

English Manual

*Interference Tool Groundsource Borehole
Energy Systems (ITGBES.com)*

1. Introduction & History

In 2013 legislation was introduced in The Netherlands concerning the design, installation, and operation of Ground Source Heat Pump (GSHP) systems using Borehole Heat Exchangers (BHE). Since then, it is common practice to calculate and document potential long-term thermal effects between all systems within a radius of 120 meters of each other. Obtaining a clear outlook on how intended systems might interact with each other, gives the designer the opportunity to account for these (potentially negative) thermal effects beforehand.

The ITGBES.com Excel-tool was created to support the assessment of thermal interactions between individual ground source heat pump systems. In 2013 a first version of the tool was introduced, based on tables and nomograms. In 2019 an automated tool was developed in Excel, and made available freely to the Dutch industry and regulators, imbedded as part of the Dutch protocol for ground source energy systems as a 'de facto' calculation tool (SIKB, 2020).

ITGBES was developed by Groenholland, and is based on an implementation of the Finite Line Source (FLS) solution. This widely used method can yield temperature effects at a certain distance from a point source extracting (or adding) energy within a medium. By considering individual BHE in a cluster as a collection of such point sources, one can determine the cumulative temperature effect at the location of each point, caused by the presence of the others, without considering the temperature effect on the borehole wall of the local system itself.

For the construction of the ITGBES Tool a large number of individual scenario's was pre-calculated using the advanced FLS-based ITGBES-PRO tool developed by Groenholland. These results were summarized as correlation coefficients of a second-degree polynomial function. This methodology allows for a fast and easy way of calculating the cumulative effects using a simple, small sized (<300 kB), Excel-sheet requiring only minimal input from the user.

Over the years ITGBES has proven itself not only as a very useful regulatory tool, but also as a valuable design tool allowing optimization of GSHP system design.

ITGBES as design support tool

Conventional design software programs (such as Earth Energy Designer, Blomberg et al. 2019) allow the design of collective borehole heat exchanger systems, where one energy demand profile is distributed equally over all individual boreholes, of equal length and which all have equal flow temperature. However, in practice often multiple systems are designed, each with their own heat pump, with varying energy profiles and different borehole heat exchanger geometries. ITGBES, which calculates actual temperature effects between these systems, can then be used for the design to provide the input for adjusting the temperature goal in the preferred design software (e.g. EED) to account for the thermal interactions of different systems (Witte, 2022).

2. Input parameters and limits

The parameters that are required to be entered by the user are the following:

| Parameter | Limits on input |
|--|--|
| Average thermal conductivity of the activated ground | Value should be ≥ 1.5 and ≤ 3.5 W/mK (2.0 in demo) |
| Number of systems in calculation | Max. number of systems is 10 (5 in demo) |
| Spatial position of all systems, given by X and Y coordinates. | Coordinates should be given as numbers. Distance between coordinates should be ≥ 5 m. |
| Size (depth of boreholes in m) and total length (amount of boreholes x depth) of the system. | Borehole depth should be ≥ 20 and ≤ 500 m Total length / by depth (quotient) should be ≤ 6 |
| Yearly energy demands of the building and efficiencies of the heat pumps. | Specific energy exchanges should be ≤ 240 kWh/m/yr Efficiencies should be ≥ 1.0 |

Furthermore, the following points of interest should be noted with regards to the input data for ITGBES:

- *Average thermal conductivity of the activated ground volume:*

When dealing with neighboring boreholes of different depths, the thermal conductivities relevant to the borehole trajectories might also differ per system, because different lithologies are present at different depths.

In such cases, it is best to take the thermal conductivity of the average depth of all regarded systems as the input value for the calculation.

- *Spatial position of all systems, given by X and Y coordinates.*

ITGBES uses a single (average) BHE coordinate for each system. It is not possible to assign multiple borehole positions to a single system. If your system is composed of 6 or less boreholes you can enter the average position of these boreholes to obtain relatively accurate results. For larger systems (>6 boreholes) the ITGBES tool will no longer be able to give accurate temperature responses since the methodology making use of a single coordinate cannot be reliably applied to these larger systems. In cases such as these, the advanced ITGBES-PRO tool is available, allowing accurate calculation of temperature effects.

The coordinates represent the spatial relation between boreholes and do not necessarily need to be from a specific reference system (e.g. National Coordinates) and can even be given as negative values. It should be noted however, that the tool coordinate unit is in meters, and therefore the distances will also be calculated in meters (e.g. distance between points with identical X-coordinates and Y-coordinates of respectively 1000 and 1010, will be calculated as 10m).

- *The size (depth of boreholes) and total length (amount of boreholes x depth) of the system*

As was noted above, ITGBES uses a single BHE location for each system, but can be used for GSHP systems that in reality will have up to 6 boreholes. When dealing with systems with more than one borehole ITGBES does require that all boreholes have the same depth (total length / depth = whole number). If you designed a GSHP system with for example 4 BHE's of slightly varying depths (e.g. 1x 90m, 2x 100m and 1x 95m) it is best to fill in the total length of all boreholes (385m in this case) and calculate and use the average depth per borehole as input (96.25m in this case).

- *Yearly energy demands of the building and efficiencies of the heat pumps.*

The energy demands are subdivided into space heating, domestic hot water and cooling. Values generally need to be filled in for the building side of the system accompanied by the efficiencies of the heat pump for these operating conditions. If (one of) the demands are only known for the ground side of the system (loads on the ground), you can also fill in those numbers accompanied with a very high value for the efficiencies (e.g. 10000).

3. Fixed boundary conditions and general notes

A certain set of input parameters required by the calculation have been set as fixed, these are as follows:

- Simulation time: 25 years
- Volumetric heat capacity of the activated ground volume: 2.4 MJ/m³/K

In the more advanced ITGBES-PRO tool these parameters can be freely adjusted to match actual values for a more specific case.

Other general points that should be considered when using ITGBES:

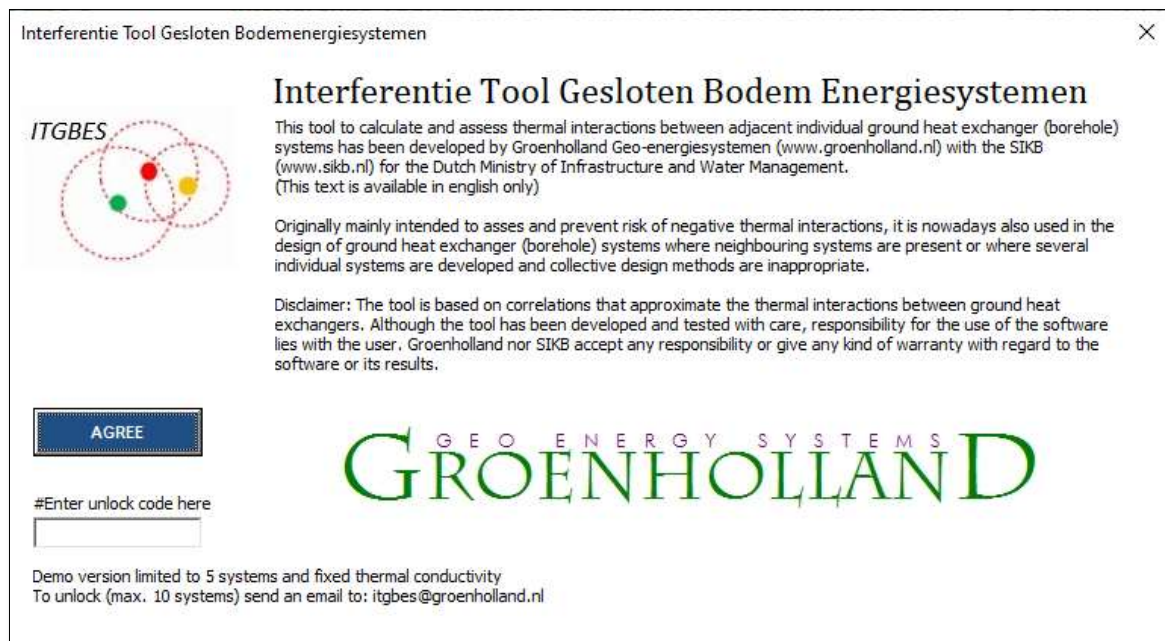
- ITGBES assumes that all individual systems have a complete vertical overlap with each other. The tool therefore is generally not suited for situations where you have very deep (e.g. > 200m) and very shallow (e.g. <50m) borehole heat exchangers right next to each other, since it might overestimate the effects of the shallower boreholes on the deeper boreholes.
- ITGBES does not account for effects of local groundwater flow on the lateral distribution of the long-term thermal effects around neighboring boreholes. When dealing with a location where a substantial effect of groundwater flow can be expected, it is best to use a more applicable modelling package.

4. How to start using ITGBES

The Excel-file "ITGBES.com.xlsm" will be present on your new memory stick along with this manual. When opening the tool, a splash screen (Figure 1) will be shown where you will have to click on "Agree". Initially the tool will be limited to a number of 5 GSHP systems per calculation and a soil thermal conductivity of 2.0 W/mK.

In case you would like to be able to use the tool up to the maximum limit of 10 GSHP, you can send an email to the following address: itgbes@groenholland.nl to receive a code to unlock your Excel-sheet to allow 10 systems and different soil thermal conductivities.

Figure 1. Splash screen ITGBES Tool



This code can then be entered in the box in the bottom left corner of the splash screen before you click on "Agree" the next time you make use of the tool, and from that moment onwards the tool is usable up to 10 systems (you do need to save the Excel-file at least once after having entered the code).

5. User interfaces

The ITGBES Excel-sheet has four different tabs. In the following section it is explained for each tab what the functionalities are.

- **TAB Project data (Figure 2)**

This tab is where all the inputs as explained in paragraph 2 need to be entered. A clarification regarding the inputs is given at the bottom of this tab. In the main horizontal bar at the top you can fill in the average thermal conductivity of the ground as well as the number of systems in the calculation. In the rectangular block below this main bar, the relevant input data of all the systems can be entered, where each column represents an individual GSHP system.

The values that are calculated automatically for each system based on your input, are the net demands on the ground for heating (DHW and space heating) and cooling in MWh/year, along with the specific energy extraction and injection in kWh/m/year. All these values are presented from the perspective of the ground (negative numbers correspond to extracting energy from the subsurface, positive numbers correspond to adding energy to the subsurface).

Once you are done with filling in the required input you can press the **“Calculate”** button in the main horizontal bar at the top. This will perform the calculation of the thermal effects and will make the screen jump to the tab *‘Report’*. If you want to make an adjustment in the data you entered you can simply alter the relevant cell, and press **“Calculate”** again (note: this will erase the results of the previous calculation shown in the other tabs).

If you have saved the results of your previous calculation and want to perform a completely new one, you can quickly delete the previous input by clicking the **“Clear input”** button and then confirming with **“Yes”** (note: this will also erase the results of the previous calculation shown in the other tabs).

If you have pressed the **“Calculate”** button but one or more inputs do not meet the limits as shown in paragraph 2, a pop-up warning screen will appear which will tell you what the problem is, or which cell it is caused by (note: when there are multiple inputs that fall outside of the imposed limits the tool will only give you one pop-up warning screen at a time)

If you want to change the language of the entire Excel-sheet you can select one of the other languages available in the drop-down menu button given in the main horizontal bar in this tab.

Figure 2. Project data tab.

Project data Interferentie Tool Gesloten Bodem Energiesystemen (ITGBES) GROENHOLLAND

| Ground thermal conductivity (W/mK) | 2.0 | | | | | | Calculate | | Clear input | | English (English) |
|--|-----|--------|--------|--------|--------|--------|------------------|--|--------------------|--|-------------------|
| Number of systems in analysis (max. 10) | 5 | | | | | | | | | | |
| Input data per system | | | | | | | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | | | | | |
| X-coordinate (m) | | 1000 | 1005 | 1010 | 1015 | 1020 | | | | | |
| Y-coordinate (m) | | 1020 | 1000 | 1000 | 1000 | 1000 | | | | | |
| Total length ground source heat exchanger system (m) | | 200 | 200 | 200 | 200 | 200 | | | | | |
| Depth of the heat exchangers (m) | | 100 | 100 | 100 | 100 | 100 | | | | | |
| Annual heating demand building (MWh/year) | | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | | | | | |
| Annual domestic hot water demand building (MWh/year) | | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | | | | | |
| Annual cooling demand building (MWh/year) | | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | | | | | |
| Efficiency heating (SPF) | | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | | | | | |
| Efficiency domestic hot water (SPF) | | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | | | | | |
| Efficiency cooling (SPF) | | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | | | | | |
| Calculated values | | | | | | | | | | | |
| Net heating demand on ground (MWh/year) | | 11.3 | 11.3 | 11.3 | 11.3 | 11.3 | | | | | |
| Net cooling demand on ground (MWh/year) | | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | | | | | |
| Net demand on ground (MWh/year) | | -7.1 | -7.1 | -7.1 | -7.1 | -7.1 | | | | | |
| Specific energy extraction (kWh/year) | | -113.3 | -113.3 | -113.3 | -113.3 | -113.3 | | | | | |
| Specific energy addition (kWh/year) | | 42.1 | 42.1 | 42.1 | 42.1 | 42.1 | | | | | |

Explanation of required inputs

Total length ground source heat exchanger system
 The total length of a ground source heat exchanger system is represented by the number of boreholes multiplied with the depth of the installed loops (heat exchangers). Note: this is not the same as the total loop length!

End depth borehole heat exchanger
 The final depth at which the heat exchangers are installed measured in meters below ground level. Note: this is not the same as the total loop length!

The annual heating demand
 The annual heating demand is the total heating (space heating) from the building which will be covered with the ground source heat exchanger system.

The annual domestic hot water demand
 The annual heating demand is the total domestic hot water from the building which will be covered with the ground source heat exchanger system.

The annual cooling demand
 The annual cooling demand is the amount of cooling required by the building which will be covered with the ground source heat exchanger system.

Efficiency (space heating, domestic hot water, cooling)
 Annual efficiency ratio (SPF)

- **TAB Distances (Figure 3)**

Once you have pressed “**Calculate**” in the ‘Project data’ tab (and the calculation was indeed successful) the distances in meters between all the systems will be presented in this tab.

The resulting values can be selected and copied to be further processed in your own documentation, or can be printed as PDF in the format given by the ITGBES tool.

Figure 3. Distances tab.

Distances between systems (m) GROENHOLLAND

| System | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------|----|----|----|----|----|---|---|---|---|----|
| 1 | 0 | 21 | 22 | 25 | 28 | | | | | |
| 2 | 21 | 0 | 5 | 10 | 15 | | | | | |
| 3 | 22 | 5 | 0 | 5 | 10 | | | | | |
| 4 | 25 | 10 | 5 | 0 | 5 | | | | | |
| 5 | 28 | 15 | 10 | 5 | 0 | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | | | | | | | | | | |
| 10 | | | | | | | | | | |

- **TAB Temperature effects (Figure 4)**

Once you have pressed “**Calculate**” in the ‘*Project data*’ tab (and the calculation was indeed successful) all individual effects (in Kelvin) of all systems on each other will be shown in this tab. Please note: the way the graph should be read is as follows (also highlighted Figure 4): the effect in the cell where the first row and the fifth column meet, represents the effect of the first system on the fifth system. The cumulative temperature effects on each system will be displayed in the bottom row of the table, as the sum of the individual effects present in a column. For example, in Figure 4 the cumulative effect experienced by system no. 5, caused by the other systems, is -2.46 K.

The values can be selected and copied to be further processed in your own documentation, or can be printed as PDF in the format given by the ITGBES tool.

Figure 4. Temperature effects tab.

| System | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------|-------|-------|-------|-------|-------|---|---|---|---|----|
| 1 | X | -0.33 | -0.30 | -0.26 | -0.21 | | | | | |
| 2 | -0.33 | X | -1.12 | -0.67 | -0.46 | | | | | |
| 3 | -0.30 | -1.12 | X | -1.12 | -0.67 | | | | | |
| 4 | -0.26 | -0.67 | -1.12 | X | -1.12 | | | | | |
| 5 | -0.21 | -0.46 | -0.67 | -1.12 | X | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | | | | | | | | | | |
| 10 | | | | | | | | | | |
| Total | -1.10 | -2.58 | -3.21 | -3.17 | -2.46 | | | | | |

Effect from BHE 1 on BHE 5

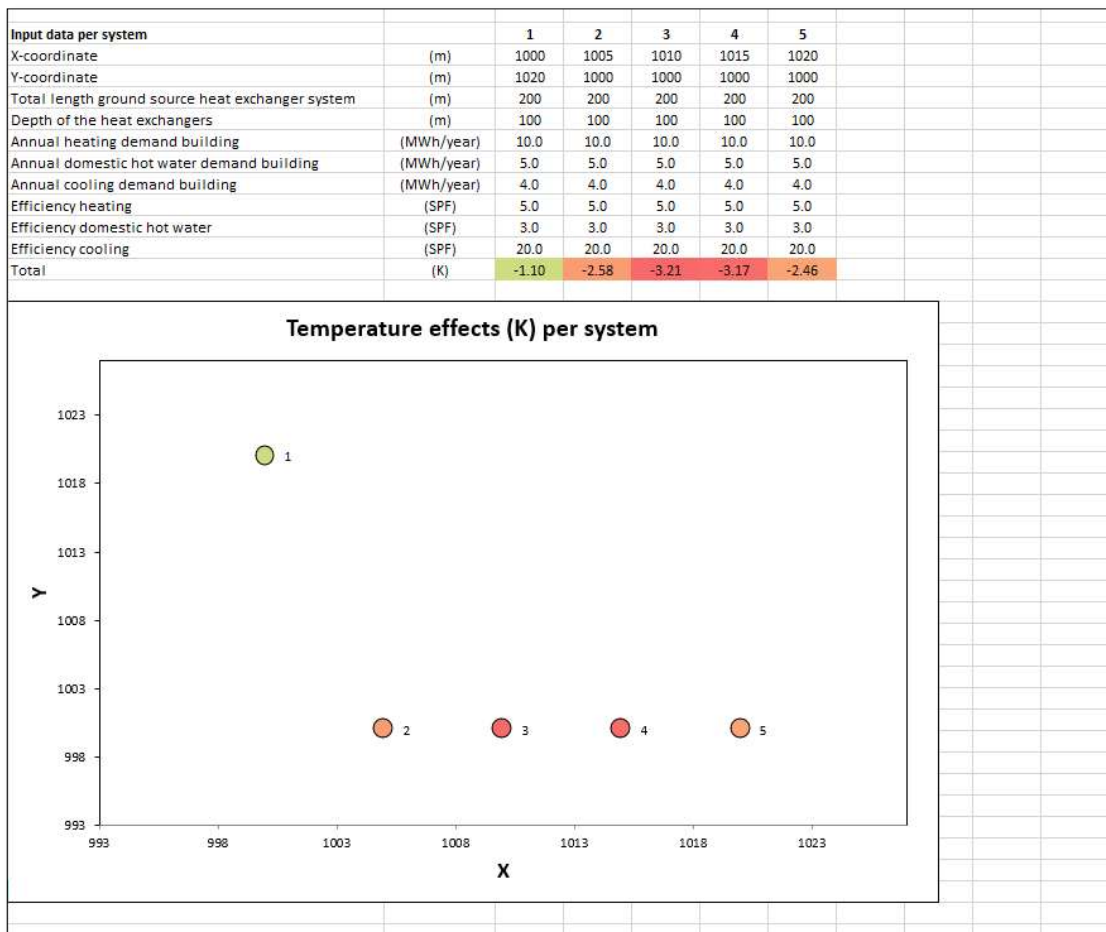
- **TAB Report (Figure 5)**

Once you have pressed “**Calculate**” in the ‘*Project data*’ tab (and the calculation was indeed successful) you will be automatically forwarded to the ‘*Report*’ tab. The ‘*Report*’ tab gives you a summary of all your input data from the ‘*Project data*’ tab, accompanied with the cumulative temperature effect for each system in the bottom row (Row 13 in Excel).

Each cell in this bottom row will be colored according to the magnitude of the cumulative effect on the corresponding BHE. Please note: the exact coloring of each cell is determined in relation to the other calculated cumulative effects within a certain calculation (red always means largest effect, yellow and green indicate lesser effects compared to the largest effect). A certain absolute cumulative effect (let’s say -0.5 K) will therefore not always be coded as the same color; it will be red for a calculation where the other cumulative effects are less significant (e.g., -0.1 or -0.2 K), and it will be greenish for a calculation where the other cumulative effects are more profound (e.g., -2.0 or -3.0 K).

Below Row 13, a graphical representation of the coordinates of all the BHE is shown. In this plot all the BHE positions are also colored, based on the magnitude of the cumulative effect. The colors match those in the cells in Row 13.

Figure 5. Report tab.



The values and graph can be selected and copied to be further processed in your own documentation, or can be printed in the format given by the ITGBES tool.

6. Example calculations

Example 1.

In Figure 6 below, a design scenario is given with 8 houses in an irregular configuration. Each house will have their own Ground Source Heat Pump (GSHP) system installed. Since the systems are all for different sized houses and lots, the energy demands is also different for each house and GSHP system.

As designer of the systems, one could therefore make 8 separate designs tailored to all the specific needs of each individual house. This way however, the long-term thermal effects between the 8 systems will not be accounted for in individual design results.

In a case like this, ITGBES can help improve the overall design process, by calculating the effects between the individual systems. With the different energy profiles and heat pump specifications for the 8 houses, along with the coordinates and the average thermal conductivity of the ground, the thermal effects can be calculated.

Figure 7 shows the results given by ITGBES from the 'Report' tab. As can be seen, the system in the middle (nr. 1 in calculation, square in Figure 6) will receive the largest net negative effect caused by the others, while systems on the rim (system 8 for example) experiences less of an effect.

Figure 6. Plan of the neighborhood of the first example calculation. Red shapes indicate the locations of the systems.

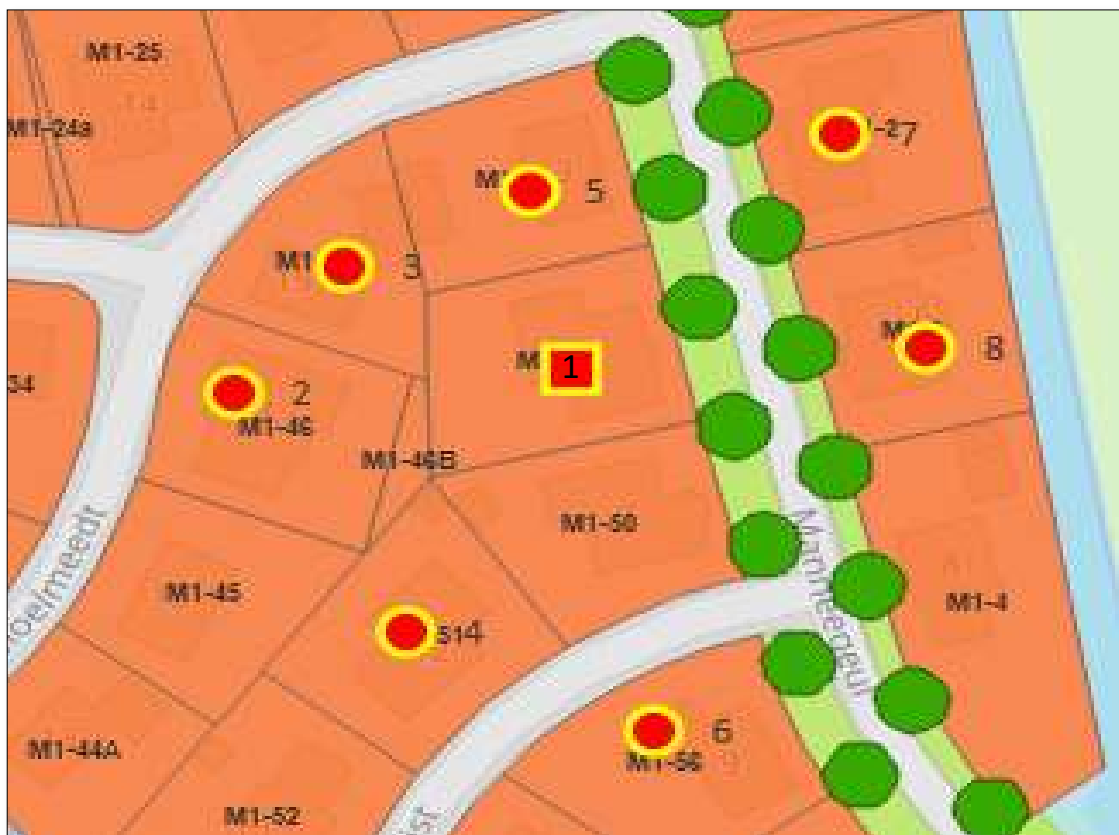
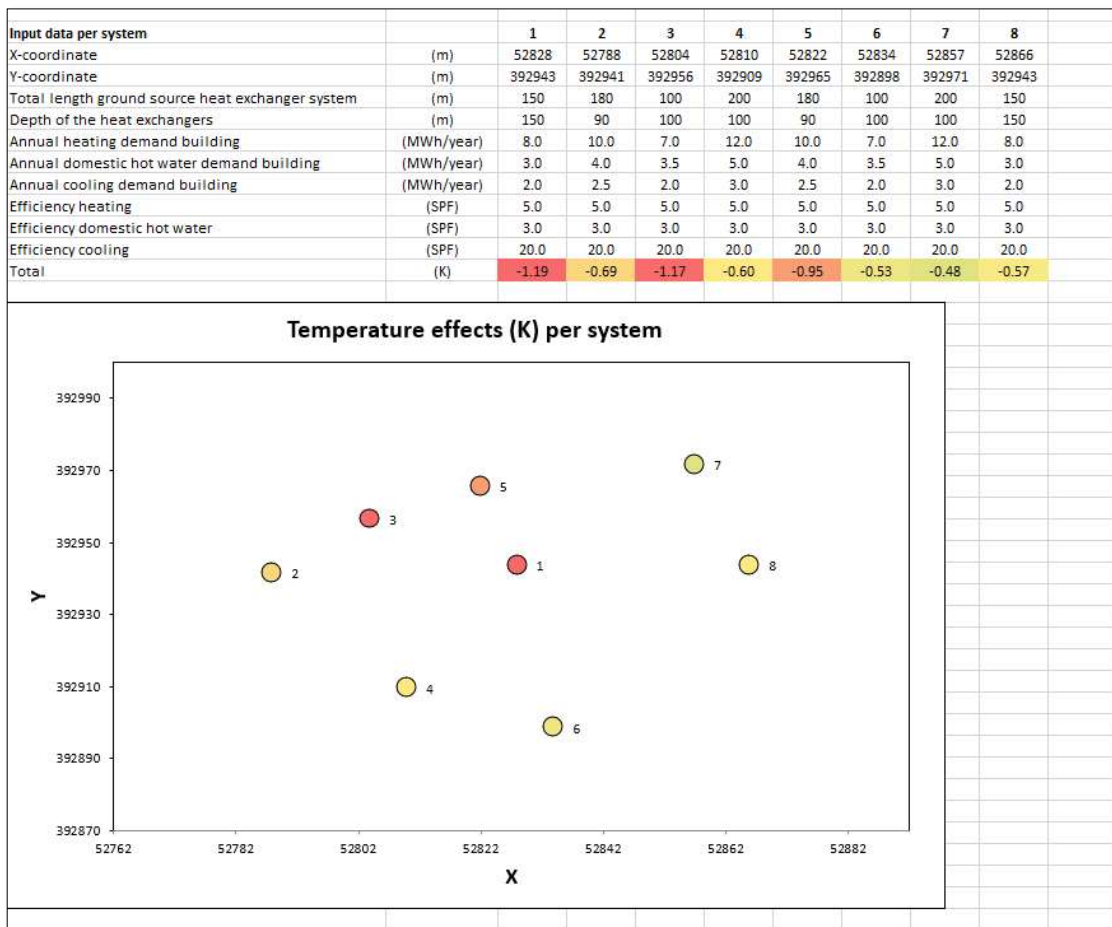


Figure 7. Results in Report tab for first example calculation.



When in this case, using the value to adjust the design of BHE 1 (for instance in EED), an amount in the order of magnitude of 20m extra borehole length would be required to compensate for the negative temperature effect. Similarly, for the seven other systems adjustments to the BHE borehole depths or configurations (repositioning your boreholes) can be made, based on the respective cumulative effects they will experience, to ensure that they will meet your design requirements.

Example 2.

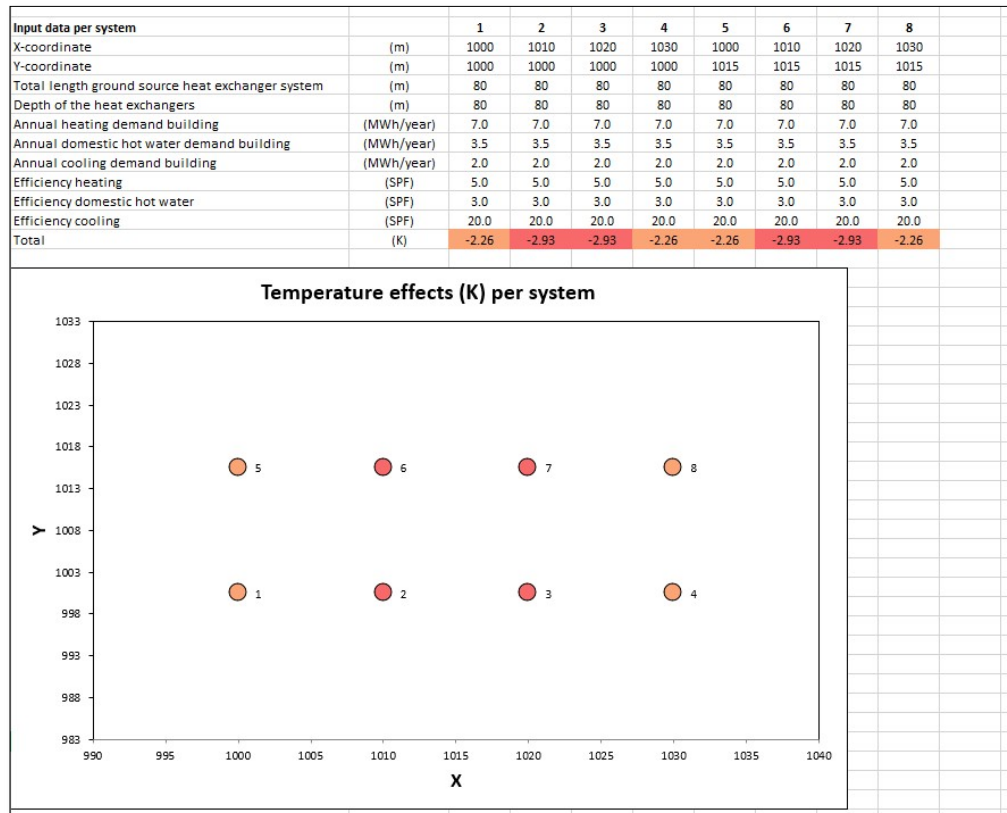
Even when dealing with more regular spaced individual BHE's, their respective positions within the overall project will still have an influence on the cumulative effects they will experience. Figure 8 shows an overview of a second example, where 8 more or less regularly spaced BHE's will be installed. In this case all have the same energy demands.

Figure 9 shows the results given by ITGBES from the 'Report' tab. The systems in the middle experience a larger cumulative effect compared to the systems on the sides. The results can be used to adjust all individual designs accordingly. If this project would have been collectively designed within a single design calculation containing the total energy demands of all 8 systems, the borehole lengths for each house would have been the same. Using ITGBES it becomes apparent that individual systems in the middle would have been slightly underdimensioned, while the systems on the sides would have been slightly overdimensioned.

Figure 8. Plan of the neighborhood of the second example. Red shapes indicate the locations of the systems.



Figure 9. Results in Report tab for second example calculation.



7. Feedback and questions

If you encounter any problems, have any questions, or have some feedback regarding ITGBES feel free to contact us via the following email address:

<mailto:itgbes@groenholland.nl>

subject: ITGBES.com

Include a description of the problem encountered and attach the ITGBES excel sheet with the problem.

For more information on other types of GSHP-design related projects Groenholland can help you with visit our website at:

<http://www.itgbespro.com>

8. References

Blomberg, T., Claesson, J., Eskilson, P., Hällström, G. & Sanner, S. 2019: Earth Energy Designer, Ver 2.20.

Witte, H.J.L. & Boots, R. 2022. ITGBES-PRO a new method for the optimization and integrated design of clustered individual borehole heat exchanger systems. European Geothermal Congress 2022, Berlin, Germany, 17-21 October.