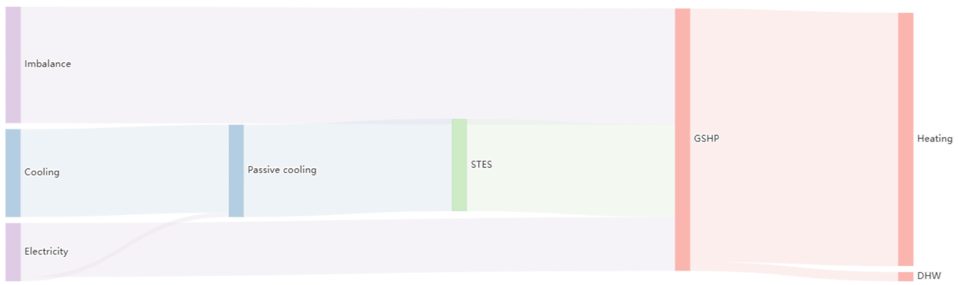
Ideally, the energy the GSHP extracts from the ground comes entirely from the stored energy from summer. However, in many cases there is an imbalance, meaning the stored energy is not sufficient to cover the full heating (or cooling) demand. In such cases, the ground is partly used as a source as well.

Both of these heat sources—the Seasonal Thermal Energy Storage (STES) and the imbalance—are shown separately in the Sankey diagrams.

> ***!Note***
> *If you are not familiar with the concept of imbalance, you can read about it in our article here.*

Sankey diagrams in GHEtool Cloud

Every calculation in GHEtool Cloud will from now on also be visualised using a Sankey diagram. Although the appearance of these plots may vary depending on the specific design, the main colour scheme will always remain the same. A first example, showing a borefield with a negative imbalance, is provided below.

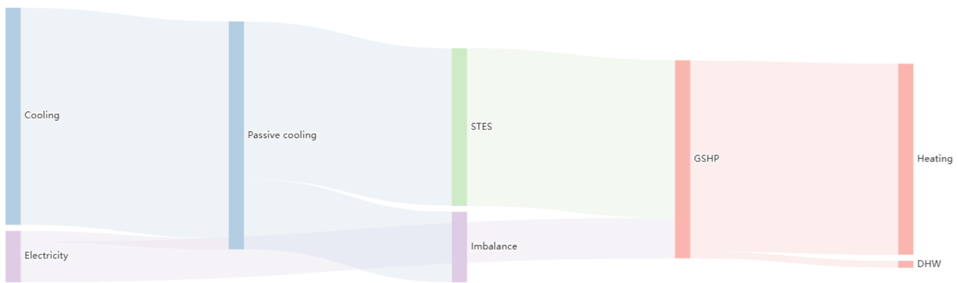


Sankey diagram for a borefield with negative imbalance.

Every such diagram in GHEtool Cloud consists of four different colours:

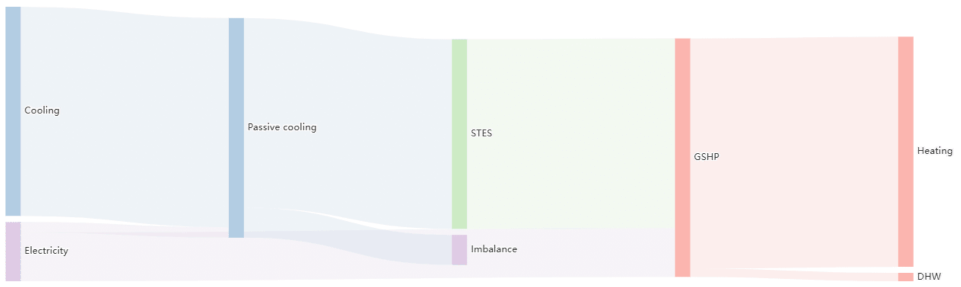
- Red/orange – represents everything related to the 'hot side' of the system, including heating and domestic hot water (DHW).
- Blue – represents everything related to the 'cold side' of the system, such as cooling.
- Purple – indicates all interactions with the environment, which can be considered input streams. This includes the electricity required to run the heat pumps, as well as the ground imbalance, which is one of the two inputs for the GSHP.
- Green – represents the Seasonal Thermal Energy Storage (STES), the other input for the GSHP.

When you have an injection-dominated borefield, the nature of the imbalance is reversed. This is illustrated in the following image.



Sankey diagram for a borefield with positive imbalance.

In the case of a positive imbalance, the imbalance is no longer a source but a sink within the total system. This means that part of the STES potential is effectively lost to the environment. Ideally, you want a borefield that is close to balanced, as shown in the figure below. In this case, the contribution from STES is significantly greater than the imbalance, resulting in the most efficient solution.

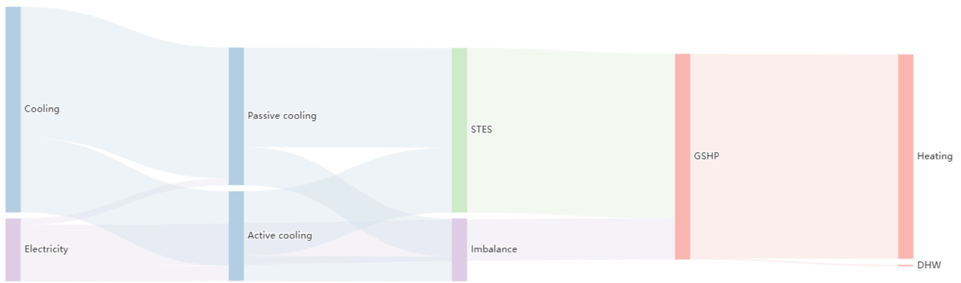


Sankey diagram for an almost balanced borefield.

This Sankey diagram can also be used to gain insight into the more complex simulations in GHEtool. These are shown below.

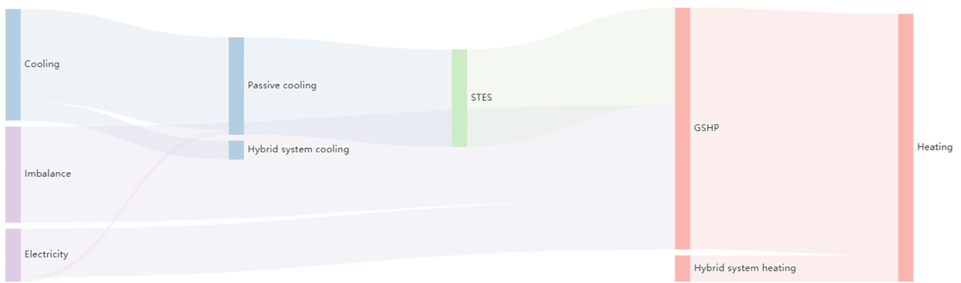
Further examples

Instead of relying entirely on passive cooling, you can also combine both active and passive cooling on your borefield (read [this article] for more information). When this is the case, the cooling demand is distributed between the passive and active components, as shown in the figure below.



Sankey diagram for a borefield with active and passive cooling.

Both passive and active cooling require electricity and contribute energy to both the STES and the imbalance (as the borefield is again injection dominated). In addition to combining active and passive cooling, one can also opt for a hybrid system.

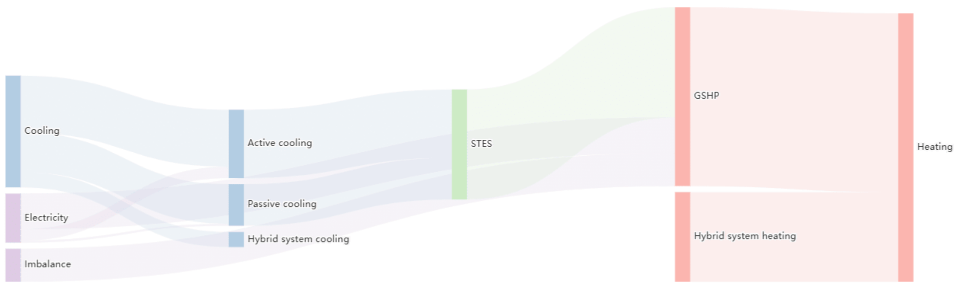


Sankey diagram for a borefield with a hybrid system.

When a hybrid system is designed, part of the heating and cooling will come from your hybrid technology. This is shown in the figure above.

> ***!Note***
> *Due to the black-box nature of the optimise load profile methods—where no assumptions are made about which technologies are used—these hybrid systems for heating and/or cooling do not consume electricity, as they could, for example, be powered by waste heat or other sources. In a future update, more specificity will be added to these hybrid systems so the Sankey diagram can be more detailed and tailored to the specific hybrid solution you've designed.*

Finally, as a last example, it is possible to combine all the different options into one main Sankey diagram, as shown below.



Sankey diagram for a borefield with active and passive cooling and hybrid system.

Conclusion

This article introduced a new type of result in GHEtool: Sankey diagrams. These flow diagrams provide insight into how energy is transferred between different parts of the system, the significance of Seasonal Thermal Energy Storage (STES), and how much we rely on external resources such as electricity, hybrid systems, or the imbalance.

We hope this additional graph, now included by default in all your simulations, will help you design borefields with confidence!

References

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

Check out GHEtool today at:
https://ghetool.eu