GHEtool calculation report

Course 9.5



26/10/26

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Enead BV

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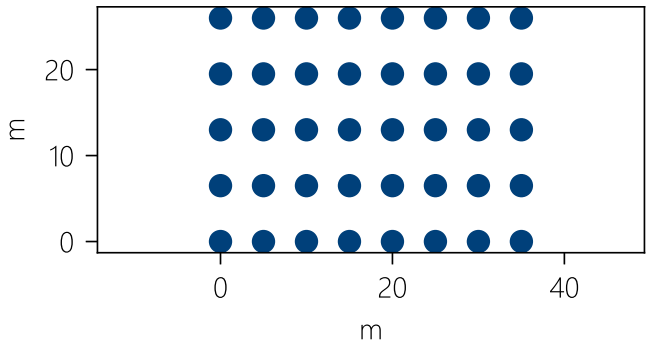
5.6 Design Data - Limit borefield power 49

1.1 Structure of the report

First, in Chapter 2, a summary of all the simulations will be provided. Chapter 3 discusses the inputs that are consistent across all scenarios. In Chapter 4, the different simulation results are presented and discussed. Chapter 5 contains appendices with more detailed information.

2.1 Req size

Input



Number of boreholes: 40

Average minimum borehole spacing: 5,0 m

Borehole depth (w.r.t. surface): 100,0 m

2 x U tube DN32 PN16

25,0 v/v% MPG

SCOP heating: 5,00; SEER cooling: 20,00; SCOP DHW: 3,00

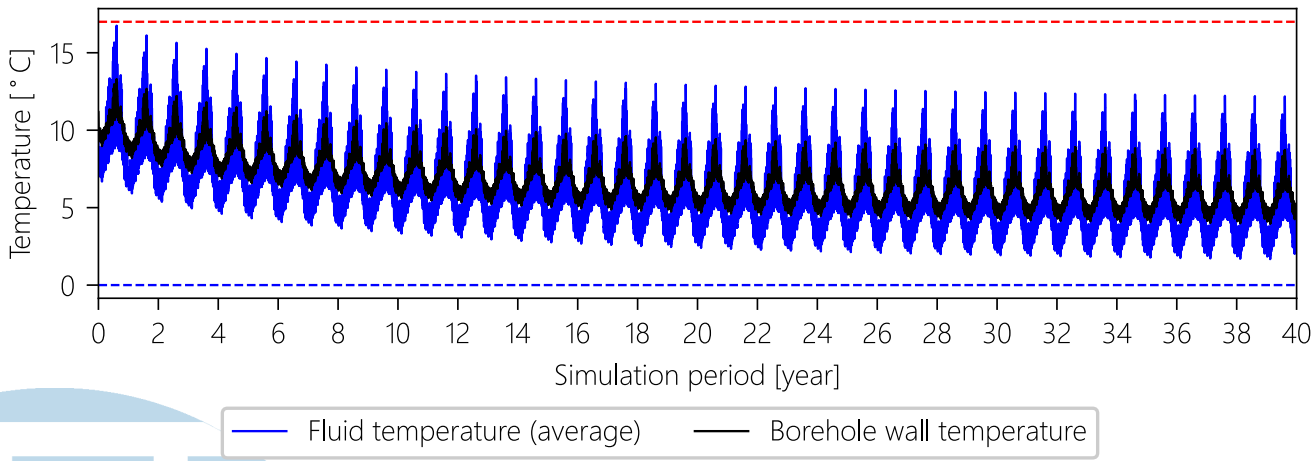
Building demand	Yearly load	Peak power
Heating demand	92 547 kWh/y	47,7 kW
Domestic hot water demand	60 017 kWh/y	29,6 kW
Cooling demand	24 084 kWh/y	96,7 kW

Results

Effective borehole thermal resistance (extraction): 0,1814 m·K/W, Reynolds number: 503 (laminar)

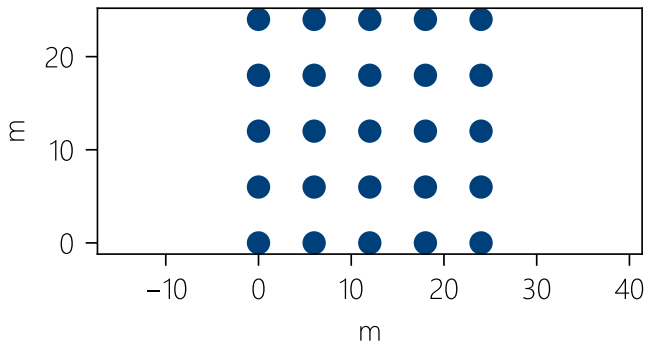
Effective borehole thermal resistance (injection): 0,1440 m·K/W, Reynolds number: 1 887 (laminar)

Maximum average fluid temperature: 16,75 °C, Minimum average fluid temperature: 1,68 °C



2.2 Temperature profile

Input



Number of boreholes: 25

Average minimum borehole spacing: 6,0 m

Borehole depth (w.r.t. surface): 100,0 m

2 x U tube DN32 PN16

25,0 v/v% MPG

SCOP heating: 5,00; SEER cooling: 20,00; SCOP DHW: 3,00

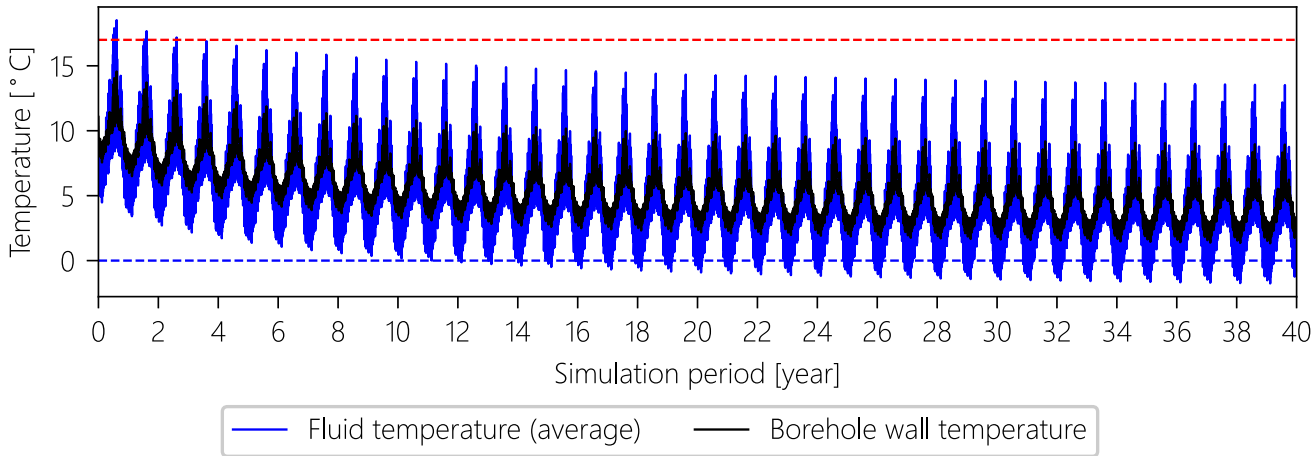
Building demand	Yearly load	Peak power
Heating demand	92 547 kWh/y	47,7 kW
Domestic hot water demand	60 017 kWh/y	29,6 kW
Cooling demand	24 084 kWh/y	96,7 kW

Results

Effective borehole thermal resistance (extraction): 0,1530 m·K/W, Reynolds number: 684 (laminar)

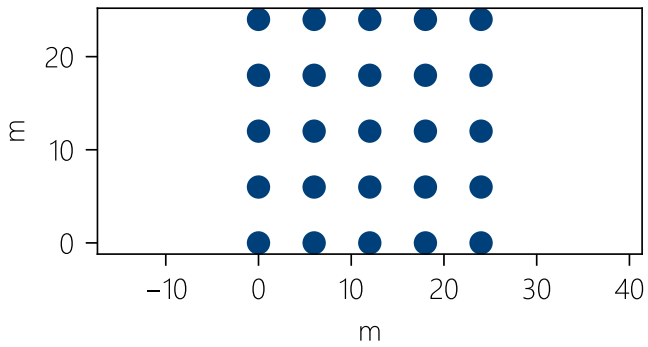
Effective borehole thermal resistance (injection): 0,0937 m·K/W, Reynolds number: 3 215 (transient)

Maximum average fluid temperature: 18,52 °C, Minimum average fluid temperature: -1,76 °C



2.3 Hybrid cooling

Input



Number of boreholes: 25

Average minimum borehole spacing: 6,0 m

Borehole depth (w.r.t. surface): 100,0 m

2 x U tube DN32 PN16

25,0 v/v% MPG

SCOP heating: 5,00; SEER cooling: 20,00; SCOP DHW: 3,00

Building demand	Yearly load	Peak power
Heating demand	92 547 kWh/y	47,7 kW
Domestic hot water demand	60 017 kWh/y	29,6 kW
Cooling demand	24 084 kWh/y	96,7 kW

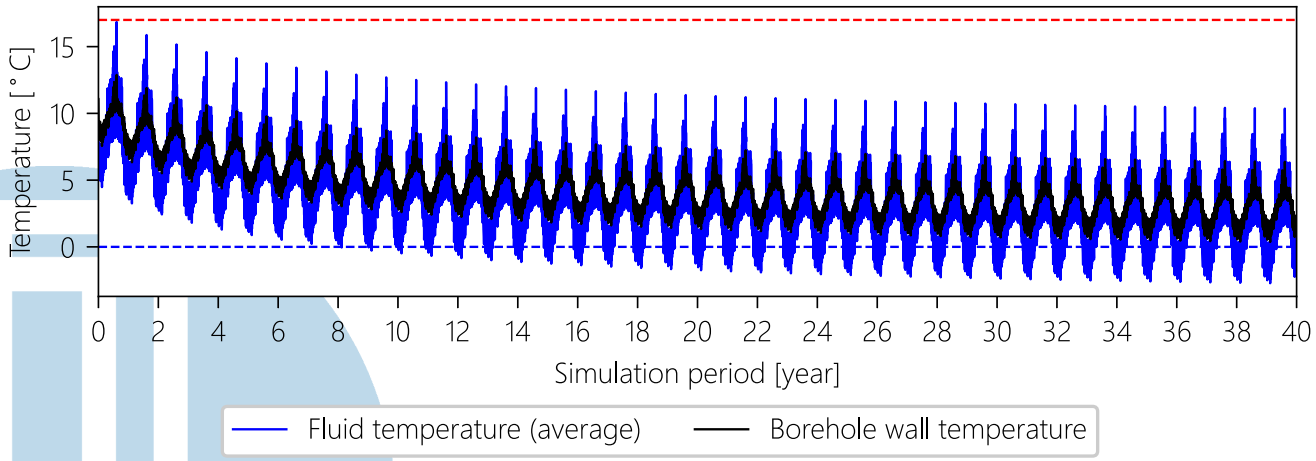
Results

Yearly load	Heating demand	Cooling demand	Domestic hot water demand
Geothermal	92 547 kWh/y (100,00 %)	11 122 kWh/y (46,18 %)	60 017 kWh/y (100,00 %)
Hybrid	0 kWh/y (0,00 %)	12 961 kWh/y (53,82 %)	0 kWh/y (0,00 %)

Effective borehole thermal resistance (extraction): 0,1531 m·K/W, Reynolds number: 653 (laminar)

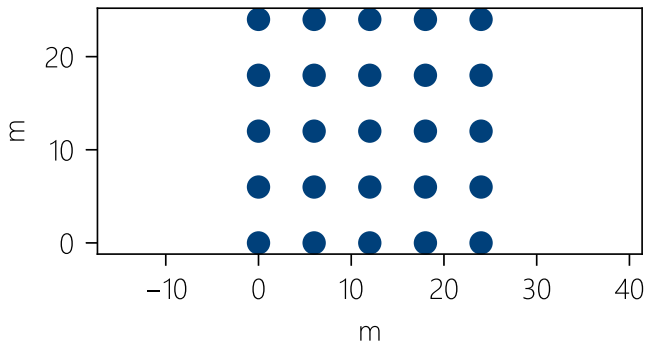
Effective borehole thermal resistance (injection): 0,1404 m·K/W, Reynolds number: 2 247 (laminar)

Maximum average fluid temperature: 16,85 °C, Minimum average fluid temperature: -2,72 °C



2.4 Hybrid cooling + heating

Input



Number of boreholes: 25

Average minimum borehole spacing: 6,0 m

Borehole depth (w.r.t. surface): 100,0 m

2 x U tube DN32 PN16

25,0 v/v% MPG

SCOP heating: 5,00; SEER cooling: 20,00; SCOP DHW: 3,00

Building demand	Yearly load	Peak power
Heating demand	92 547 kWh/y	47,7 kW
Domestic hot water demand	60 017 kWh/y	29,6 kW
Cooling demand	24 084 kWh/y	96,7 kW

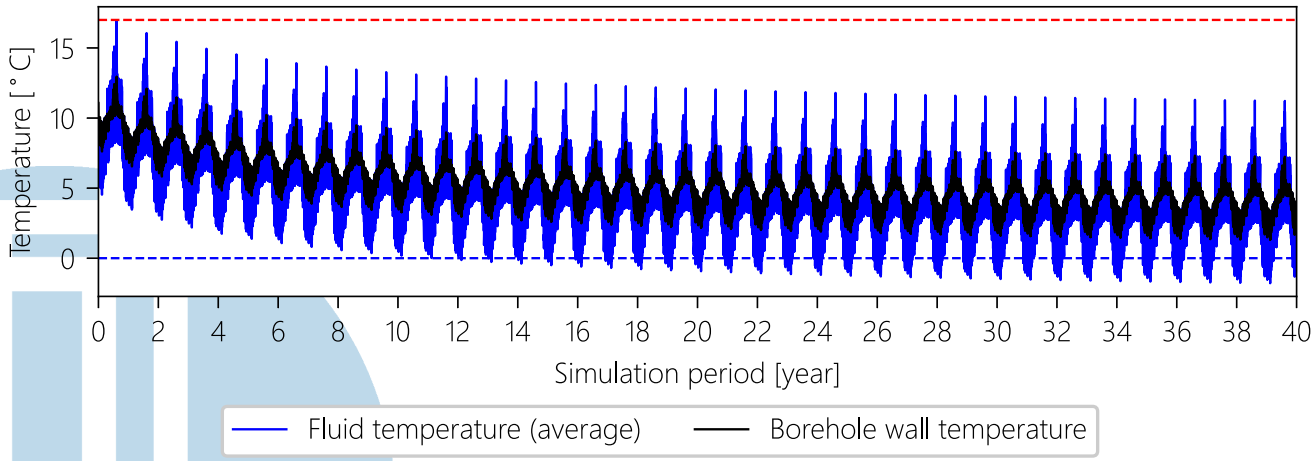
Results

Yearly load	Heating demand	Cooling demand	Domestic hot water demand
Geothermal	77 263 kWh/y (83,49 %)	11 122 kWh/y (46,18 %)	60 017 kWh/y (100,00 %)
Hybrid	15 283 kWh/y (16,51 %)	12 961 kWh/y (53,82 %)	0 kWh/y (0,00 %)

Effective borehole thermal resistance (extraction): 0,1530 m·K/W, Reynolds number: 684 (laminar)

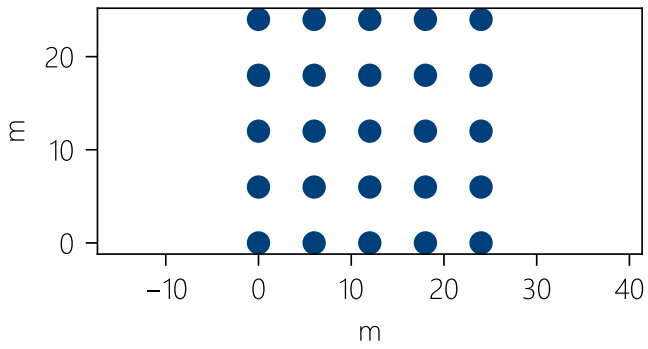
Effective borehole thermal resistance (injection): 0,1404 m·K/W, Reynolds number: 2 252 (laminar)

Maximum average fluid temperature: 16,92 °C, Minimum average fluid temperature: -1,79 °C



2.5 Hybrid cooling + heating + top heating

Input



Number of boreholes: 25

Average minimum borehole spacing: 6,0 m

Borehole depth (w.r.t. surface): 100,0 m

2 x U tube DN32 PN16

25,0 v/v% MPG

SCOP heating: 5,00; SEER cooling: 20,00; SCOP DHW: 3,00

Building demand	Yearly load	Peak power
Heating demand	92 547 kWh/y	47,7 kW
Domestic hot water demand	60 017 kWh/y	29,6 kW
Cooling demand	24 084 kWh/y	96,7 kW

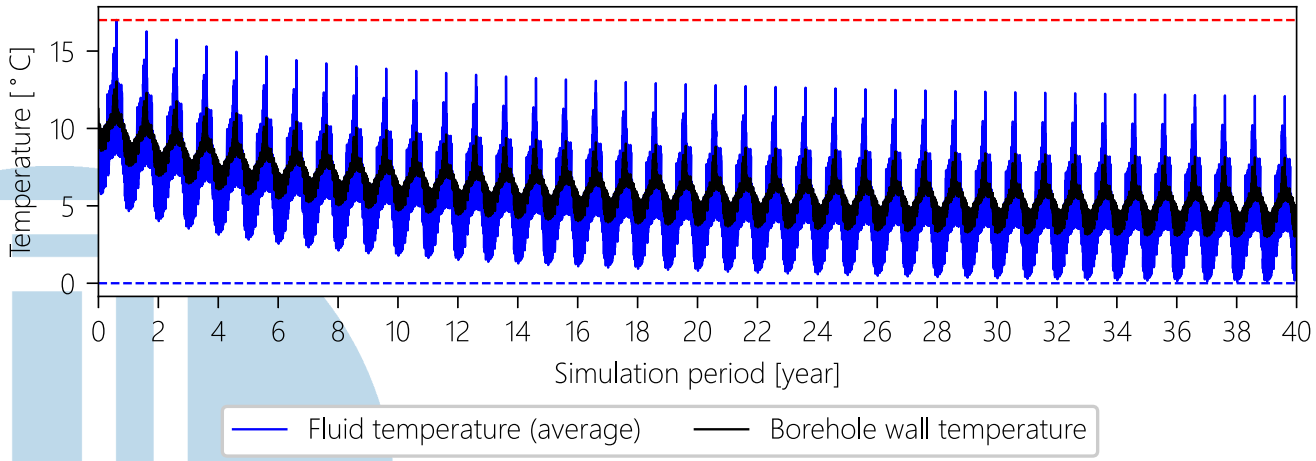
Results

Yearly load	Heating demand	Cooling demand	Domestic hot water demand
Geothermal	61 779 kWh/y (66,75 %)	11 122 kWh/y (46,18 %)	60 017 kWh/y (100,00 %)
Hybrid	30 768 kWh/y (33,25 %)	12 961 kWh/y (53,82 %)	0 kWh/y (0,00 %)

Effective borehole thermal resistance (extraction): 0,1548 m·K/W, Reynolds number: 711 (laminar)

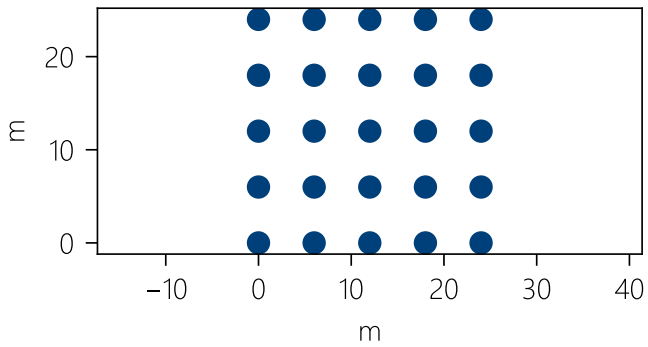
Effective borehole thermal resistance (injection): 0,1404 m·K/W, Reynolds number: 2 260 (laminar)

Maximum average fluid temperature: 17,01 °C, Minimum average fluid temperature: 0,06 °C



2.6 Limit borefield power

Input



Number of boreholes: 25

Average minimum borehole spacing: 6,0 m

Borehole depth (w.r.t. surface): 100,0 m

2 x U tube DN32 PN16

25,0 v/v% MPG

SCOP heating: 5,00; SEER cooling: 20,00; SCOP DHW: 3,00

Building demand	Yearly load	Peak power
Heating demand	92 547 kWh/y	47,7 kW
Domestic hot water demand	60 017 kWh/y	29,6 kW
Cooling demand	24 084 kWh/y	96,7 kW

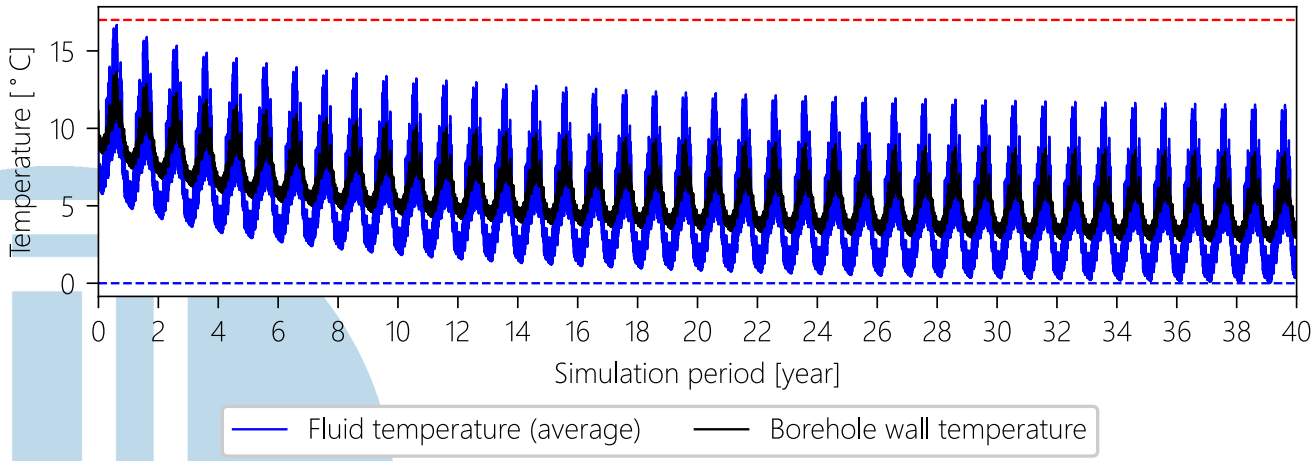
Results

Yearly load	Heating demand	Cooling demand	Domestic hot water demand
Geothermal	82 432 kWh/y (89,07 %)	23 177 kWh/y (96,24 %)	60 017 kWh/y (100,00 %)
Hybrid	10 115 kWh/y (10,93 %)	906 kWh/y (3,76 %)	0 kWh/y (0,00 %)

Effective borehole thermal resistance (extraction): 0,1640 m·K/W, Reynolds number: 591 (laminar)

Effective borehole thermal resistance (injection): 0,1497 m·K/W, Reynolds number: 1 557 (laminar)

Maximum average fluid temperature: 16,68 °C, Minimum average fluid temperature: 0,03 °C



This section contains all the input data that is identical across all simulations. Input data that varies between scenarios is provided and discussed within the relevant scenario sections. The following subsections cover the following topics: general simulation settings, ground data, pipe data, fluid data, flow data, load data, and efficiency data.

3.1 General simulation settings

The scenarios in this report have been simulated with a simulation period of 40 years, starting in January. The maximum and minimum average fluid temperatures were 0,00 °C and 17,00 °C respectively. The simulations were carried out with GHEtool Cloud v2.9.1.2.

3.2 Ground data

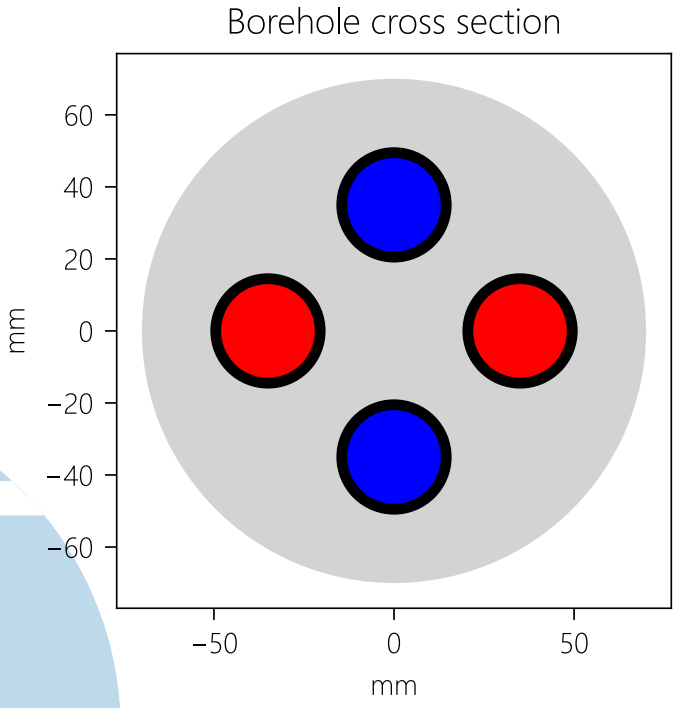
The ground is modelled as a single homogeneous layer with an average thermal conductivity of 2,00 W/(m·K) and a volumetric heat capacity of 2,40 MJ/(m³·K). This means that the ground properties are assumed to remain constant at all depths.

A ground temperature gradient is taken into account. Using a geothermal heat flux of 0,07 W/m², a ground surface temperature of 9,60 °C and the ground thermal conductivity, the average ground temperature can be calculated for each borehole depth. For example, the average ground temperature is 10,47 °C at 50 m and 11,33 °C at 99 m.

Please note that for all ground property calculations, both the borehole depth and the buried depth are taken into account. This means that the average ground properties, as seen by the borehole, are calculated from the buried depth down to the full borehole depth. The region above the buried depth is not considered.

3.3 Pipe data

Inside the borehole with a diameter of 140 mm, 2 DN32 PN16 U-tubes will be installed and the pipe legs are positioned at a distance of 35 mm from the borehole center. The borehole will be grouted with a material that has a thermal conductivity of 1,50 W/(m·K).



3.4 Fluid data

As a heat transfer fluid, MPG with 25,0 v/v% was selected, which provides frost protection down to approximately -10 °C. For a more accurate simulation, the fluid properties (such as viscosity and density) are assumed to be temperature-dependent and therefore vary throughout the simulation period. This is particularly important for buildings with a high cooling demand, since heat transfer during heat injection (i.e., cooling) is more efficient than during extraction (i.e., heating). To account for this, no single fixed value should be used for the fluid properties.

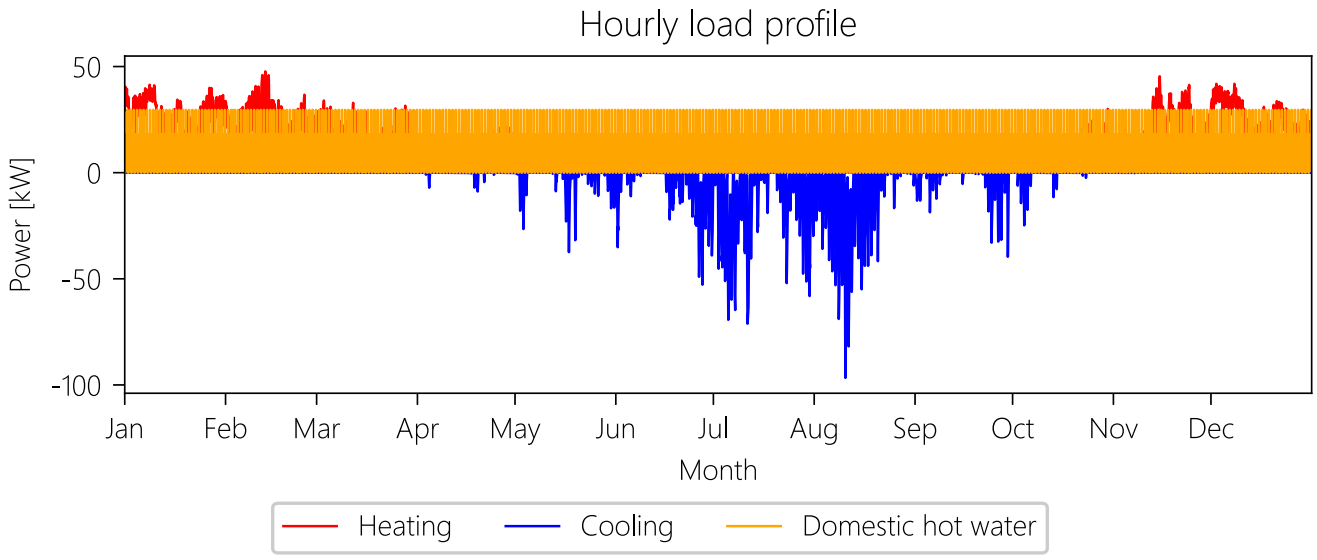
3.5 Flow data

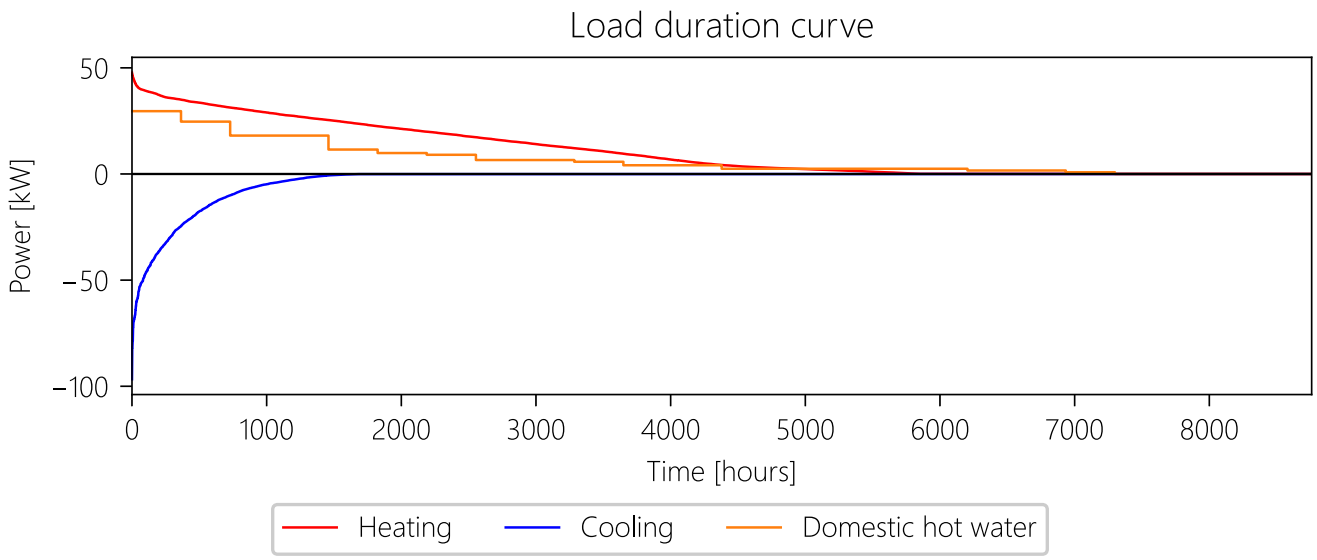
The system was simulated with a variable flow rate, where a constant temperature difference across the borefield was used of 3,00 °C in extraction and 3,00 °C in injection, with a minimum flow percentage of 10%. The resulting maximum flow rate through the borefield is 4,21 l/s and 8,49 l/s respectively.

3.6 Load data

For the simulation, a building load was used. This means that, in order to calculate the resulting extraction and injection loads for the ground, the efficiency of the heat pump will be taken into account. Below you can find a summary of the load.

Building demand	Yearly load	Peak power
Heating demand	92 547 kWh/y	47,7 kW
Domestic hot water demand	60 017 kWh/y	29,6 kW
Cooling demand	24 084 kWh/y	96,7 kW





3.7 Efficiency data

To calculate the resulting geothermal load, the heat pump is modelled to have a SCOP of 5,00 in heating and 3,00 for the production of domestic hot water. The cooling is modelled with an SEER of 20,00.

4.1 Req size

In the first subsection, the scenario-specific input parameters will be discussed. Afterwards, the simulation results are presented.

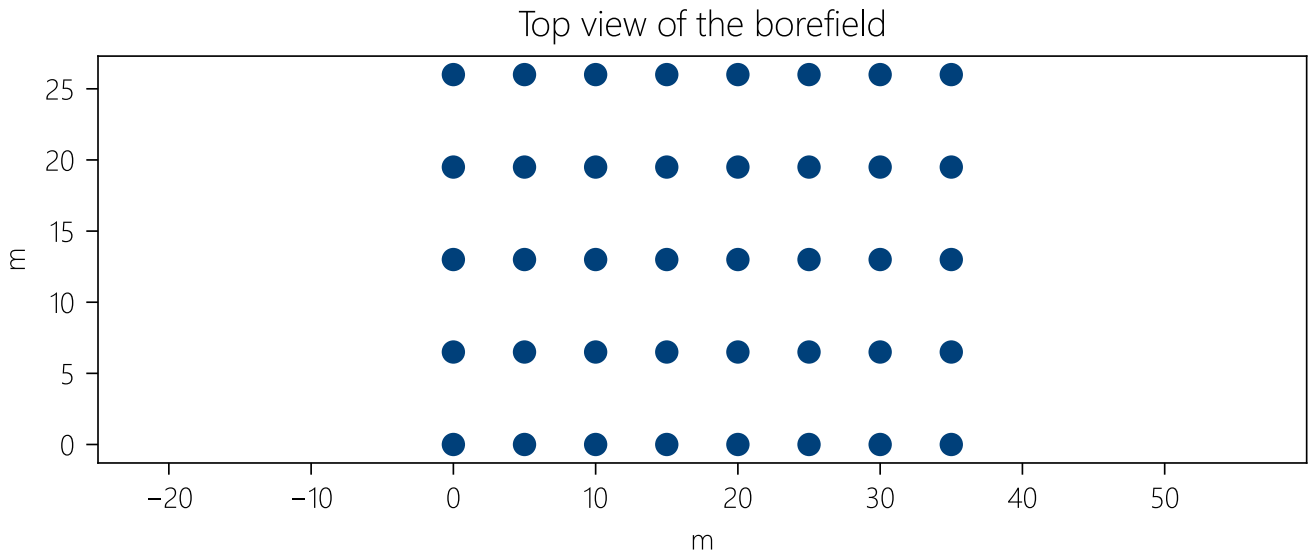
4.1.1 Input

Borefield configuration

The simulations were carried out with a borefield consisting of 40 boreholes, with an average buried depth of 1,00 m, an average borehole depth of 100,00 m and an average borehole length of 99,00 m. This results in a total borehole length of 3 960,00 m.

The minimum average borehole spacing is 5,00 m. This is defined as the average of the smallest distances between the centres of all pairs of boreholes in the borefield.

(The borehole depth is defined as the vertical distance between the ground surface and the deepest point of the borehole. The buried depth is the distance between the ground surface and the start of the borehole. The borehole length, sometimes called the 'active length' is the actual length of the heat exchanger measured along the borehole.)



The coordinates of the different boreholes are given in the table below.

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
5,00	0,00	99,00	100,00	1,00	0,00	0,00
10,00	0,00	99,00	100,00	1,00	0,00	0,00
15,00	0,00	99,00	100,00	1,00	0,00	0,00
20,00	0,00	99,00	100,00	1,00	0,00	0,00
25,00	0,00	99,00	100,00	1,00	0,00	0,00
30,00	0,00	99,00	100,00	1,00	0,00	0,00
35,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,50	99,00	100,00	1,00	0,00	0,00
5,00	6,50	99,00	100,00	1,00	0,00	0,00
10,00	6,50	99,00	100,00	1,00	0,00	0,00
15,00	6,50	99,00	100,00	1,00	0,00	0,00
20,00	6,50	99,00	100,00	1,00	0,00	0,00
25,00	6,50	99,00	100,00	1,00	0,00	0,00
30,00	6,50	99,00	100,00	1,00	0,00	0,00
35,00	6,50	99,00	100,00	1,00	0,00	0,00
0,00	13,00	99,00	100,00	1,00	0,00	0,00
5,00	13,00	99,00	100,00	1,00	0,00	0,00
10,00	13,00	99,00	100,00	1,00	0,00	0,00
15,00	13,00	99,00	100,00	1,00	0,00	0,00
20,00	13,00	99,00	100,00	1,00	0,00	0,00
25,00	13,00	99,00	100,00	1,00	0,00	0,00
30,00	13,00	99,00	100,00	1,00	0,00	0,00
35,00	13,00	99,00	100,00	1,00	0,00	0,00
0,00	19,50	99,00	100,00	1,00	0,00	0,00
5,00	19,50	99,00	100,00	1,00	0,00	0,00
10,00	19,50	99,00	100,00	1,00	0,00	0,00
15,00	19,50	99,00	100,00	1,00	0,00	0,00
20,00	19,50	99,00	100,00	1,00	0,00	0,00
25,00	19,50	99,00	100,00	1,00	0,00	0,00
30,00	19,50	99,00	100,00	1,00	0,00	0,00
35,00	19,50	99,00	100,00	1,00	0,00	0,00

0,00	26,00	99,00	100,00	1,00	0,00	0,00
5,00	26,00	99,00	100,00	1,00	0,00	0,00
10,00	26,00	99,00	100,00	1,00	0,00	0,00
15,00	26,00	99,00	100,00	1,00	0,00	0,00
20,00	26,00	99,00	100,00	1,00	0,00	0,00
25,00	26,00	99,00	100,00	1,00	0,00	0,00
30,00	26,00	99,00	100,00	1,00	0,00	0,00
35,00	26,00	99,00	100,00	1,00	0,00	0,00

4.1.2 Results

Ground load

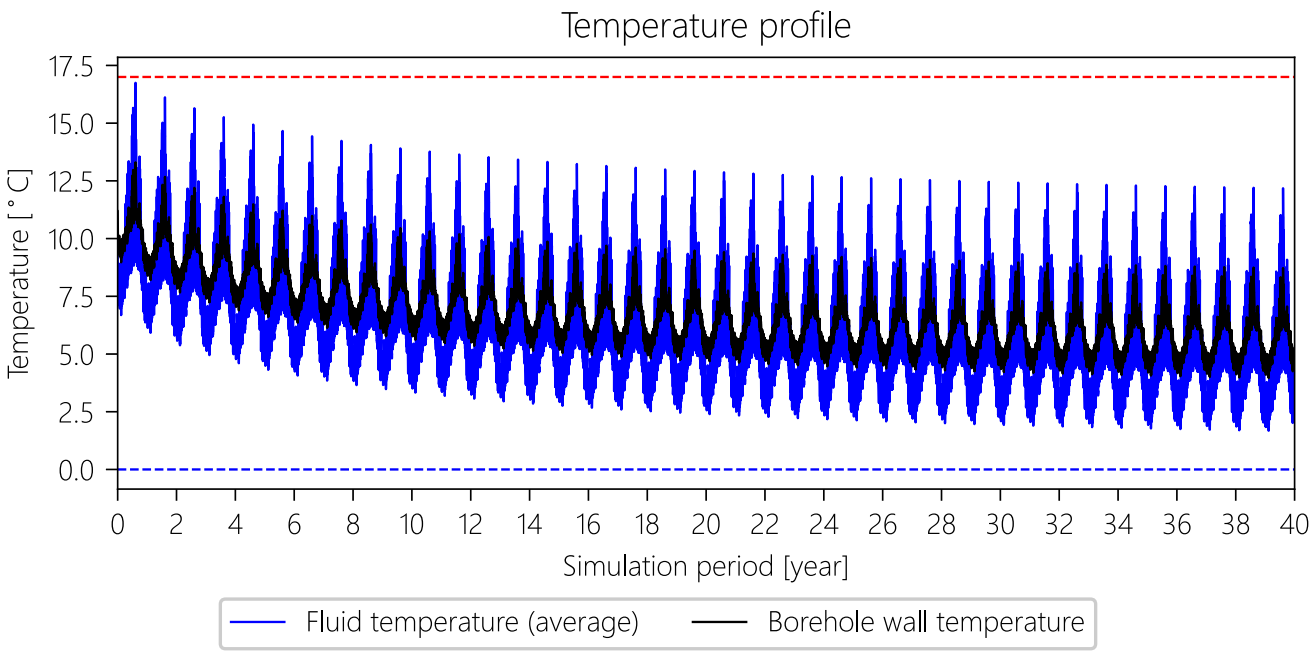
Because we are working with building loads (i.e. secondary loads), these must be converted into injection and extraction loads using the efficiency data. A summary of the resulting yearly ground load is given in the table below.

Ground demand	Yearly load	Peak power
Extraction demand	114 049 kWh/y	50,1 kW
Injection demand	25 288 kWh/y	101,5 kW

Temperature evolution of the borefield

Using the pipe, fluid, and flow properties, the Reynolds number was calculated. Since this number depends on the fluid temperature and therefore varies over the simulation period, it was updated at every timestep to achieve the most accurate result possible.
Doing so, the Reynolds number during heat extraction was 503, whilst it was 1 887 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,1814 m·K/W and 0,1440 m·K/W during heat extraction and injection.

Below, the hourly simulation for the borefield is shown. The blue line represents the average fluid temperature between the inlet and outlet of the borehole at each hour of the simulation. The black line shows the borehole wall temperature, which is the interface between the borehole and the ground. The difference between both lines is determined by the effective borehole thermal resistance.



The maximum average fluid temperature over the whole simulation period is 16,75 °C, and the minimum average fluid temperature is 1,68 °C.

Pressure drop

The pressure drop over a single borehole is 4,88 kPa during extration and 6,28 kPa during injection.

4.2 Temperature profile

In the first subsection, the scenario-specific input parameters will be discussed. Afterwards, the simulation results are presented.

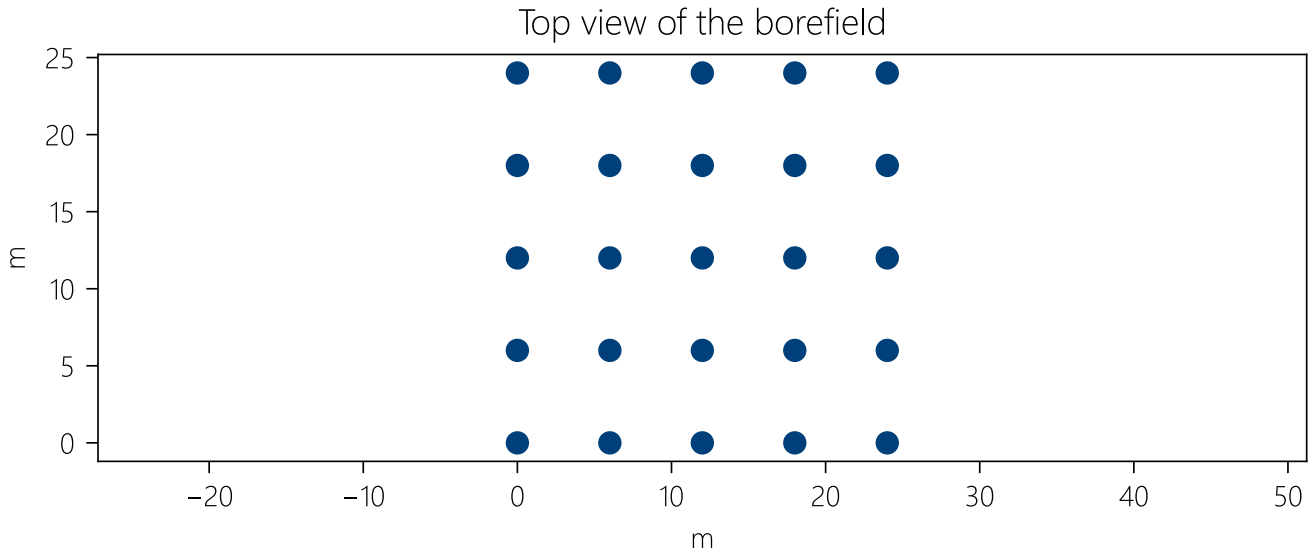
4.2.1 Input

Borefield configuration

The simulations were carried out with a borefield consisting of 25 boreholes, with an average buried depth of 1,00 m, an average borehole depth of 100,00 m and an average borehole length of 99,00 m. This results in a total borehole length of 2 475,00 m.

The minimum average borehole spacing is 6,00 m. This is defined as the average of the smallest distances between the centres of all pairs of boreholes in the borefield.

(The borehole depth is defined as the vertical distance between the ground surface and the deepest point of the borehole. The buried depth is the distance between the ground surface and the start of the borehole. The borehole length, sometimes called the 'active length' is the actual length of the heat exchanger measured along the borehole.)



The coordinates of the different boreholes are given in the table below.

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00

4.2.2 Results

Ground load

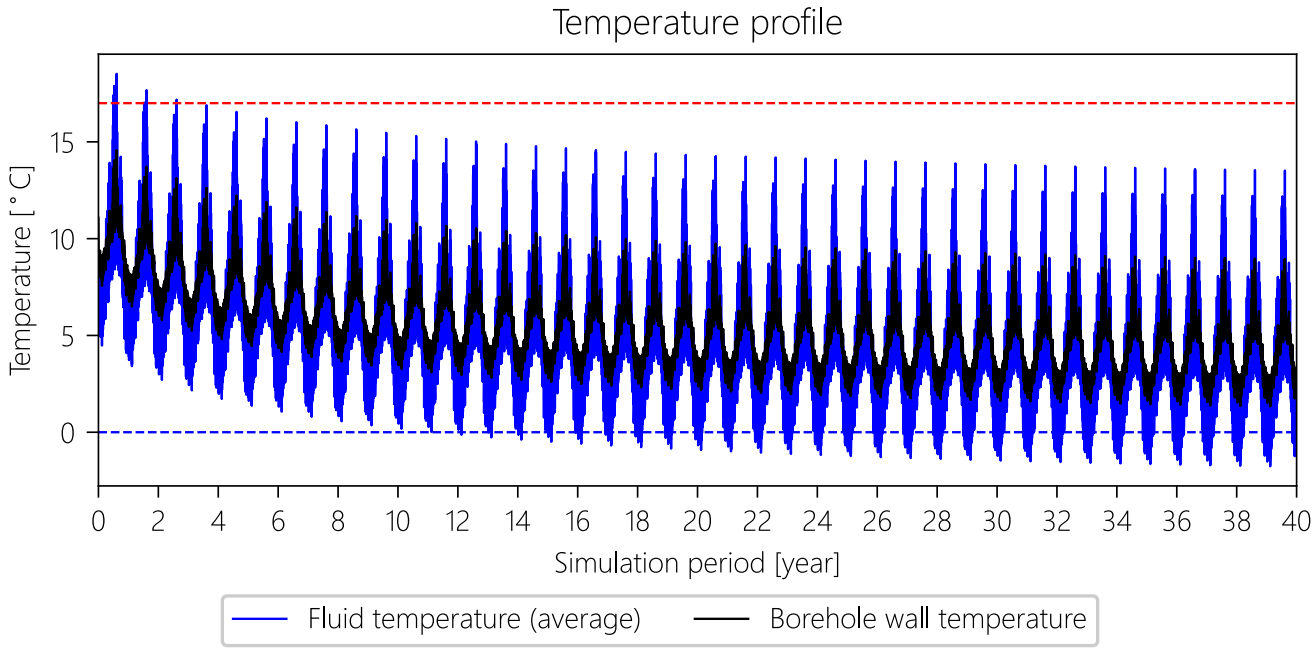
Because we are working with building loads (i.e. secondary loads), these must be converted into injection and extraction loads using the efficiency data. A summary of the resulting yearly ground load is given in the table below.

Ground demand	Yearly load	Peak power
Extraction demand	114 049 kWh/y	50,1 kW
Injection demand	25 288 kWh/y	101,5 kW

Temperature evolution of the borefield

Using the pipe, fluid, and flow properties, the Reynolds number was calculated. Since this number depends on the fluid temperature and therefore varies over the simulation period, it was updated at every timestep to achieve the most accurate result possible.
Doing so, the Reynolds number during heat extraction was 684, whilst it was 3 215 during injection. This corresponds respectively to a laminar and transient flow regime, with an effective borehole thermal resistance of 0,1530 m·K/W and 0,0937 m·K/W during heat extraction and injection.

Below, the hourly simulation for the borefield is shown. The blue line represents the average fluid temperature between the inlet and outlet of the borehole at each hour of the simulation. The black line shows the borehole wall temperature, which is the interface between the borehole and the ground. The difference between both lines is determined by the effective borehole thermal resistance.



The maximum average fluid temperature over the whole simulation period is 18,52 °C, and the minimum average fluid temperature is -1,76 °C.

Pressure drop

The pressure drop over a single borehole is 9,21 kPa during extration and 18,16 kPa during injection.

4.3 Hybrid cooling

In the first subsection, the scenario-specific input parameters will be discussed. Afterwards, the simulation results are presented.

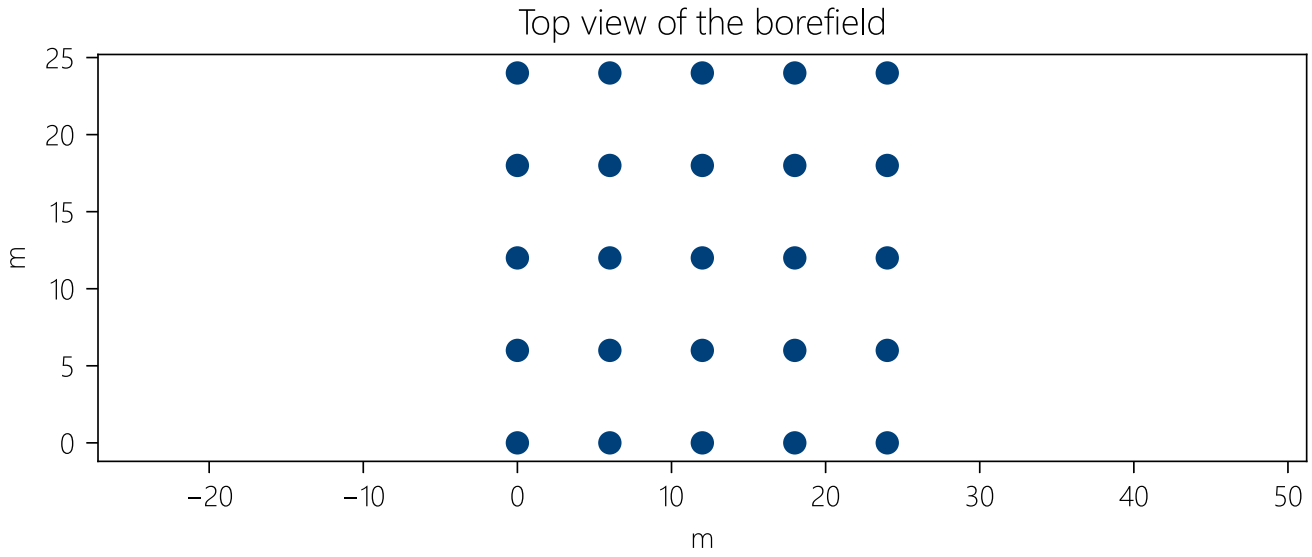
4.3.1 Input

Borefield configuration

The simulations were carried out with a borefield consisting of 25 boreholes, with an average buried depth of 1,00 m, an average borehole depth of 100,00 m and an average borehole length of 99,00 m. This results in a total borehole length of 2 475,00 m.

The minimum average borehole spacing is 6,00 m. This is defined as the average of the smallest distances between the centres of all pairs of boreholes in the borefield.

(The borehole depth is defined as the vertical distance between the ground surface and the deepest point of the borehole. The buried depth is the distance between the ground surface and the start of the borehole. The borehole length, sometimes called the 'active length' is the actual length of the heat exchanger measured along the borehole.)



The coordinates of the different boreholes are given in the table below.

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00

Hybrid system data

For the simulations, a hybrid system was considered. This was done by abstracting from the specific hybrid solution and working instead with a maximum power and a temperature threshold for the outside temperature, above or below which the hybrid solution is the preferred option. In the table below, one can find which hybrid solutions were taken into account.

For example, when a hybrid system of x kW of type 'heating above threshold' is used with a threshold of 15,00 °C, whenever the outside air temperature rises above 15,00 °C, this hybrid system switches on and takes x kW of the building heating demand. The remaining demand is therefore covered by the ground source heat pump.

Type of hybrid system	Threshold temperature [°C]	Maximum power [kW]
Cooling above threshold	20,00	25,00

The weather file that was used is: BEL_Brussels.064510_IWEC.epw.

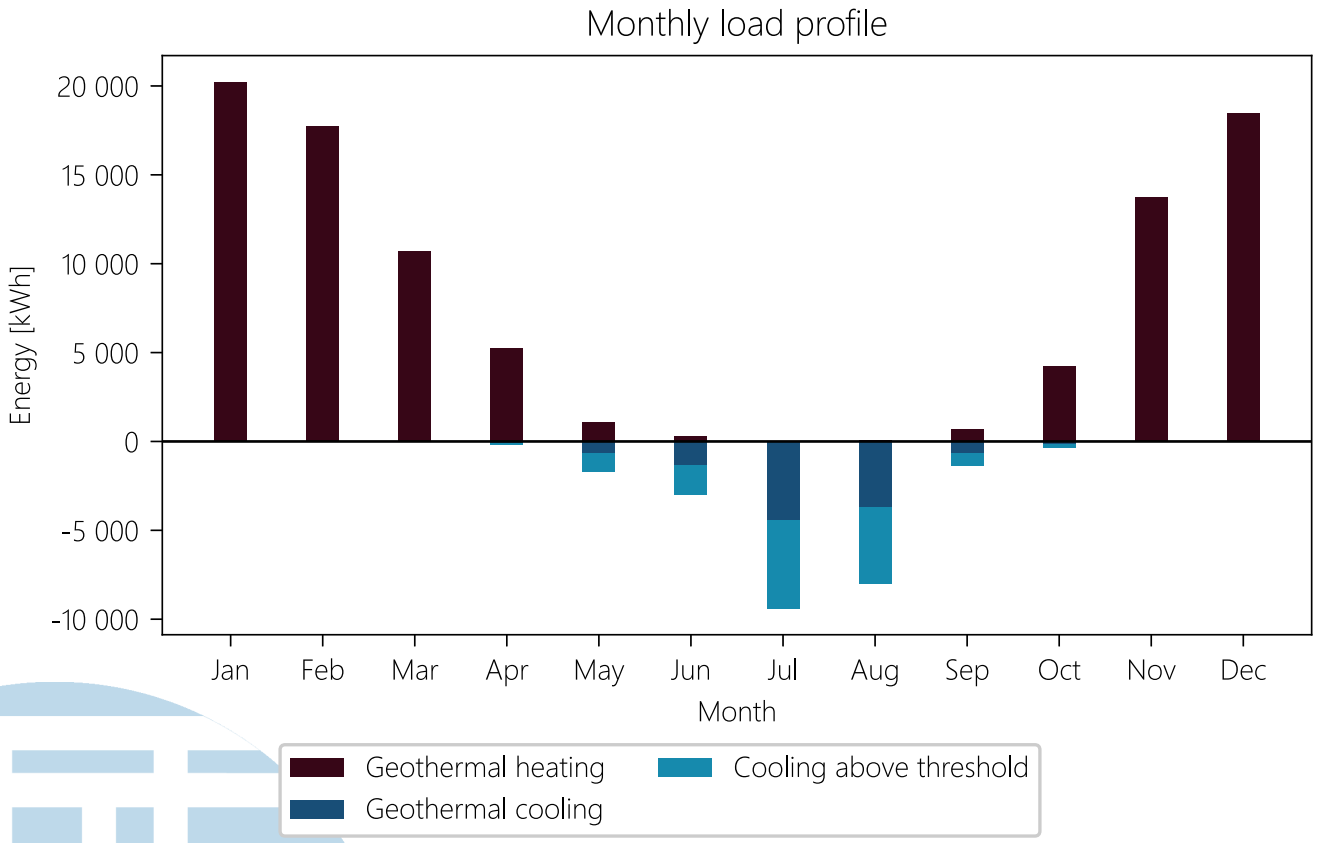
4.3.2 Results

Hybrid system

For this scenario, a hybrid system was simulated. Below you can find the yearly average share of the building load that is fulfilled by either the hybrid system or the geothermal system.

Yearly load	Heating demand	Cooling demand	Domestic hot water demand
Geothermal	92 547 kWh/y (100,00 %)	11 122 kWh/y (46,18 %)	60 017 kWh/y (100,00 %)
Hybrid	0 kWh/y (0,00 %)	12 961 kWh/y (53,82 %)	0 kWh/y (0,00 %)

Type of hybrid system	Heating demand	Cooling demand
Cooling above threshold	-	12 961 kWh/y



Ground load

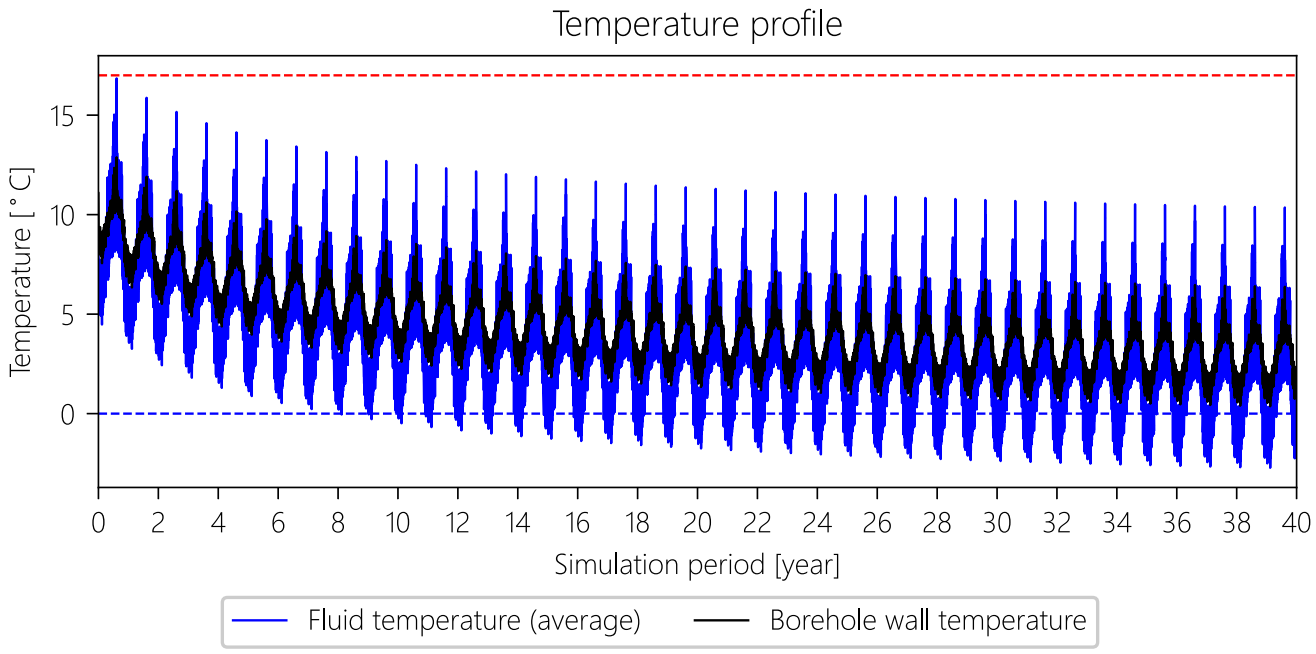
Because we are working with building loads (i.e. secondary loads), these must be converted into injection and extraction loads using the efficiency data. A summary of the resulting yearly ground load is given in the table below.

Ground demand	Yearly load	Peak power
Extraction demand	114 049 kWh/y	50,1 kW
Injection demand	11 678 kWh/y	75,3 kW

Temperature evolution of the borefield

Using the pipe, fluid, and flow properties, the Reynolds number was calculated. Since this number depends on the fluid temperature and therefore varies over the simulation period, it was updated at every timestep to achieve the most accurate result possible.
Doing so, the Reynolds number during heat extraction was 653, whilst it was 2 247 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,1531 m·K/W and 0,1404 m·K/W during heat extraction and injection.

Below, the hourly simulation for the borefield is shown. The blue line represents the average fluid temperature between the inlet and outlet of the borehole at each hour of the simulation. The black line shows the borehole wall temperature, which is the interface between the borehole and the ground. The difference between both lines is determined by the effective borehole thermal resistance.



The maximum average fluid temperature over the whole simulation period is 16,85 °C, and the minimum average fluid temperature is -2,72 °C.

Pressure drop

The pressure drop over a single borehole is 9,66 kPa during extration and 8,02 kPa during injection.

4.4 Hybrid cooling + heating

In the first subsection, the scenario-specific input parameters will be discussed. Afterwards, the simulation results are presented.

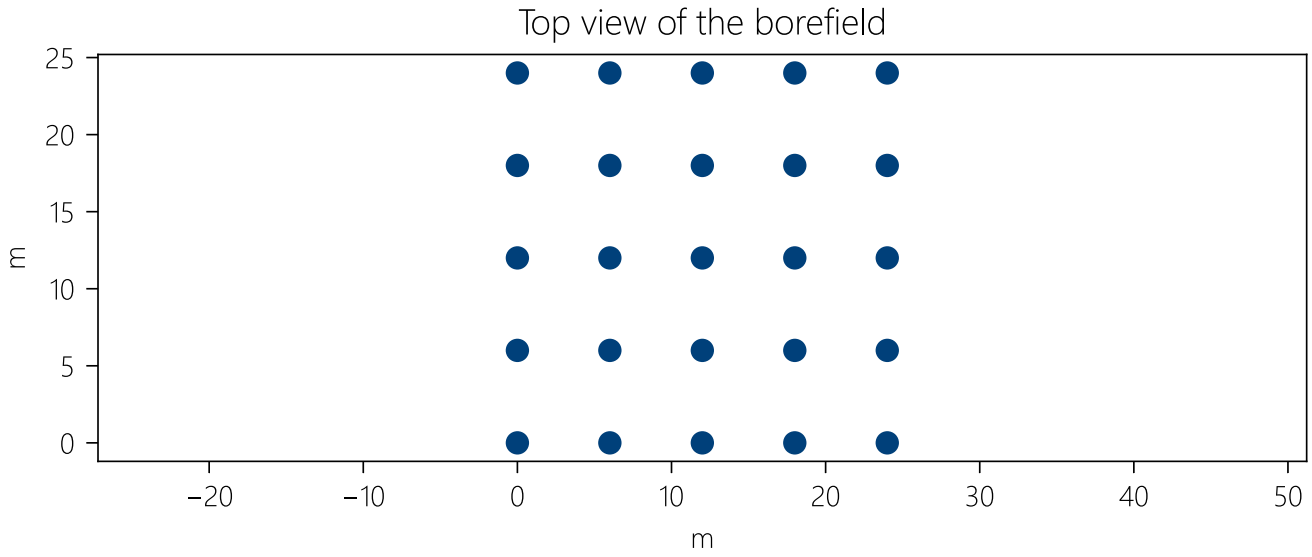
4.4.1 Input

Borefield configuration

The simulations were carried out with a borefield consisting of 25 boreholes, with an average buried depth of 1,00 m, an average borehole depth of 100,00 m and an average borehole length of 99,00 m. This results in a total borehole length of 2 475,00 m.

The minimum average borehole spacing is 6,00 m. This is defined as the average of the smallest distances between the centres of all pairs of boreholes in the borefield.

(The borehole depth is defined as the vertical distance between the ground surface and the deepest point of the borehole. The buried depth is the distance between the ground surface and the start of the borehole. The borehole length, sometimes called the 'active length' is the actual length of the heat exchanger measured along the borehole.)



The coordinates of the different boreholes are given in the table below.

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00

Hybrid system data

For the simulations, a hybrid system was considered. This was done by abstracting from the specific hybrid solution and working instead with a maximum power and a temperature threshold for the outside temperature, above or below which the hybrid solution is the preferred option. In the table below, one can find which hybrid solutions were taken into account.

For example, when a hybrid system of x kW of type 'heating above threshold' is used with a threshold of 15,00 °C, whenever the outside air temperature rises above 15,00 °C, this hybrid system switches on and takes x kW of the building heating demand. The remaining demand is therefore covered by the ground source heat pump.

Type of hybrid system	Threshold temperature [°C]	Maximum power [kW]
Heating above threshold	8,00	25,00
Cooling above threshold	20,00	25,00

The weather file that was used is: BEL_Brussels.064510_IWEC.epw.

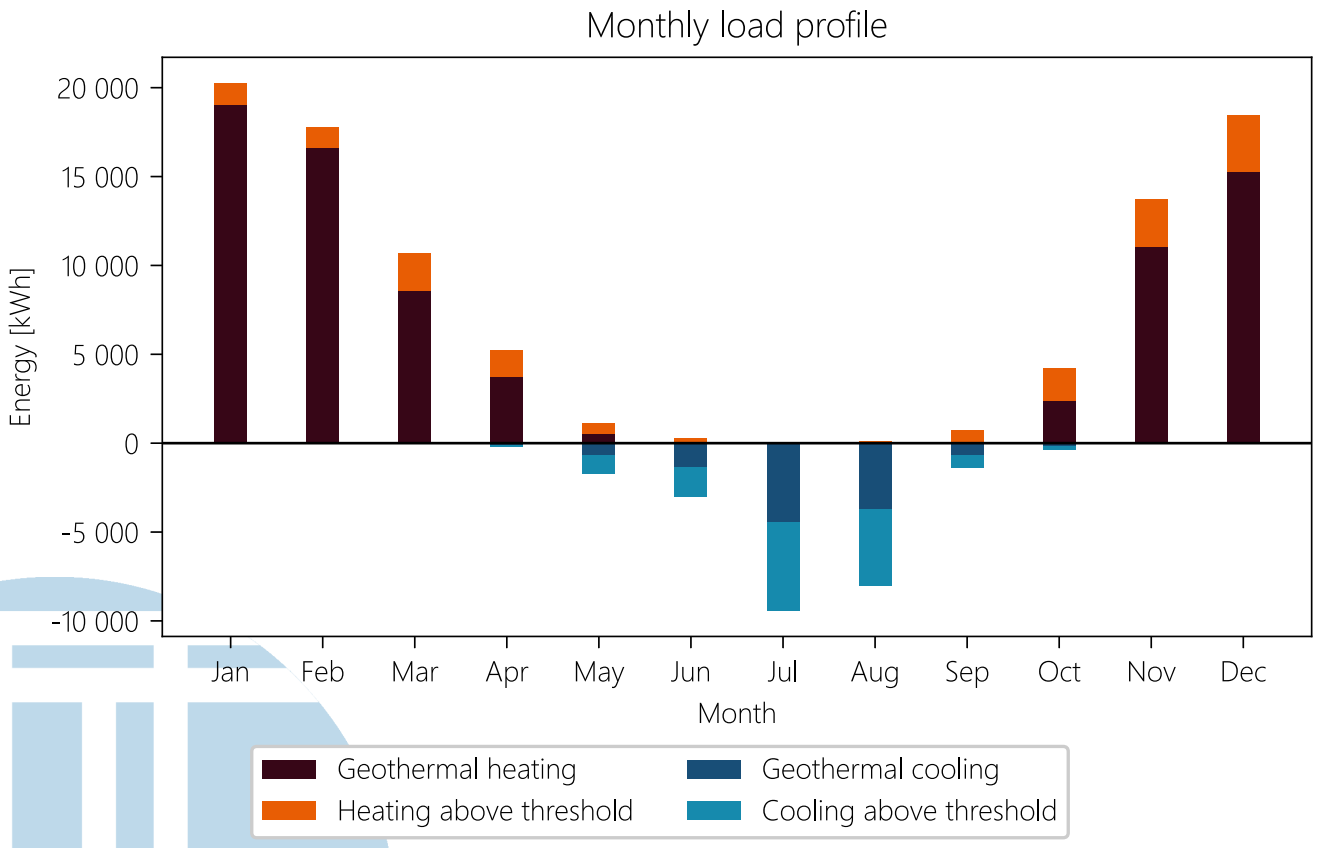
4.4.2 Results

Hybrid system

For this scenario, a hybrid system was simulated. Below you can find the yearly average share of the building load that is fulfilled by either the hybrid system or the geothermal system.

Yearly load	Heating demand	Cooling demand	Domestic hot water demand
Geothermal	77 263 kWh/y (83,49 %)	11 122 kWh/y (46,18 %)	60 017 kWh/y (100,00 %)
Hybrid	15 283 kWh/y (16,51 %)	12 961 kWh/y (53,82 %)	0 kWh/y (0,00 %)

Type of hybrid system	Heating demand	Cooling demand
Heating above threshold	15 283 kWh/y	-
Cooling above threshold	-	12 961 kWh/y



Ground load

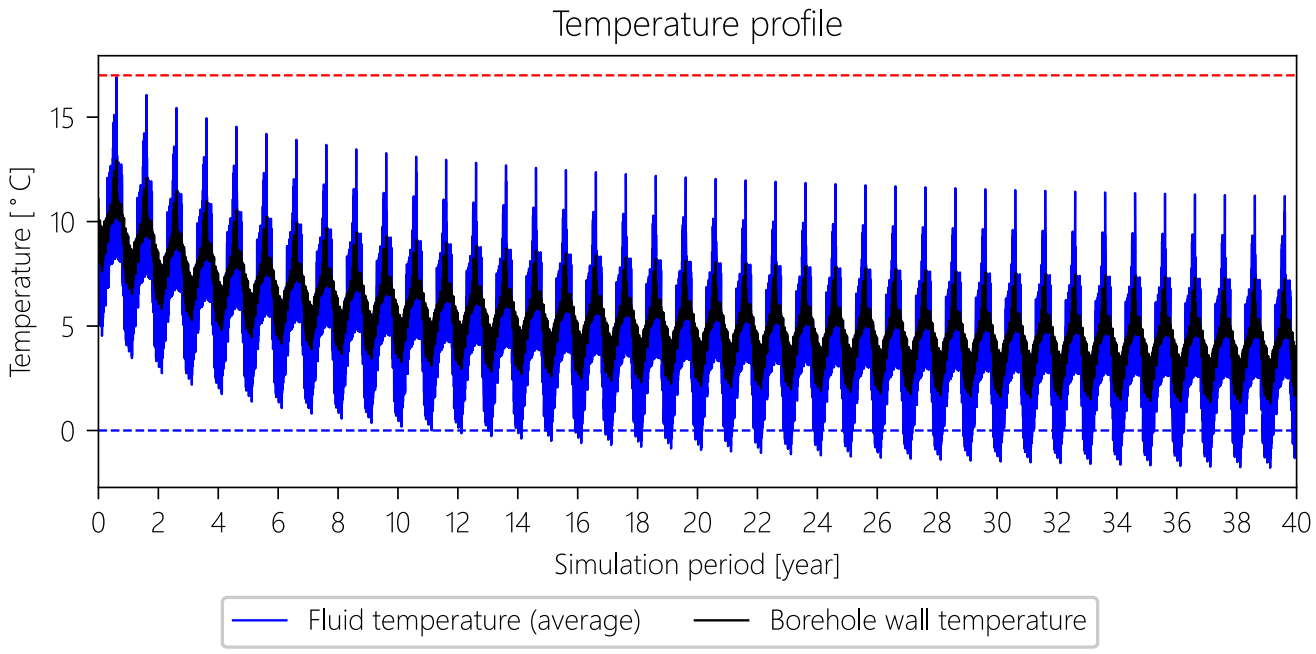
Because we are working with building loads (i.e. secondary loads), these must be converted into injection and extraction loads using the efficiency data. A summary of the resulting yearly ground load is given in the table below.

Ground demand	Yearly load	Peak power
Extraction demand	101 822 kWh/y	50,1 kW
Injection demand	11 678 kWh/y	75,3 kW

Temperature evolution of the borefield

Using the pipe, fluid, and flow properties, the Reynolds number was calculated. Since this number depends on the fluid temperature and therefore varies over the simulation period, it was updated at every timestep to achieve the most accurate result possible.
Doing so, the Reynolds number during heat extraction was 684, whilst it was 2 252 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,1530 m·K/W and 0,1404 m·K/W during heat extraction and injection.

Below, the hourly simulation for the borefield is shown. The blue line represents the average fluid temperature between the inlet and outlet of the borehole at each hour of the simulation. The black line shows the borehole wall temperature, which is the interface between the borehole and the ground. The difference between both lines is determined by the effective borehole thermal resistance.



The maximum average fluid temperature over the whole simulation period is 16,92 °C, and the minimum average fluid temperature is -1,79 °C.

Pressure drop

The pressure drop over a single borehole is 9,22 kPa during extration and 7,74 kPa during injection.

4.5 Hybrid cooling + heating + top heating

In the first subsection, the scenario-specific input parameters will be discussed. Afterwards, the simulation results are presented.

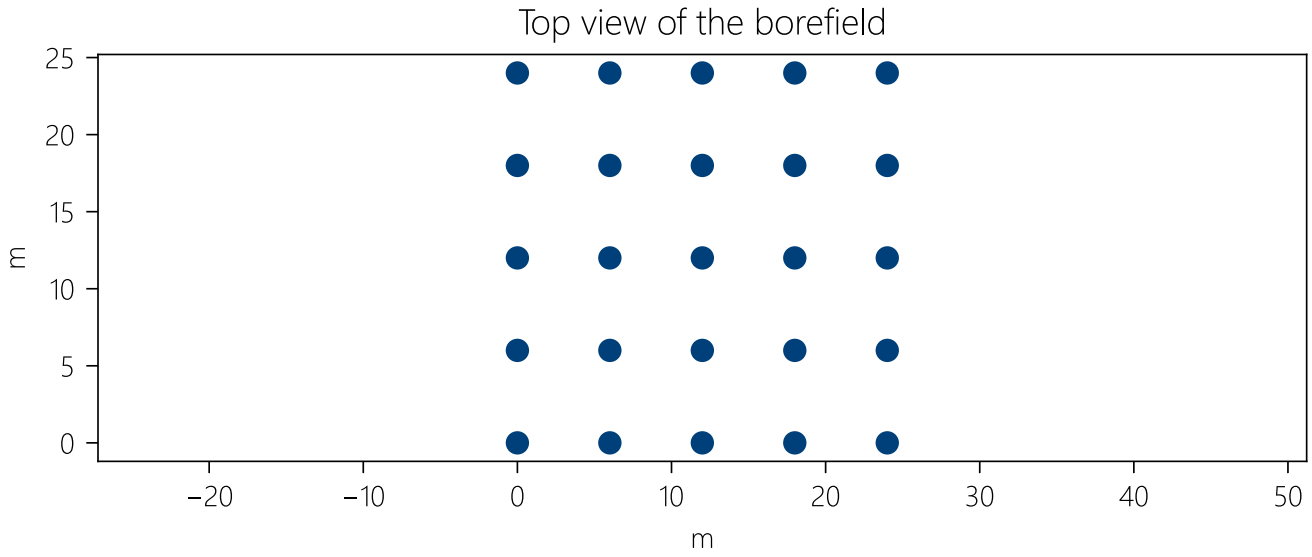
4.5.1 Input

Borefield configuration

The simulations were carried out with a borefield consisting of 25 boreholes, with an average buried depth of 1,00 m, an average borehole depth of 100,00 m and an average borehole length of 99,00 m. This results in a total borehole length of 2 475,00 m.

The minimum average borehole spacing is 6,00 m. This is defined as the average of the smallest distances between the centres of all pairs of boreholes in the borefield.

(The borehole depth is defined as the vertical distance between the ground surface and the deepest point of the borehole. The buried depth is the distance between the ground surface and the start of the borehole. The borehole length, sometimes called the 'active length' is the actual length of the heat exchanger measured along the borehole.)



The coordinates of the different boreholes are given in the table below.

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00

Hybrid system data

For the simulations, a hybrid system was considered. This was done by abstracting from the specific hybrid solution and working instead with a maximum power and a temperature threshold for the outside temperature, above or below which the hybrid solution is the preferred option. In the table below, one can find which hybrid solutions were taken into account.

For example, when a hybrid system of x kW of type 'heating above threshold' is used with a threshold of 15,00 °C, whenever the outside air temperature rises above 15,00 °C, this hybrid system switches on and takes x kW of the building heating demand. The remaining demand is therefore covered by the ground source heat pump.

Type of hybrid system	Threshold temperature [°C]	Maximum power [kW]
Heating above threshold	8,00	25,00
Heating below threshold	1,00	20,00
Cooling above threshold	20,00	25,00

The weather file that was used is: BEL_Brussels.064510_IWEC.epw.

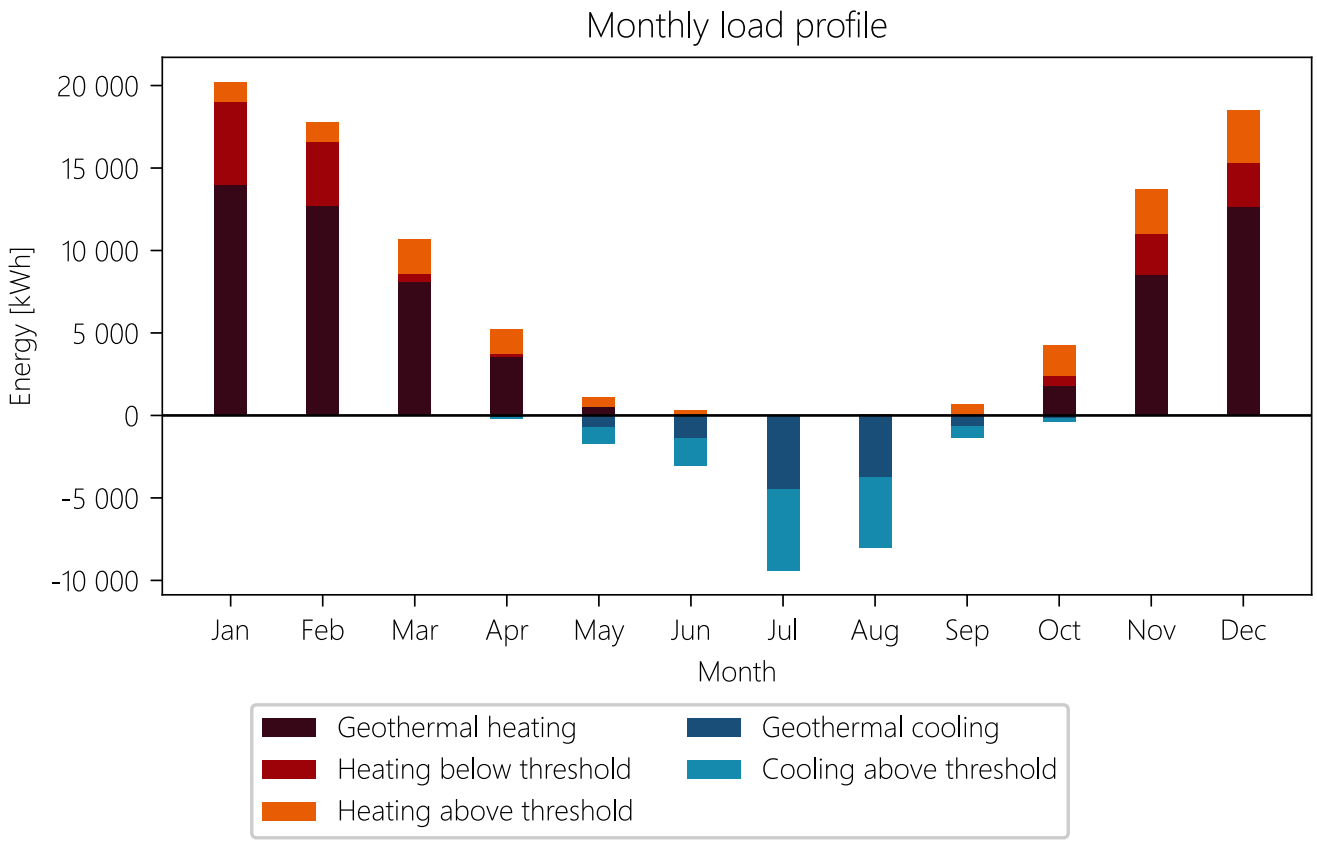
4.5.2 Results

Hybrid system

For this scenario, a hybrid system was simulated. Below you can find the yearly average share of the building load that is fulfilled by either the hybrid system or the geothermal system.

Yearly load	Heating demand	Cooling demand	Domestic hot water demand
Geothermal	61 779 kWh/y (66,75 %)	11 122 kWh/y (46,18 %)	60 017 kWh/y (100,00 %)
Hybrid	30 768 kWh/y (33,25 %)	12 961 kWh/y (53,82 %)	0 kWh/y (0,00 %)

Type of hybrid system	Heating demand	Cooling demand
Heating below threshold	15 485 kWh/y	-
Heating above threshold	15 283 kWh/y	-
Cooling above threshold	-	12 961 kWh/y



Ground load

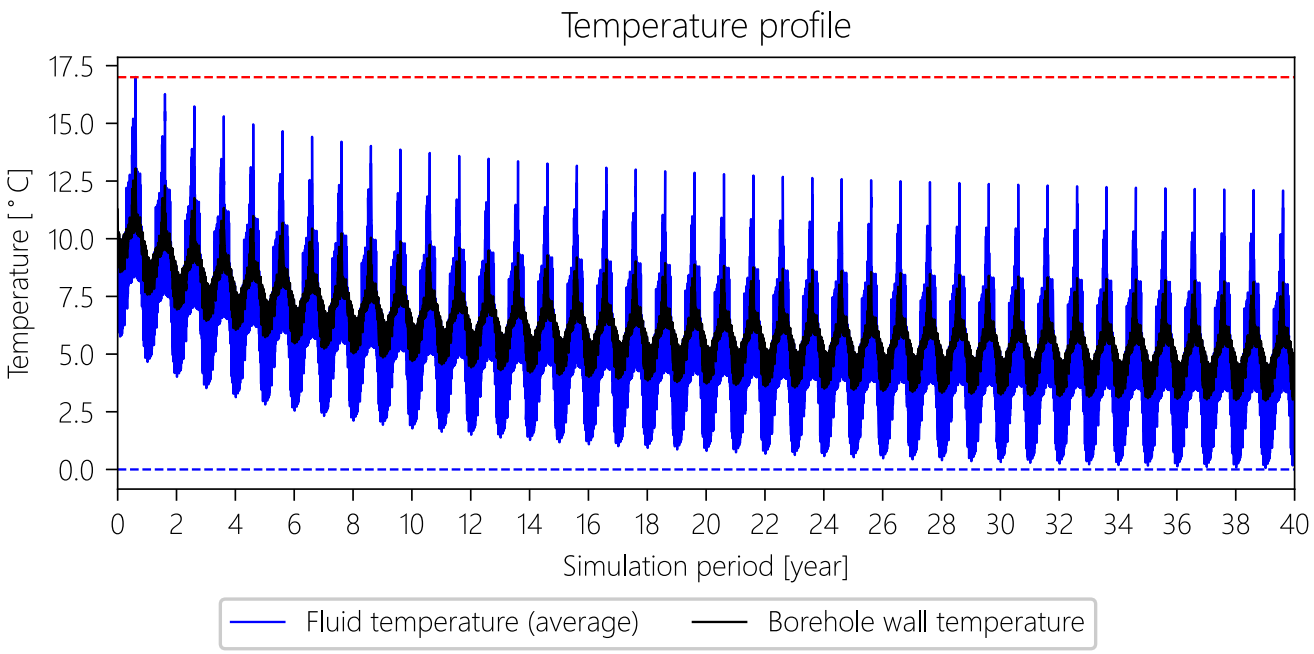
Because we are working with building loads (i.e. secondary loads), these must be converted into injection and extraction loads using the efficiency data. A summary of the resulting yearly ground load is given in the table below.

Ground demand	Yearly load	Peak power
Extraction demand	89 434 kWh/y	47,7 kW
Injection demand	11 678 kWh/y	75,3 kW

Temperature evolution of the borefield

Using the pipe, fluid, and flow properties, the Reynolds number was calculated. Since this number depends on the fluid temperature and therefore varies over the simulation period, it was updated at every timestep to achieve the most accurate result possible.
Doing so, the Reynolds number during heat extraction was 711, whilst it was 2 260 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,1548 m·K/W and 0,1404 m·K/W during heat extraction and injection.

Below, the hourly simulation for the borefield is shown. The blue line represents the average fluid temperature between the inlet and outlet of the borehole at each hour of the simulation. The black line shows the borehole wall temperature, which is the interface between the borehole and the ground. The difference between both lines is determined by the effective borehole thermal resistance.



The maximum average fluid temperature over the whole simulation period is 17,01 °C, and the minimum average fluid temperature is 0,06 °C.

Pressure drop

The pressure drop over a single borehole is 7,98 kPa during extration and 7,47 kPa during injection.

4.6 Limit borefield power

In the first subsection, the scenario-specific input parameters will be discussed. Afterwards, the simulation results are presented.

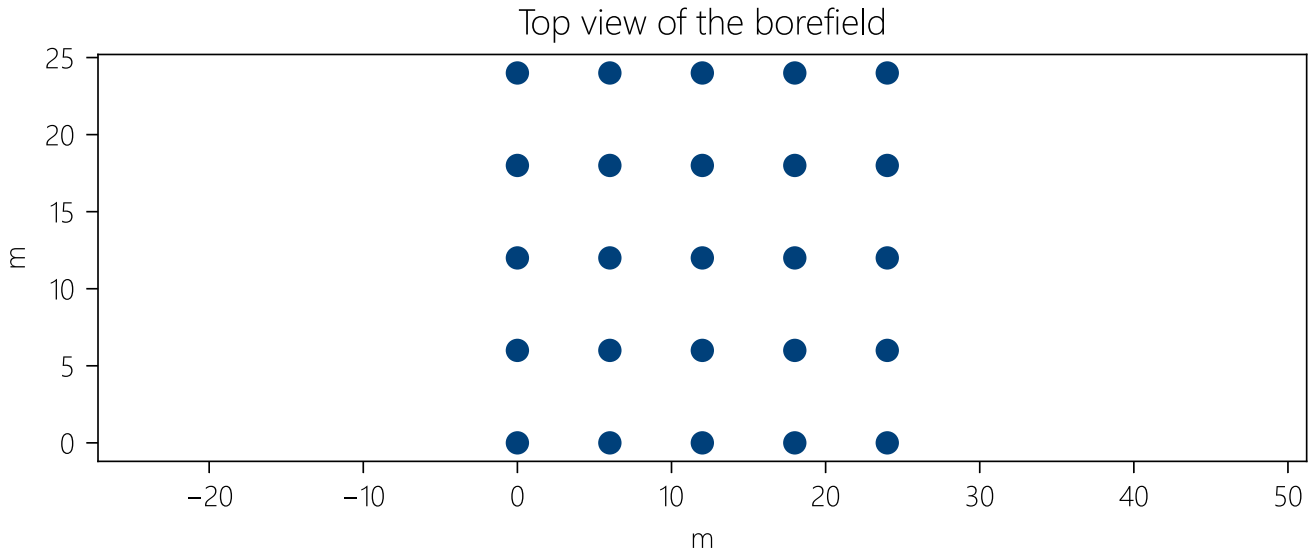
4.6.1 Input

Borefield configuration

The simulations were carried out with a borefield consisting of 25 boreholes, with an average buried depth of 1,00 m, an average borehole depth of 100,00 m and an average borehole length of 99,00 m. This results in a total borehole length of 2 475,00 m.

The minimum average borehole spacing is 6,00 m. This is defined as the average of the smallest distances between the centres of all pairs of boreholes in the borefield.

(The borehole depth is defined as the vertical distance between the ground surface and the deepest point of the borehole. The buried depth is the distance between the ground surface and the start of the borehole. The borehole length, sometimes called the 'active length' is the actual length of the heat exchanger measured along the borehole.)



The coordinates of the different boreholes are given in the table below.

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00

Hybrid system data

The maximum installed geothermal heating and cooling power was set to respectively 25,00 kW and 50,00 kW.

4.6.2 Results

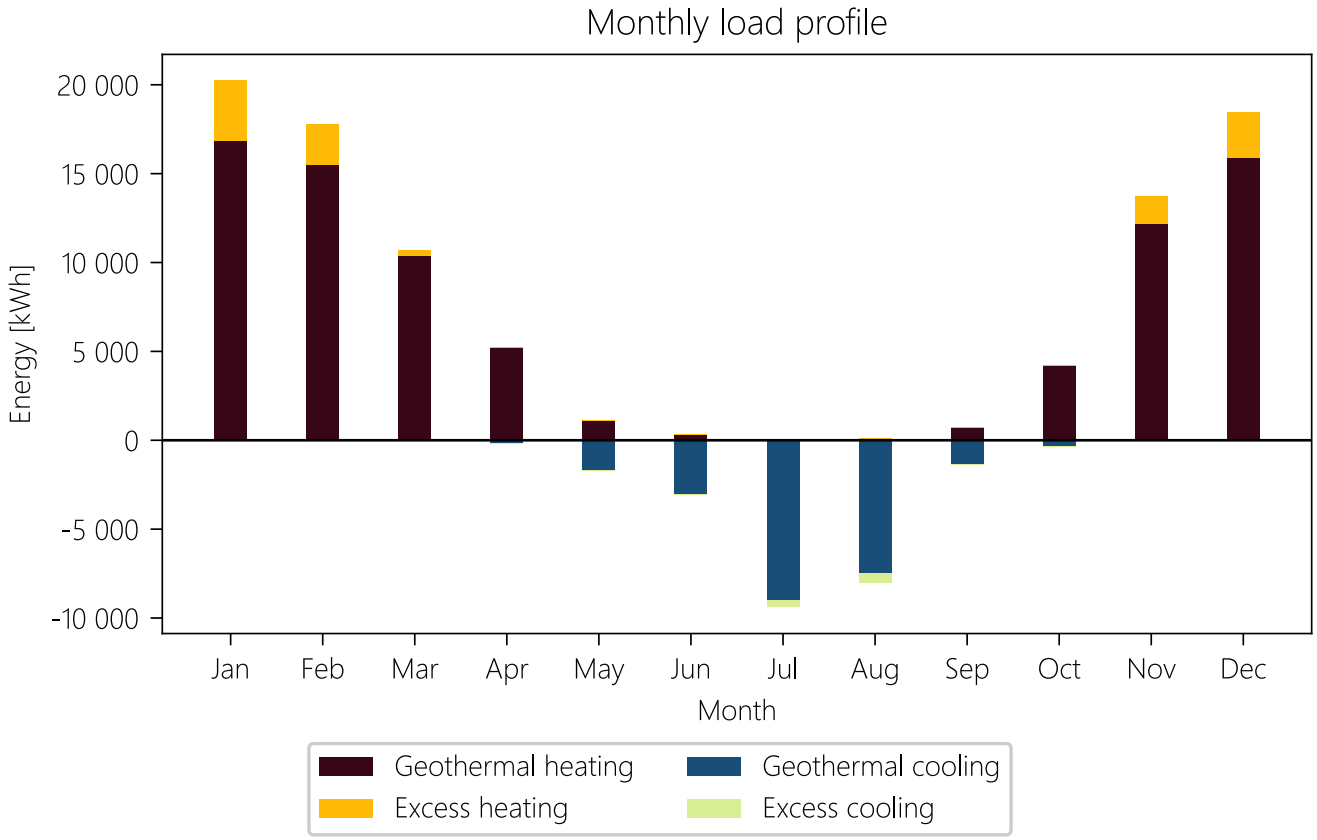
Hybrid system

For this scenario, a hybrid system was simulated. Below you can find the yearly average share of the building load that is fulfilled by either the hybrid system or the geothermal system.

Yearly load	Heating demand	Cooling demand	Domestic hot water demand
Geothermal	82 432 kWh/y (89,07 %)	23 177 kWh/y (96,24 %)	60 017 kWh/y (100,00 %)
Hybrid	10 115 kWh/y (10,93 %)	906 kWh/y (3,76 %)	0 kWh/y (0,00 %)

Type of hybrid system	Heating demand	Cooling demand
Excess	10 115 kWh/y	906 kWh/y

Due to a limitation set for the geothermal power, part of the heating and cooling cannot be delivered by the current system. This amount is indicated as 'excess' heating or cooling. In practice, this means that if no other (existing) hybrid system covers this gap, the building demand is not met. The maximum excess power is 22,73 kW for heating and 46,69 kW for cooling.



Ground load

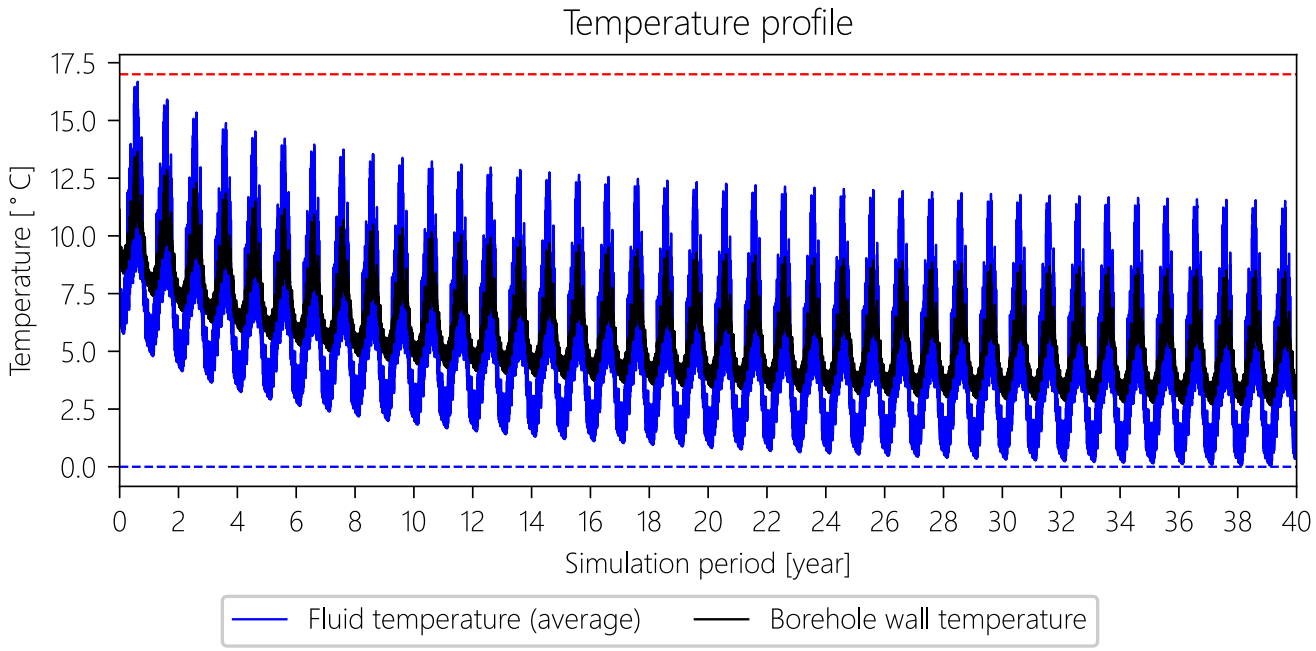
Because we are working with building loads (i.e. secondary loads), these must be converted into injection and extraction loads using the efficiency data. A summary of the resulting yearly ground load is given in the table below.

Ground demand	Yearly load	Peak power
Extraction demand	105 957 kWh/y	39,7 kW
Injection demand	24 336 kWh/y	52,5 kW

Temperature evolution of the borefield

Using the pipe, fluid, and flow properties, the Reynolds number was calculated. Since this number depends on the fluid temperature and therefore varies over the simulation period, it was updated at every timestep to achieve the most accurate result possible.
Doing so, the Reynolds number during heat extraction was 591, whilst it was 1 557 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,1640 m·K/W and 0,1497 m·K/W during heat extraction and injection.

Below, the hourly simulation for the borefield is shown. The blue line represents the average fluid temperature between the inlet and outlet of the borehole at each hour of the simulation. The black line shows the borehole wall temperature, which is the interface between the borehole and the ground. The difference between both lines is determined by the effective borehole thermal resistance.



The maximum average fluid temperature over the whole simulation period is 16,68 °C, and the minimum average fluid temperature is 0,03 °C.

Pressure drop

The pressure drop over a single borehole is 6,69 kPa during extration and 5,67 kPa during injection.

5.1 Design Data - Req size

Design parameters

- Maximum average fluid temperature: 17 °C
- Minimum average fluid temperature: 0 °C
- First month of simulation: 1
- Simulation period: 40 years

Ground parameters

- Homogeneous ground conductivity: 2 W/(m·K)
- Homogeneous volumetric heat capacity: 2,4 MJ/(m^3·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m^2

Borehole parameters

- Borehole diameter: 140 mm

Pipe parameters

- U tube DN32 PN16
- Grout thermal conductivity: 1,5 W/(m·K)
- Number of U-tubes: 2
- Pipe conductivity: 0,4 W/(m·K)
- Pipe roughness: 0,001 mm

Fluid properties

- 25.0 v/v% MPG
- Temperature difference in extraction: 3 °C
- Temperature difference in injection: 3 °C
- Minimum flow percentage: 10
- Flow rate through borefield in extraction: 4,21 l/s
- Flow rate through borefield in injection: 8,50 l/s
- Number of boreholes in series: 1

Thermal demand

- Type of load: Hourly building load
- Domestic hot water: 60 016,95 kWh/year
- SCOP heating: 5
- SCOP domestic hot water: 3
- SEER cooling: 20

Borefield parameters

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
5,00	0,00	99,00	100,00	1,00	0,00	0,00
10,00	0,00	99,00	100,00	1,00	0,00	0,00
15,00	0,00	99,00	100,00	1,00	0,00	0,00
20,00	0,00	99,00	100,00	1,00	0,00	0,00
25,00	0,00	99,00	100,00	1,00	0,00	0,00
30,00	0,00	99,00	100,00	1,00	0,00	0,00
35,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,50	99,00	100,00	1,00	0,00	0,00
5,00	6,50	99,00	100,00	1,00	0,00	0,00
10,00	6,50	99,00	100,00	1,00	0,00	0,00
15,00	6,50	99,00	100,00	1,00	0,00	0,00
20,00	6,50	99,00	100,00	1,00	0,00	0,00
25,00	6,50	99,00	100,00	1,00	0,00	0,00
30,00	6,50	99,00	100,00	1,00	0,00	0,00
35,00	6,50	99,00	100,00	1,00	0,00	0,00
0,00	13,00	99,00	100,00	1,00	0,00	0,00
5,00	13,00	99,00	100,00	1,00	0,00	0,00
10,00	13,00	99,00	100,00	1,00	0,00	0,00
15,00	13,00	99,00	100,00	1,00	0,00	0,00
20,00	13,00	99,00	100,00	1,00	0,00	0,00
25,00	13,00	99,00	100,00	1,00	0,00	0,00
30,00	13,00	99,00	100,00	1,00	0,00	0,00
35,00	13,00	99,00	100,00	1,00	0,00	0,00
0,00	19,50	99,00	100,00	1,00	0,00	0,00
5,00	19,50	99,00	100,00	1,00	0,00	0,00
10,00	19,50	99,00	100,00	1,00	0,00	0,00
15,00	19,50	99,00	100,00	1,00	0,00	0,00
20,00	19,50	99,00	100,00	1,00	0,00	0,00
25,00	19,50	99,00	100,00	1,00	0,00	0,00
30,00	19,50	99,00	100,00	1,00	0,00	0,00
35,00	19,50	99,00	100,00	1,00	0,00	0,00
0,00	26,00	99,00	100,00	1,00	0,00	0,00
5,00	26,00	99,00	100,00	1,00	0,00	0,00
10,00	26,00	99,00	100,00	1,00	0,00	0,00
15,00	26,00	99,00	100,00	1,00	0,00	0,00
20,00	26,00	99,00	100,00	1,00	0,00	0,00

25,00	26,00	99,00	100,00	1,00	0,00	0,00
30,00	26,00	99,00	100,00	1,00	0,00	0,00
35,00	26,00	99,00	100,00	1,00	0,00	0,00

5.2 Design Data - Temperature profile

Design parameters

- Maximum average fluid temperature: 17 °C
- Minimum average fluid temperature: 0 °C
- First month of simulation: 1
- Simulation period: 40 years

Ground parameters

- Homogeneous ground conductivity: 2 W/(m·K)
- Homogeneous volumetric heat capacity: 2,4 MJ/(m^3·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m^2

Borehole parameters

- Borehole diameter: 140 mm

Pipe parameters

- U tube DN32 PN16
- Grout thermal conductivity: 1,5 W/(m·K)
- Number of U-tubes: 2
- Pipe conductivity: 0,4 W/(m·K)
- Pipe roughness: 0,001 mm

Fluid properties

- 25.0 v/v% MPG
- Temperature difference in extraction: 3 °C
- Temperature difference in injection: 3 °C
- Minimum flow percentage: 10
- Flow rate through borefield in extraction: 4,21 l/s
- Flow rate through borefield in injection: 8,49 l/s
- Number of boreholes in series: 1

Thermal demand

- Type of load: Hourly building load
- Domestic hot water: 60 016,95 kWh/year
- SCOP heating: 5
- SCOP domestic hot water: 3
- SEER cooling: 20

Borefield parameters

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00

5.3 Design Data - Hybrid cooling

Design parameters

- Maximum average fluid temperature: 17 °C
- Minimum average fluid temperature: 0 °C
- First month of simulation: 1
- Simulation period: 40 years

Ground parameters

- Homogeneous ground conductivity: 2 W/(m·K)
- Homogeneous volumetric heat capacity: 2,4 MJ/(m^3·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m^2

Borehole parameters

- Borehole diameter: 140 mm

Pipe parameters

- U tube DN32 PN16
- Grout thermal conductivity: 1,5 W/(m·K)
- Number of U-tubes: 2
- Pipe conductivity: 0,4 W/(m·K)
- Pipe roughness: 0,001 mm

Fluid properties

- 25.0 v/v% MPG
- Temperature difference in extraction: 3 °C
- Temperature difference in injection: 3 °C
- Minimum flow percentage: 10
- Flow rate through borefield in extraction: 4,21 l/s
- Flow rate through borefield in injection: 6,30 l/s
- Number of boreholes in series: 1

Thermal demand

- Type of load: Hourly building load
- Domestic hot water: 60 016,95 kWh/year
- SCOP heating: 5
- SCOP domestic hot water: 3
- SEER cooling: 20

Borefield parameters

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00

5.4 Design Data - Hybrid cooling + heating

Design parameters

- Maximum average fluid temperature: 17 °C
- Minimum average fluid temperature: 0 °C
- First month of simulation: 1
- Simulation period: 40 years

Ground parameters

- Homogeneous ground conductivity: 2 W/(m·K)
- Homogeneous volumetric heat capacity: 2,4 MJ/(m^3·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m^2

Borehole parameters

- Borehole diameter: 140 mm

Pipe parameters

- U tube DN32 PN16
- Grout thermal conductivity: 1,5 W/(m·K)
- Number of U-tubes: 2
- Pipe conductivity: 0,4 W/(m·K)
- Pipe roughness: 0,001 mm

Fluid properties

- 25.0 v/v% MPG
- Temperature difference in extraction: 3 °C
- Temperature difference in injection: 3 °C
- Minimum flow percentage: 10
- Flow rate through borefield in extraction: 4,21 l/s
- Flow rate through borefield in injection: 6,30 l/s
- Number of boreholes in series: 1

Thermal demand

- Type of load: Hourly building load
- Domestic hot water: 60 016,95 kWh/year
- SCOP heating: 5
- SCOP domestic hot water: 3
- SEER cooling: 20

Borefield parameters

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00

5.5 Design Data - Hybrid cooling + heating + top heating

Design parameters

- Maximum average fluid temperature: 17 °C
- Minimum average fluid temperature: 0 °C
- First month of simulation: 1
- Simulation period: 40 years

Ground parameters

- Homogeneous ground conductivity: 2 W/(m·K)
- Homogeneous volumetric heat capacity: 2,4 MJ/(m^3·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m^2

Borehole parameters

- Borehole diameter: 140 mm

Pipe parameters

- U tube DN32 PN16
- Grout thermal conductivity: 1,5 W/(m·K)
- Number of U-tubes: 2
- Pipe conductivity: 0,4 W/(m·K)
- Pipe roughness: 0,001 mm

Fluid properties

- 25.0 v/v% MPG
- Temperature difference in extraction: 3 °C
- Temperature difference in injection: 3 °C
- Minimum flow percentage: 10
- Flow rate through borefield in extraction: 4,01 l/s
- Flow rate through borefield in injection: 6,30 l/s
- Number of boreholes in series: 1

Thermal demand

- Type of load: Hourly building load
- Domestic hot water: 60 016,95 kWh/year
- SCOP heating: 5
- SCOP domestic hot water: 3
- SEER cooling: 20

Borefield parameters

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00

5.6 Design Data - Limit borefield power

Design parameters

- Maximum average fluid temperature: 17 °C
- Minimum average fluid temperature: 0 °C
- First month of simulation: 1
- Simulation period: 40 years

Ground parameters

- Homogeneous ground conductivity: 2 W/(m·K)
- Homogeneous volumetric heat capacity: 2,4 MJ/(m^3·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m^2

Borehole parameters

- Borehole diameter: 140 mm

Pipe parameters

- U tube DN32 PN16
- Grout thermal conductivity: 1,5 W/(m·K)
- Number of U-tubes: 2
- Pipe conductivity: 0,4 W/(m·K)
- Pipe roughness: 0,001 mm

Fluid properties

- 25.0 v/v% MPG
- Temperature difference in extraction: 3 °C
- Temperature difference in injection: 3 °C
- Minimum flow percentage: 10
- Flow rate through borefield in extraction: 3,34 l/s
- Flow rate through borefield in injection: 4,40 l/s
- Number of boreholes in series: 1

Thermal demand

- Type of load: Hourly building load
- Domestic hot water: 60 016,95 kWh/year
- SCOP heating: 5
- SCOP domestic hot water: 3
- SEER cooling: 20

Borefield parameters

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	99,00	100,00	1,00	0,00	0,00
0,00	6,00	99,00	100,00	1,00	0,00	0,00
0,00	12,00	99,00	100,00	1,00	0,00	0,00
0,00	18,00	99,00	100,00	1,00	0,00	0,00
0,00	24,00	99,00	100,00	1,00	0,00	0,00
6,00	0,00	99,00	100,00	1,00	0,00	0,00
6,00	6,00	99,00	100,00	1,00	0,00	0,00
6,00	12,00	99,00	100,00	1,00	0,00	0,00
6,00	18,00	99,00	100,00	1,00	0,00	0,00
6,00	24,00	99,00	100,00	1,00	0,00	0,00
12,00	0,00	99,00	100,00	1,00	0,00	0,00
12,00	6,00	99,00	100,00	1,00	0,00	0,00
12,00	12,00	99,00	100,00	1,00	0,00	0,00
12,00	18,00	99,00	100,00	1,00	0,00	0,00
12,00	24,00	99,00	100,00	1,00	0,00	0,00
18,00	0,00	99,00	100,00	1,00	0,00	0,00
18,00	6,00	99,00	100,00	1,00	0,00	0,00
18,00	12,00	99,00	100,00	1,00	0,00	0,00
18,00	18,00	99,00	100,00	1,00	0,00	0,00
18,00	24,00	99,00	100,00	1,00	0,00	0,00
24,00	0,00	99,00	100,00	1,00	0,00	0,00
24,00	6,00	99,00	100,00	1,00	0,00	0,00
24,00	12,00	99,00	100,00	1,00	0,00	0,00
24,00	18,00	99,00	100,00	1,00	0,00	0,00
24,00	24,00	99,00	100,00	1,00	0,00	0,00



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