

GHEtool calculation report

Course 8.3



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Licensed report by:

Enead BV

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1.1 Structure of the report

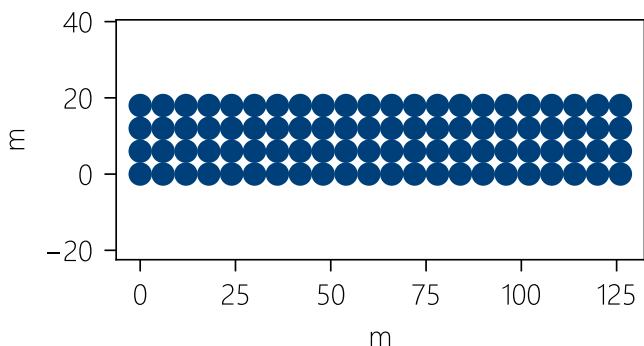
First, in Chapter 2, a summary of all the simulations will be provided. Chapter 3 discusses the inputs that are consistent across all scenarios. In Chapter 4, the different simulation results are presented and discussed. Chapter 5 contains appendices with more detailed information.



2. Summary of the simulations

2.1 Scenario 1

Input



Number of boreholes: 88

Average minimum borehole spacing: 6,0 m

Borehole depth (w.r.t. surface): 150,0 m

2 x U tube DN32 PN16

25,0 v/v% MPG

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

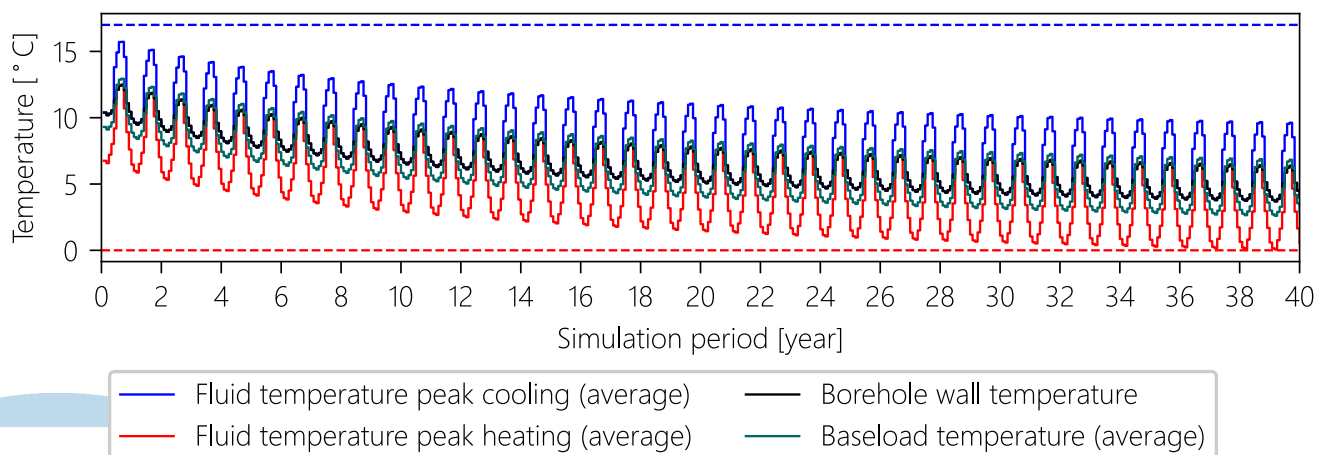
Building demand	Yearly load	Peak power
Heating demand	408 000 kWh/y	272,0 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	160,0 kW

Results

Effective borehole thermal resistance (extraction): 0,1621 m·K/W, Reynolds number: 922 (laminar)

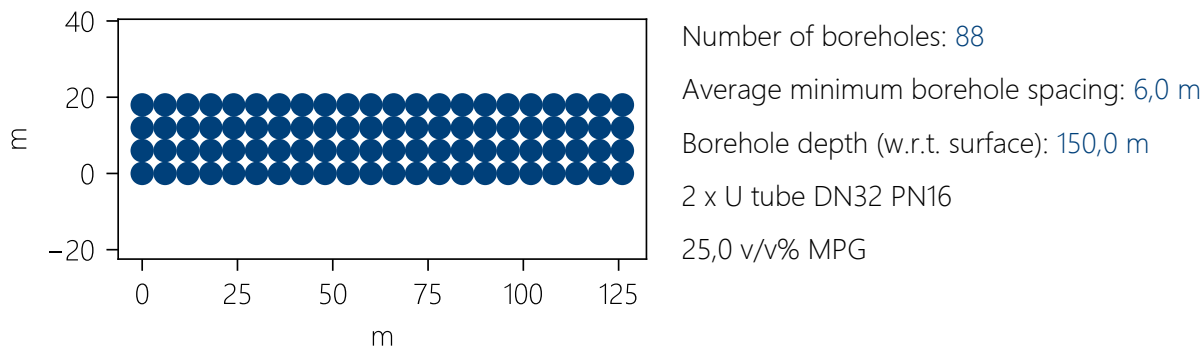
Effective borehole thermal resistance (injection): 0,1794 m·K/W, Reynolds number: 1 368 (laminar)

Maximum average fluid temperature: 15,73 °C, Minimum average fluid temperature: 0,06 °C



2.2 Scenario 2 (simultaneity)

Input



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

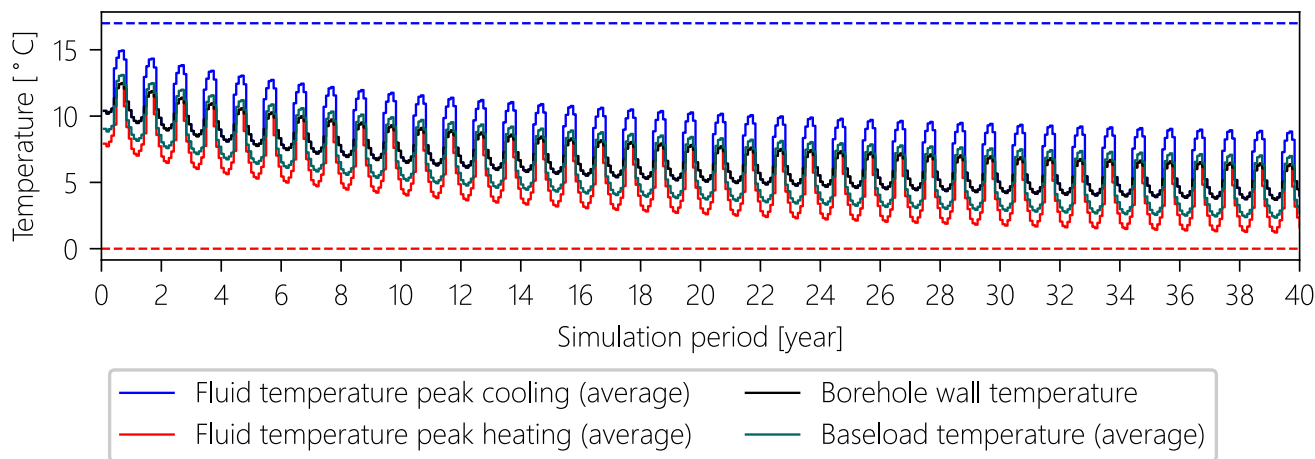
Building demand	Yearly load	Peak power
Heating demand	408 000 kWh/y	172,0 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	101,0 kW

Results

Effective borehole thermal resistance (extraction): 0,2013 m·K/W, Reynolds number: 615 (laminar)

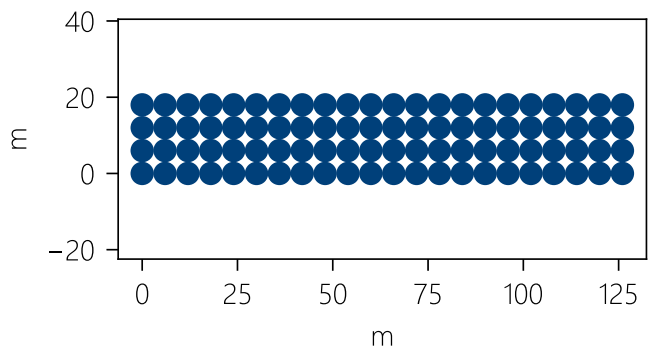
Effective borehole thermal resistance (injection): 0,2410 m·K/W, Reynolds number: 839 (laminar)

Maximum average fluid temperature: 14,95 °C, Minimum average fluid temperature: 1,22 °C



2.3 Scenario 3 (simultaneity + PD)

Input



Number of boreholes: 88
Average minimum borehole spacing: 6,0 m
Borehole depth (w.r.t. surface): 150,0 m
2 x U tube DN32 PN16
25,0 v/v% MPG

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

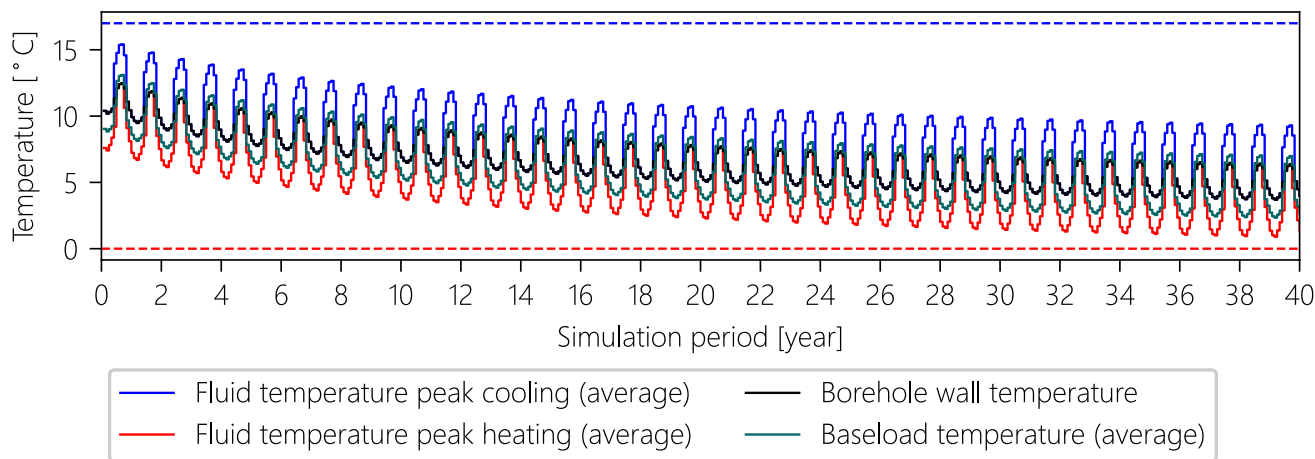
Building demand	Yearly load	Peak power
Heating demand	408 000 kWh/y	172,0 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	101,0 kW

Results

Effective borehole thermal resistance (extraction): 0,2013 m·K/W, Reynolds number: 606 (laminar)

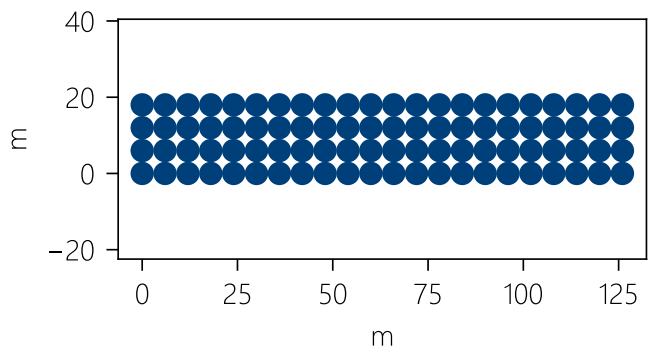
Effective borehole thermal resistance (injection): 0,2410 m·K/W, Reynolds number: 853 (laminar)

Maximum average fluid temperature: 15,41 °C, Minimum average fluid temperature: 0,90 °C



2.4 Scenario 4 (hourly)

Input



Number of boreholes: 88
Average minimum borehole spacing: 6,0 m
Borehole depth (w.r.t. surface): 150,0 m
2 x U tube DN32 PN16
25,0 v/v% MPG

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

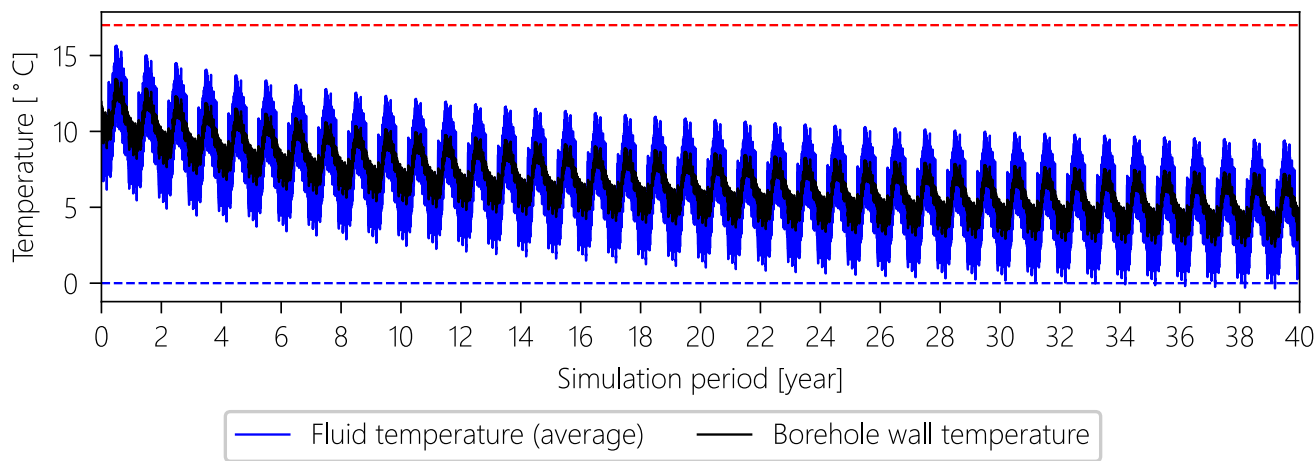
Building demand	Yearly load	Peak power
Heating demand	408 000 kWh/y	272,0 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	160,0 kW

Results

Effective borehole thermal resistance (extraction): 0,1598 m·K/W, Reynolds number: 944 (laminar)

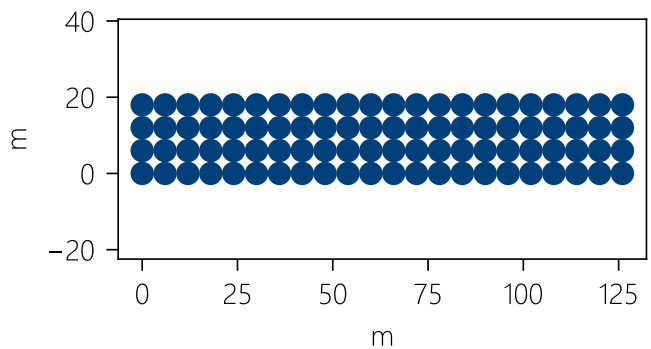
Effective borehole thermal resistance (injection): 0,1794 m·K/W, Reynolds number: 1 364 (laminar)

Maximum average fluid temperature: 15,65 °C, Minimum average fluid temperature: -0,35 °C



2.5 Scenario 5 (hourly - simultaneity)

Input



Number of boreholes: 88
Average minimum borehole spacing: 6,0 m
Borehole depth (w.r.t. surface): 150,0 m
2 x U tube DN32 PN16
25,0 v/v% MPG

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

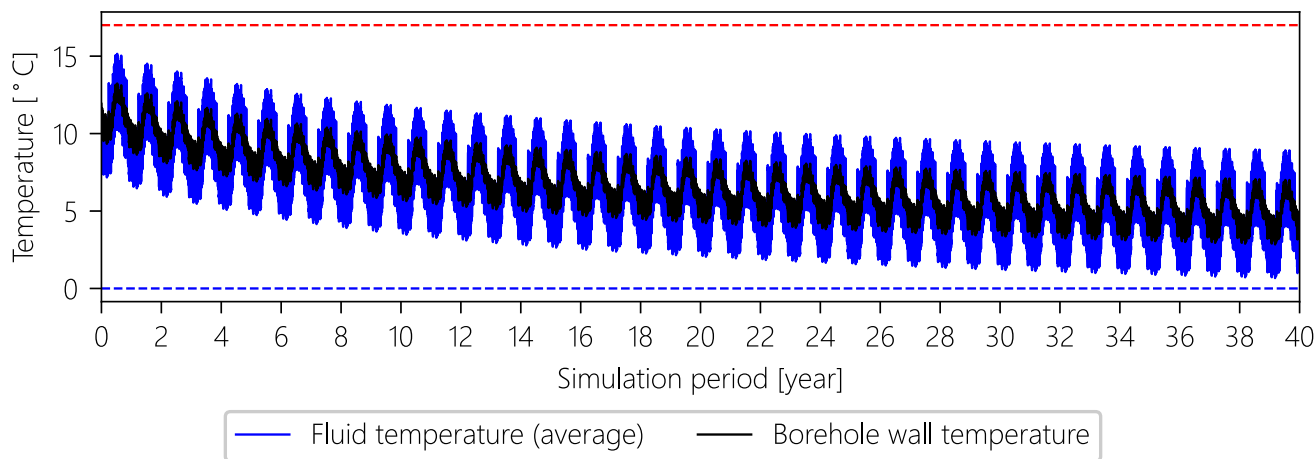
Building demand	Yearly load	Peak power
Heating demand	408 000 kWh/y	172,1 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	101,2 kW

Results

Effective borehole thermal resistance (extraction): 0,1933 m·K/W, Reynolds number: 642 (laminar)

Effective borehole thermal resistance (injection): 0,2406 m·K/W, Reynolds number: 847 (laminar)

Maximum average fluid temperature: 15,15 °C, Minimum average fluid temperature: 0,67 °C



3. Shared input data

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, borefield configuration, pipe data, fluid 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 v2.8.0.2.

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 10,90 °C at 74 m and 12,21 °C at 149 m.

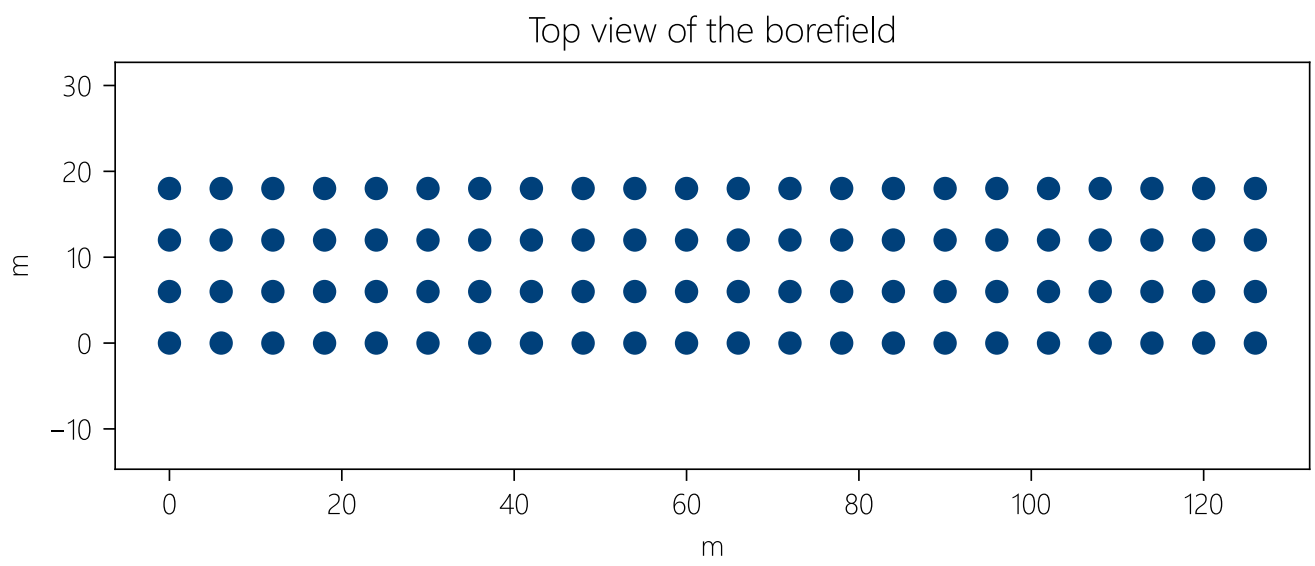
Please note that for all ground property calculations, both the borehole depth and the buried depth are taken into account. This means that the average ground properties, as seen by the borehole, are calculated from the buried depth down to the full borehole depth. The region above the buried depth is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

3.3 Borefield configuration

The simulations were carried out with a borefield consisting of 88 boreholes, with an average buried depth of 1,00 m, an average borehole depth of 150,00 m and an average borehole length of 149,00 m. This results in a total borehole length of 13 112,00 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	149,00	150,00	1,00	0,00	0,00
0,00	6,00	149,00	150,00	1,00	0,00	0,00
0,00	12,00	149,00	150,00	1,00	0,00	0,00
0,00	18,00	149,00	150,00	1,00	0,00	0,00
6,00	0,00	149,00	150,00	1,00	0,00	0,00
6,00	6,00	149,00	150,00	1,00	0,00	0,00
6,00	12,00	149,00	150,00	1,00	0,00	0,00
6,00	18,00	149,00	150,00	1,00	0,00	0,00
12,00	0,00	149,00	150,00	1,00	0,00	0,00
12,00	6,00	149,00	150,00	1,00	0,00	0,00
12,00	12,00	149,00	150,00	1,00	0,00	0,00
12,00	18,00	149,00	150,00	1,00	0,00	0,00
18,00	0,00	149,00	150,00	1,00	0,00	0,00
18,00	6,00	149,00	150,00	1,00	0,00	0,00
18,00	12,00	149,00	150,00	1,00	0,00	0,00
18,00	18,00	149,00	150,00	1,00	0,00	0,00
24,00	0,00	149,00	150,00	1,00	0,00	0,00
24,00	6,00	149,00	150,00	1,00	0,00	0,00
24,00	12,00	149,00	150,00	1,00	0,00	0,00
24,00	18,00	149,00	150,00	1,00	0,00	0,00
30,00	0,00	149,00	150,00	1,00	0,00	0,00
30,00	6,00	149,00	150,00	1,00	0,00	0,00
30,00	12,00	149,00	150,00	1,00	0,00	0,00
30,00	18,00	149,00	150,00	1,00	0,00	0,00
36,00	0,00	149,00	150,00	1,00	0,00	0,00
36,00	6,00	149,00	150,00	1,00	0,00	0,00
36,00	12,00	149,00	150,00	1,00	0,00	0,00
36,00	18,00	149,00	150,00	1,00	0,00	0,00
42,00	0,00	149,00	150,00	1,00	0,00	0,00
42,00	6,00	149,00	150,00	1,00	0,00	0,00
42,00	12,00	149,00	150,00	1,00	0,00	0,00
42,00	18,00	149,00	150,00	1,00	0,00	0,00

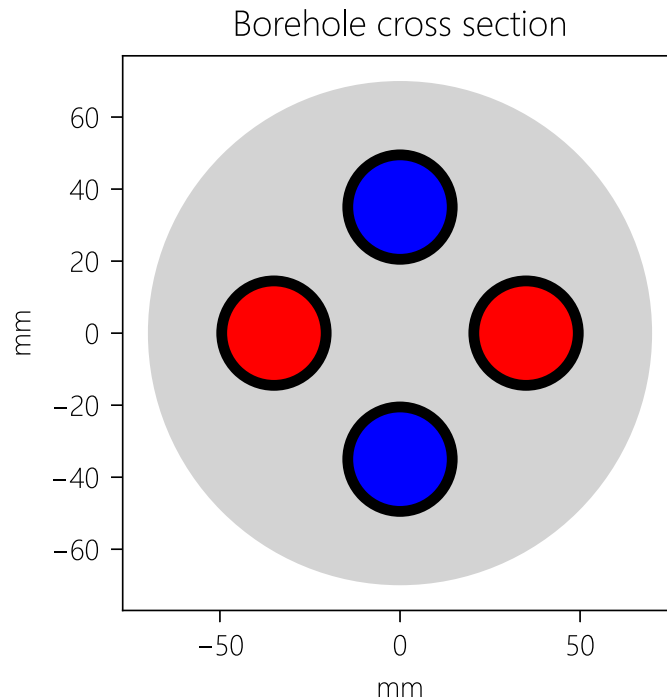
48,00	0,00	149,00	150,00	1,00	0,00	0,00
48,00	6,00	149,00	150,00	1,00	0,00	0,00
48,00	12,00	149,00	150,00	1,00	0,00	0,00
48,00	18,00	149,00	150,00	1,00	0,00	0,00
54,00	0,00	149,00	150,00	1,00	0,00	0,00
54,00	6,00	149,00	150,00	1,00	0,00	0,00
54,00	12,00	149,00	150,00	1,00	0,00	0,00
54,00	18,00	149,00	150,00	1,00	0,00	0,00
60,00	0,00	149,00	150,00	1,00	0,00	0,00
60,00	6,00	149,00	150,00	1,00	0,00	0,00
60,00	12,00	149,00	150,00	1,00	0,00	0,00
60,00	18,00	149,00	150,00	1,00	0,00	0,00
66,00	0,00	149,00	150,00	1,00	0,00	0,00
66,00	6,00	149,00	150,00	1,00	0,00	0,00
66,00	12,00	149,00	150,00	1,00	0,00	0,00
66,00	18,00	149,00	150,00	1,00	0,00	0,00
72,00	0,00	149,00	150,00	1,00	0,00	0,00
72,00	6,00	149,00	150,00	1,00	0,00	0,00
72,00	12,00	149,00	150,00	1,00	0,00	0,00
72,00	18,00	149,00	150,00	1,00	0,00	0,00
78,00	0,00	149,00	150,00	1,00	0,00	0,00
78,00	6,00	149,00	150,00	1,00	0,00	0,00
78,00	12,00	149,00	150,00	1,00	0,00	0,00
78,00	18,00	149,00	150,00	1,00	0,00	0,00
84,00	0,00	149,00	150,00	1,00	0,00	0,00
84,00	6,00	149,00	150,00	1,00	0,00	0,00
84,00	12,00	149,00	150,00	1,00	0,00	0,00
84,00	18,00	149,00	150,00	1,00	0,00	0,00
90,00	0,00	149,00	150,00	1,00	0,00	0,00
90,00	6,00	149,00	150,00	1,00	0,00	0,00
90,00	12,00	149,00	150,00	1,00	0,00	0,00
90,00	18,00	149,00	150,00	1,00	0,00	0,00
96,00	0,00	149,00	150,00	1,00	0,00	0,00
96,00	6,00	149,00	150,00	1,00	0,00	0,00
96,00	12,00	149,00	150,00	1,00	0,00	0,00

96,00	18,00	149,00	150,00	1,00	0,00	0,00
102,00	0,00	149,00	150,00	1,00	0,00	0,00
102,00	6,00	149,00	150,00	1,00	0,00	0,00
102,00	12,00	149,00	150,00	1,00	0,00	0,00
102,00	18,00	149,00	150,00	1,00	0,00	0,00
108,00	0,00	149,00	150,00	1,00	0,00	0,00
108,00	6,00	149,00	150,00	1,00	0,00	0,00
108,00	12,00	149,00	150,00	1,00	0,00	0,00
108,00	18,00	149,00	150,00	1,00	0,00	0,00
114,00	0,00	149,00	150,00	1,00	0,00	0,00
114,00	6,00	149,00	150,00	1,00	0,00	0,00
114,00	12,00	149,00	150,00	1,00	0,00	0,00
114,00	18,00	149,00	150,00	1,00	0,00	0,00
120,00	0,00	149,00	150,00	1,00	0,00	0,00
120,00	6,00	149,00	150,00	1,00	0,00	0,00
120,00	12,00	149,00	150,00	1,00	0,00	0,00
120,00	18,00	149,00	150,00	1,00	0,00	0,00
126,00	0,00	149,00	150,00	1,00	0,00	0,00
126,00	6,00	149,00	150,00	1,00	0,00	0,00
126,00	12,00	149,00	150,00	1,00	0,00	0,00
126,00	18,00	149,00	150,00	1,00	0,00	0,00

3.4 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).





3.5 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.

3.6 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. Results

4.1 Scenario 1

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

4.1.1 Input

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 18,29 l/s and 14,05 l/s respectively.

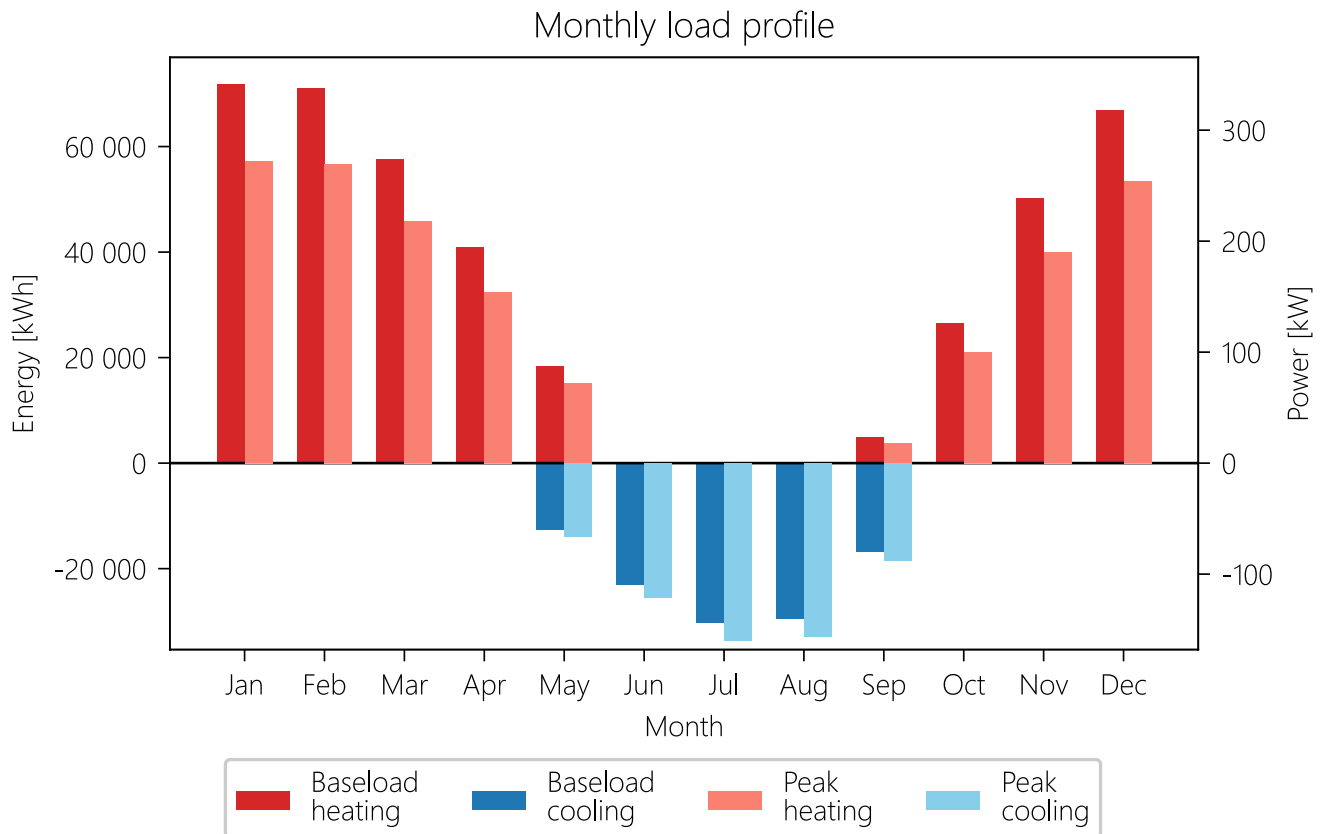
Load data

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	408 000 kWh/y	272,0 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	160,0 kW

The monthly distribution is given in the table below.

Month	Baseload heating [kWh]	Baseload cooling [kWh]	Peak heating [kW]	Peak cooling [kW]
January	71 808	0	272,0	0,0
February	70 992	0	269,6	0,0
March	57 528	0	218,1	0,0
April	40 800	0	154,0	0,0
May	18 360	12 544	71,8	66,4
June	0	22 960	0,0	121,0
July	0	30 240	0,0	160,0
August	0	29 568	0,0	156,2
September	4 896	16 688	18,0	87,8
October	26 520	0	100,1	0,0
November	50 184	0	189,9	0,0
December	66 912	0	254,0	0,0



The peak duration during heating is 8 hours, and for cooling it is 8 hours. The peak duration is defined as the longest runtime of the maximum heating/cooling power in a year. This value is typically higher with slow emission systems (such as floor heating or concrete core activation) and lower for fast emission systems (such as air-based systems).

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	411 733 kWh/y	217,6 kW
Injection demand	117 600 kWh/y	168,0 kW

Temperature evolution of the borefield

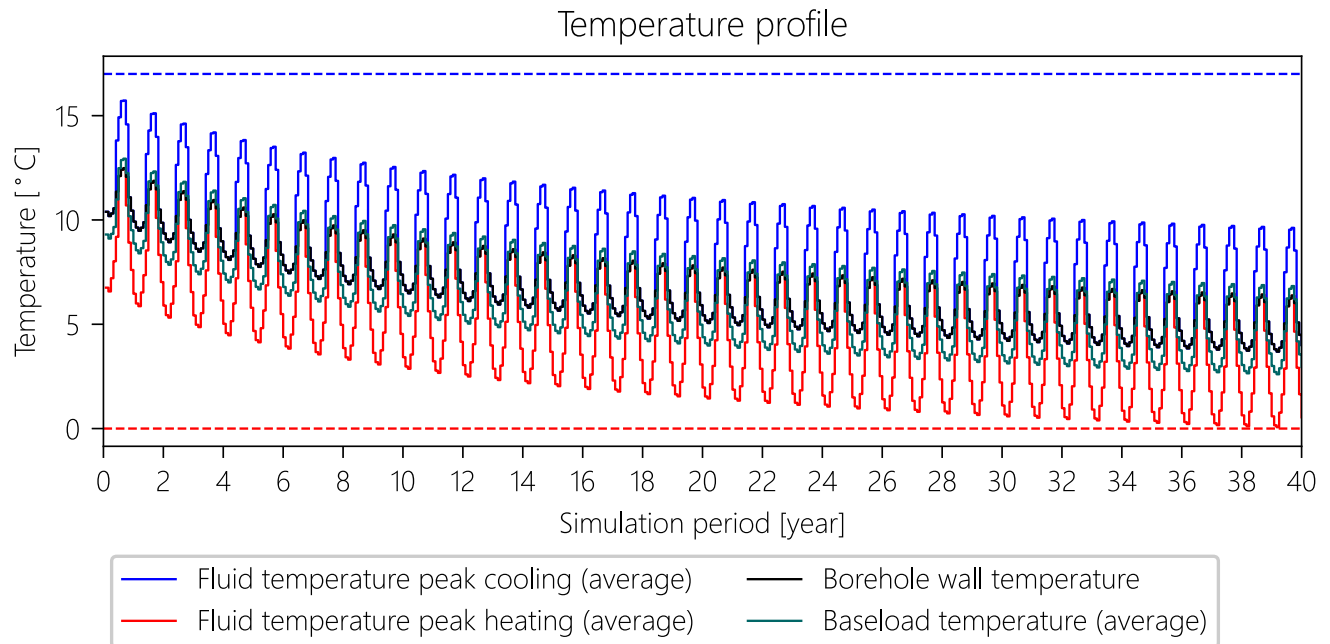
Using the pipe, fluid, and flow properties, the Reynolds number was calculated. Since this number depends on the fluid temperature and therefore varies over the simulation period, it was updated at every timestep to achieve the most accurate result possible.

Doing so, the Reynolds number during heat extraction was 922, whilst it was 1 368 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,1621 m·K/W and 0,1794 m·K/W during heat extraction and injection.

Below, the monthly simulation for the borefield is shown. For each month, three lines are displayed. The black line represents the borehole wall temperature, which is the temperature at the interface between the borehole

and the ground. The other two lines, red and blue, show the average fluid temperature (between borehole inlet and outlet) during peak heating and peak cooling, respectively.

Since the simulation uses monthly resolution, both heating and cooling peaks can occur in the same month. Therefore, both fluid temperatures are always shown. The difference between the borehole wall temperature and the average fluid temperature is determined by the effective borehole thermal resistance.



The maximum and minimum average fluid temperature over the whole simulation period at peak power are 15,73 °C and 0,06 °C respectively. The minimum and maximum average fluid temperatures during the baseload are respectively 2,60 °C and 12,94 °C.

Pressure drop

The pressure drop over a single borehole is 15,65 kPa during extration and 6,19 kPa during injection.

4.2 Scenario 2 (simultaneity)

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

4.2.1 Input

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 11,56 l/s and 8,87 l/s respectively.

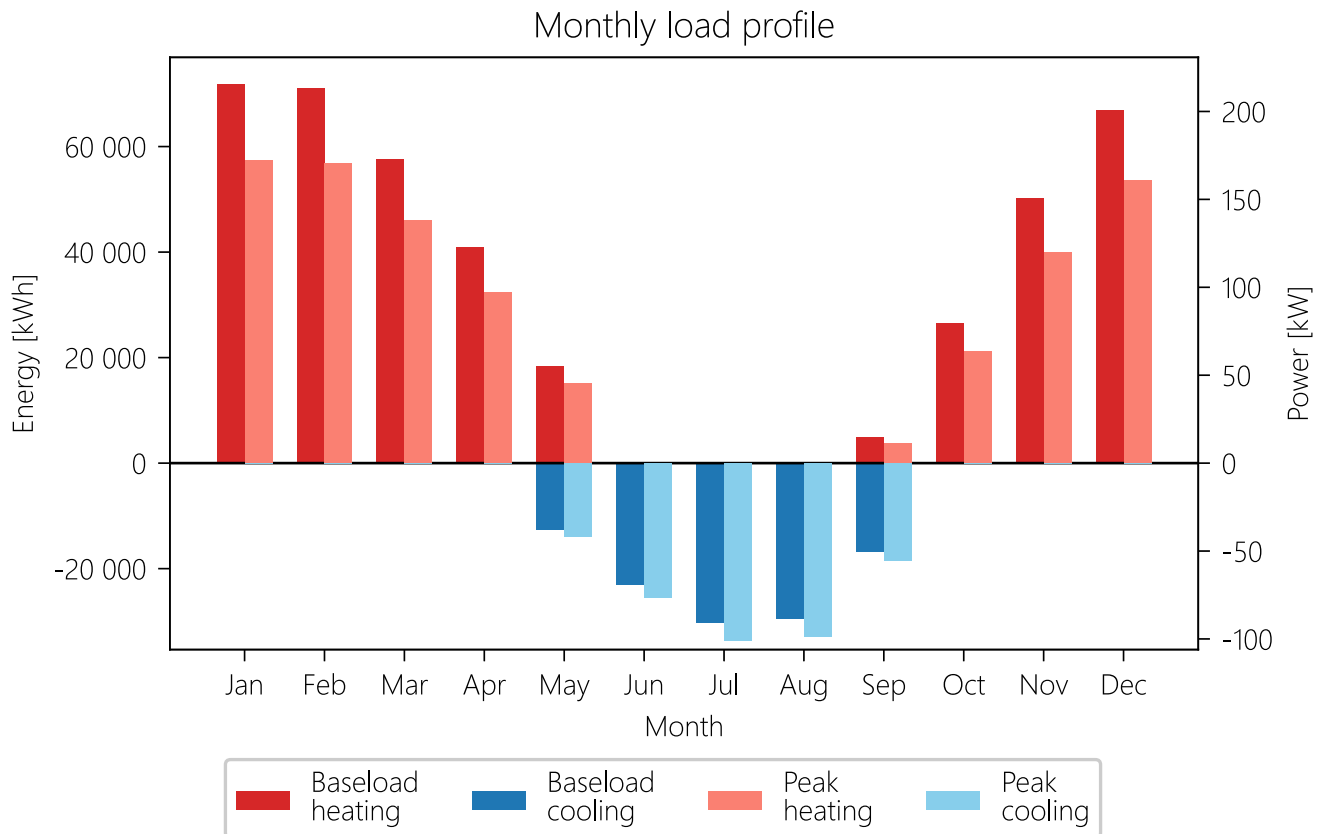
Load data

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	408 000 kWh/y	172,0 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	101,0 kW

The monthly distribution is given in the table below.

Month	Baseload heating [kWh]	Baseload cooling [kWh]	Peak heating [kW]	Peak cooling [kW]
January	71 808	0	172,0	0,0
February	70 992	0	170,5	0,0
March	57 528	0	137,9	0,0
April	40 800	0	97,4	0,0
May	18 360	12 544	45,4	41,9
June	0	22 960	0,0	76,4
July	0	30 240	0,0	101,0
August	0	29 568	0,0	98,6
September	4 896	16 688	11,4	55,4
October	26 520	0	63,3	0,0
November	50 184	0	120,1	0,0
December	66 912	0	160,6	0,0



The peak duration during heating is 8 hours, and for cooling it is 8 hours. The peak duration is defined as the longest runtime of the maximum heating/cooling power in a year. This value is typically higher with slow emission systems (such as floor heating or concrete core activation) and lower for fast emission systems (such as air-based systems).

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	411 733 kWh/y	137,6 kW
Injection demand	117 600 kWh/y	106,0 kW

Temperature evolution of the borefield

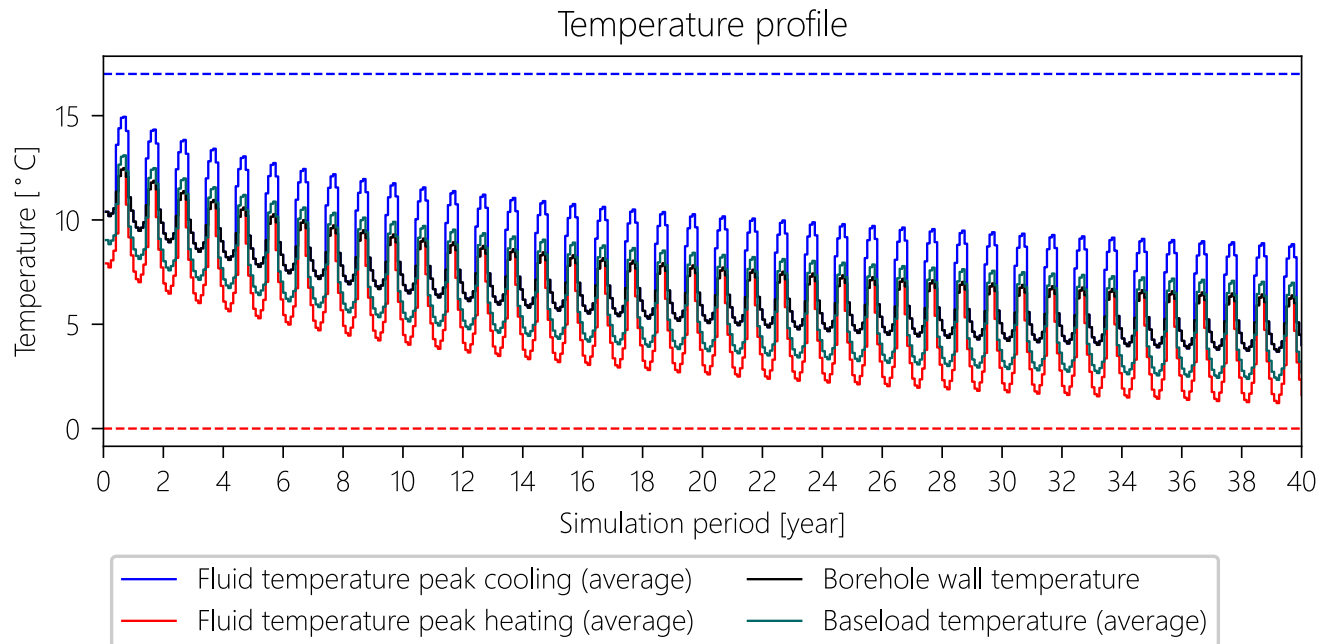
Using the pipe, fluid, and flow properties, the Reynolds number was calculated. Since this number depends on the fluid temperature and therefore varies over the simulation period, it was updated at every timestep to achieve the most accurate result possible.

Doing so, the Reynolds number during heat extraction was 615, whilst it was 839 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,2013 m·K/W and 0,2410 m·K/W during heat extraction and injection.

Below, the monthly simulation for the borefield is shown. For each month, three lines are displayed. The black line represents the borehole wall temperature, which is the temperature at the interface between the borehole

and the ground. The other two lines, red and blue, show the average fluid temperature (between borehole inlet and outlet) during peak heating and peak cooling, respectively.

Since the simulation uses monthly resolution, both heating and cooling peaks can occur in the same month. Therefore, both fluid temperatures are always shown. The difference between the borehole wall temperature and the average fluid temperature is determined by the effective borehole thermal resistance.



The maximum and minimum average fluid temperature over the whole simulation period at peak power are 14,95 °C and 1,22 °C respectively. The minimum and maximum average fluid temperatures during the baseload are respectively 2,33 °C and 13,10 °C.

Pressure drop

The pressure drop over a single borehole is 9,36 kPa during extration and 4,03 kPa during injection.

4.3 Scenario 3 (simultaneity + PD)

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

4.3.1 Input

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 11,56 l/s and 8,87 l/s respectively.

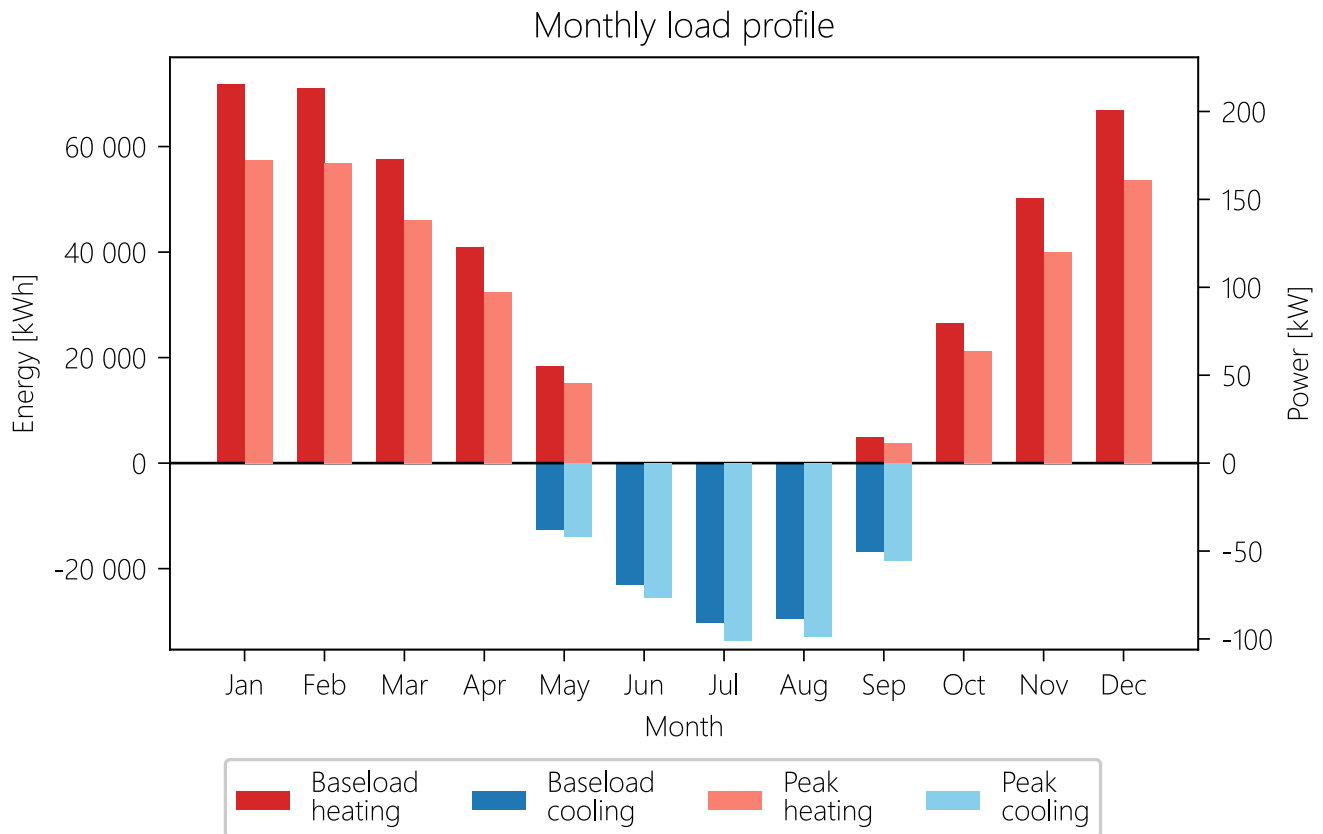
Load data

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	408 000 kWh/y	172,0 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	101,0 kW

The monthly distribution is given in the table below.

Month	Baseload heating [kWh]	Baseload cooling [kWh]	Peak heating [kW]	Peak cooling [kW]
January	71 808	0	172,0	0,0
February	70 992	0	170,5	0,0
March	57 528	0	137,9	0,0
April	40 800	0	97,4	0,0
May	18 360	12 544	45,4	41,9
June	0	22 960	0,0	76,4
July	0	30 240	0,0	101,0
August	0	29 568	0,0	98,6
September	4 896	16 688	11,4	55,4
October	26 520	0	63,3	0,0
November	50 184	0	120,1	0,0
December	66 912	0	160,6	0,0



The peak duration during heating is 72 hours, and for cooling it is 72 hours. The peak duration is defined as the longest runtime of the maximum heating/cooling power in a year. This value is typically higher with slow emission systems (such as floor heating or concrete core activation) and lower for fast emission systems (such as air-based systems).

4.3.2 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	411 733 kWh/y	137,6 kW
Injection demand	117 600 kWh/y	106,0 kW

Temperature evolution of the borefield

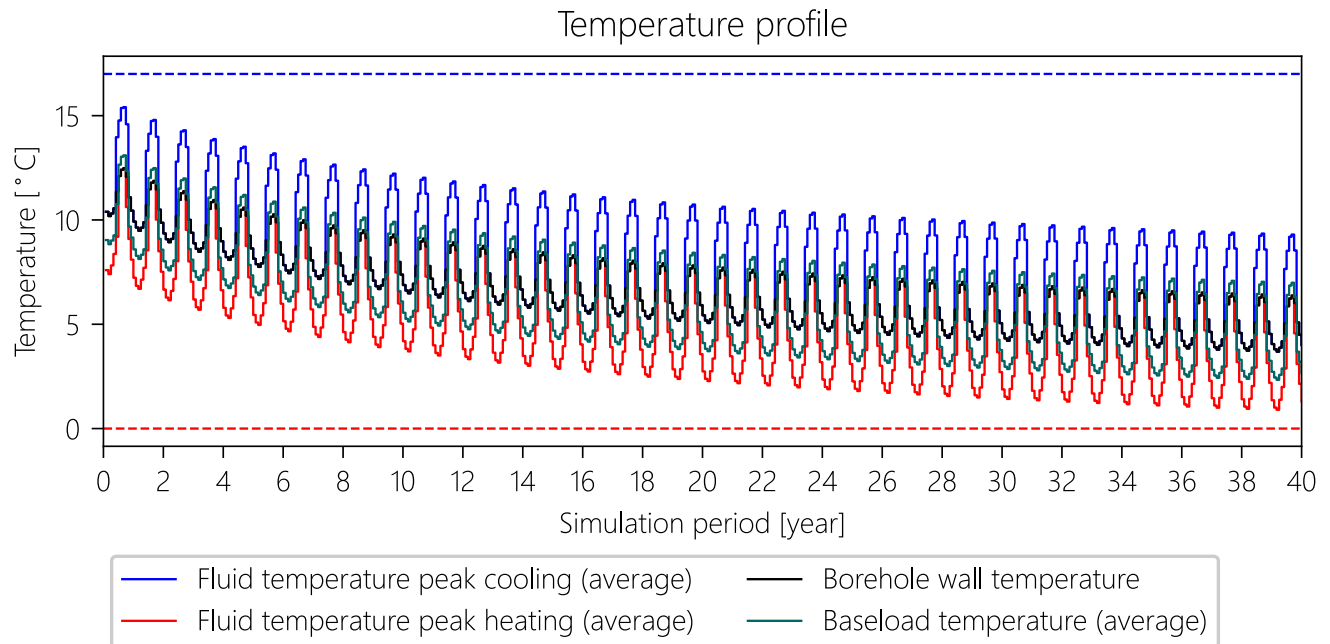
Using the pipe, fluid, and flow properties, the Reynolds number was calculated. Since this number depends on the fluid temperature and therefore varies over the simulation period, it was updated at every timestep to achieve the most accurate result possible.

Doing so, the Reynolds number during heat extraction was 606, whilst it was 853 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,2013 m·K/W and 0,2410 m·K/W during heat extraction and injection.

Below, the monthly simulation for the borefield is shown. For each month, three lines are displayed. The black line represents the borehole wall temperature, which is the temperature at the interface between the borehole

and the ground. The other two lines, red and blue, show the average fluid temperature (between borehole inlet and outlet) during peak heating and peak cooling, respectively.

Since the simulation uses monthly resolution, both heating and cooling peaks can occur in the same month. Therefore, both fluid temperatures are always shown. The difference between the borehole wall temperature and the average fluid temperature is determined by the effective borehole thermal resistance.



The maximum and minimum average fluid temperature over the whole simulation period at peak power are 15,41 °C and 0,90 °C respectively. The minimum and maximum average fluid temperatures during the baseload are respectively 2,33 °C and 13,10 °C.

Pressure drop

The pressure drop over a single borehole is 9,51 kPa during extration and 3,96 kPa during injection.

4.4 Scenario 4 (hourly)

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

4.4.1 Input

Flow data

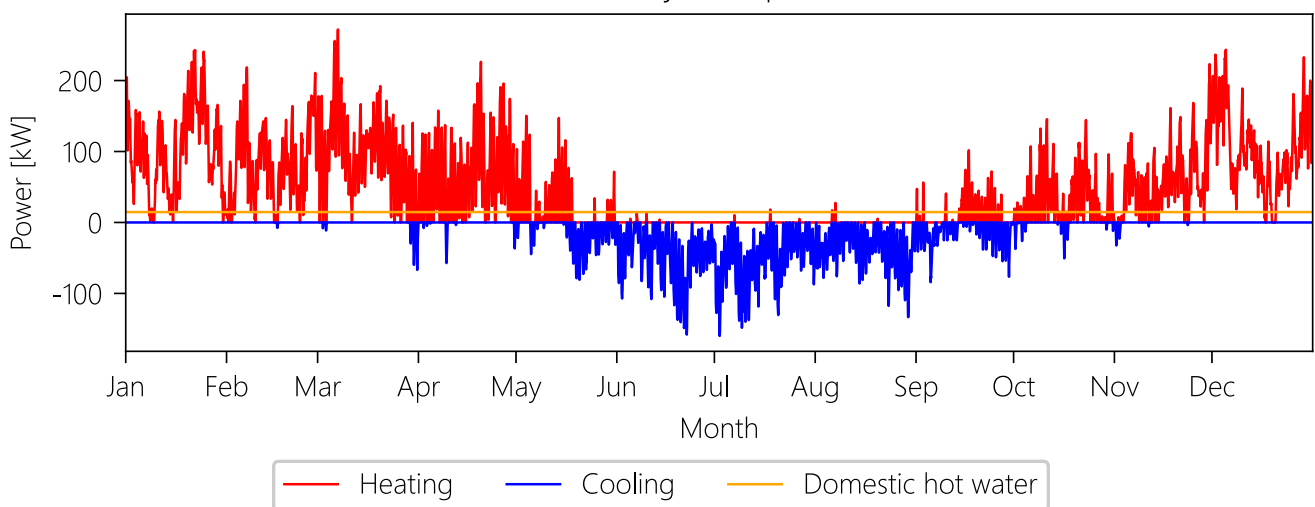
The system was simulated with a variable flow rate, where a constant temperature difference across the borefield was used of 3,00 °C in extraction and 3,00 °C in injection, with a minimum flow percentage of 10%. The resulting maximum flow rate through the borefield is 19,11 l/s and 14,05 l/s respectively.

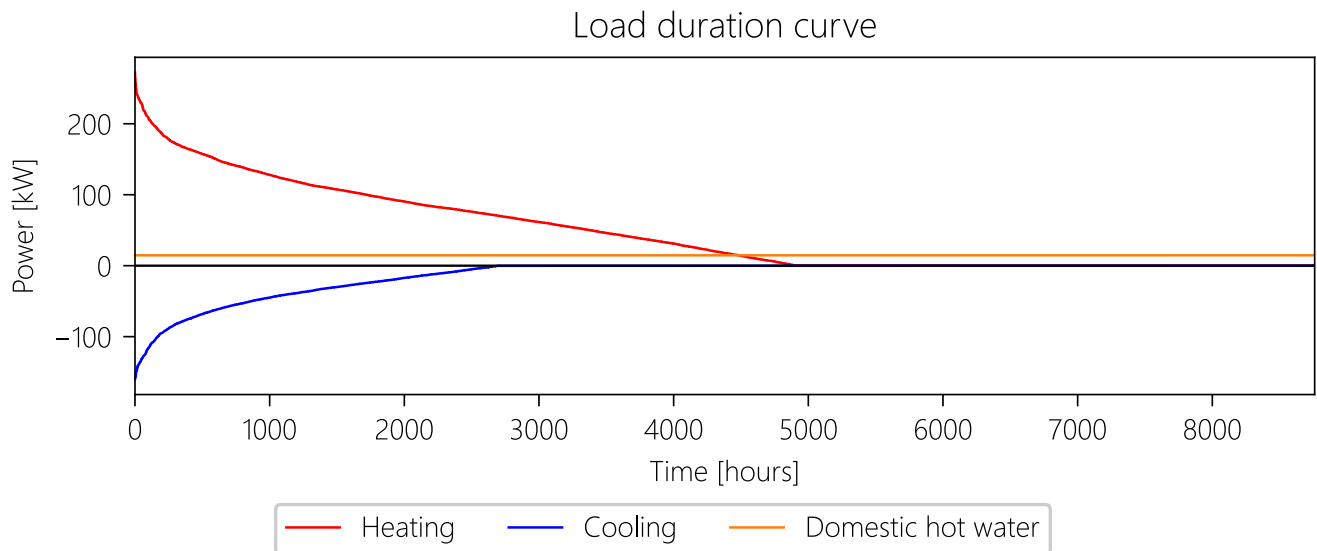
Load data

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	408 000 kWh/y	272,0 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	160,0 kW

Hourly load profile





4.4.2 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.

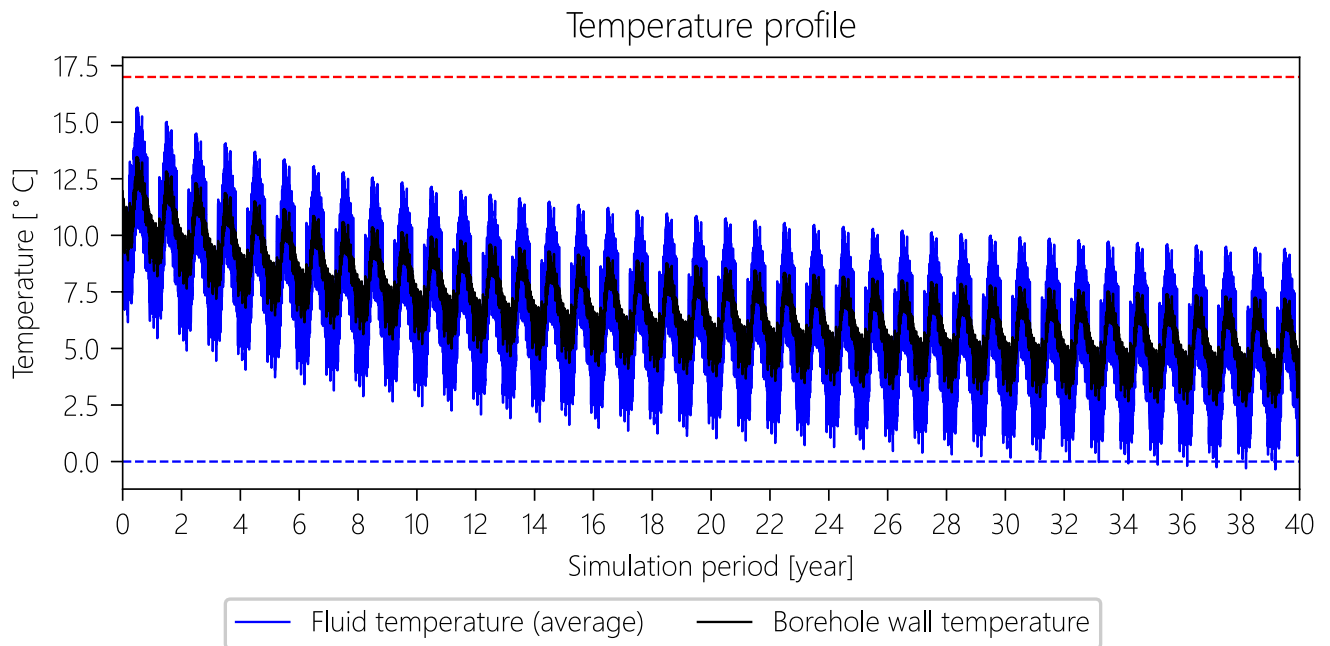
Ground demand	Yearly load	Peak power
Extraction demand	411 733 kWh/y	227,3 kW
Injection demand	117 600 kWh/y	168,0 kW

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 944, whilst it was 1 364 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,1598 m·K/W and 0,1794 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 15,65 °C, and the minimum average fluid temperature is -0,35 °C.

Pressure drop

The pressure drop over a single borehole is 16,68 kPa during extration and 7,96 kPa during injection.

4.5 Scenario 5 (hourly - simultaneity)

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

4.5.1 Input

Flow data

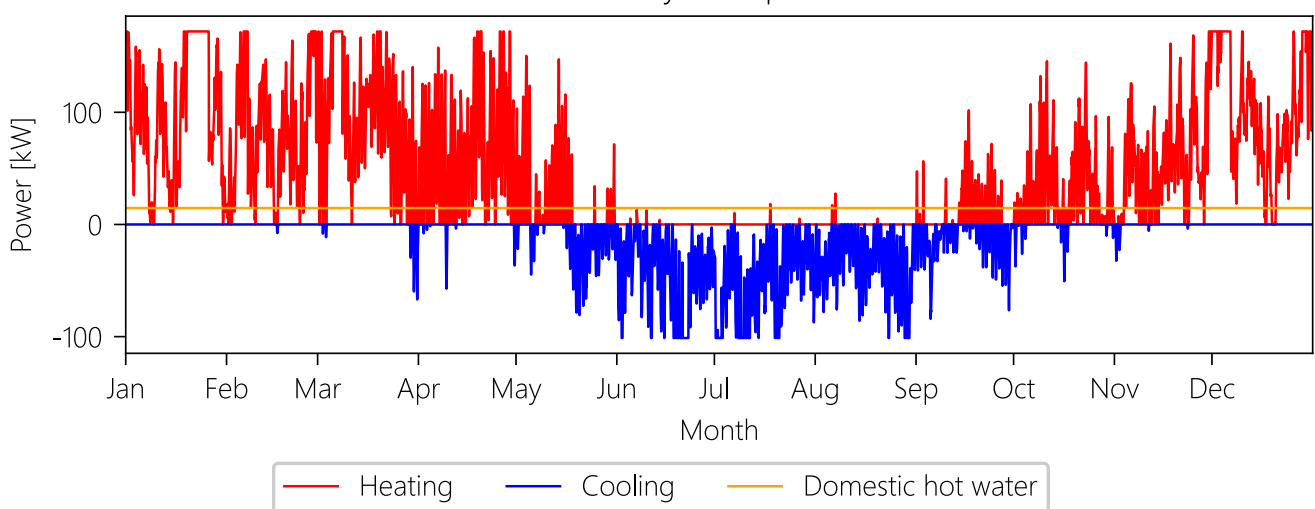
The system was simulated with a variable flow rate, where a constant temperature difference across the borefield was used of 3,00 °C in extraction and 3,00 °C in injection, with a minimum flow percentage of 10%. The resulting maximum flow rate through the borefield is 12,38 l/s and 8,89 l/s respectively.

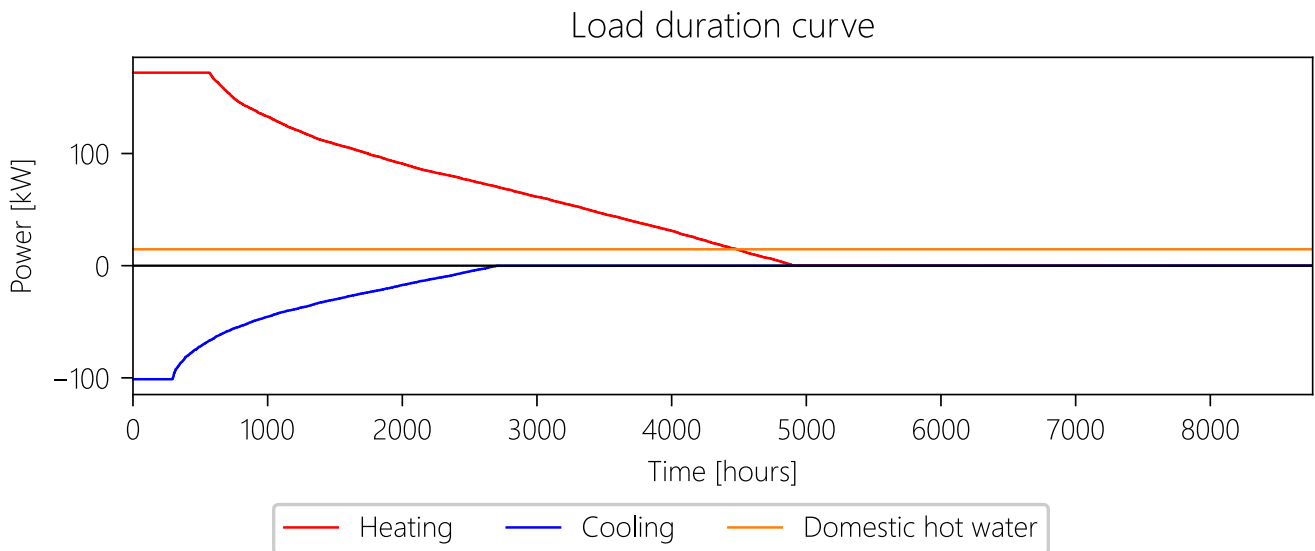
Load data

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	408 000 kWh/y	172,1 kW
Domestic hot water demand	128 000 kWh/y	-
Cooling demand	112 000 kWh/y	101,2 kW

Hourly load profile





4.5.2 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.

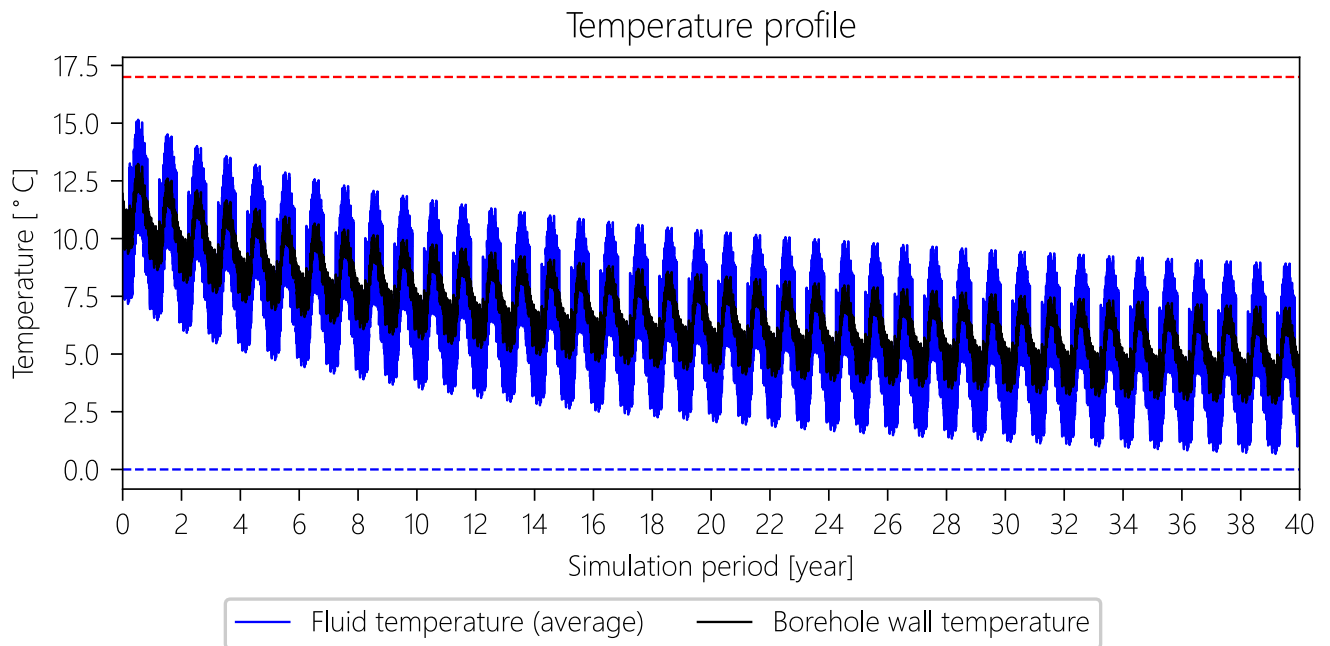
Ground demand	Yearly load	Peak power
Extraction demand	411 733 kWh/y	147,4 kW
Injection demand	117 600 kWh/y	106,3 kW

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 642, whilst it was 847 during injection. This corresponds respectively to a laminar and laminar flow regime, with an effective borehole thermal resistance of 0,1933 m·K/W and 0,2406 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 15,15 °C, and the minimum average fluid temperature is 0,67 °C.

Pressure drop

The pressure drop over a single borehole is 10,30 kPa during extration and 5,38 kPa during injection.

5.1 Design Data - Scenario 1

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/(m³·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m²

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: 18,29 l/s
- Flow rate through borefield in injection: 14,05 l/s
- Number of boreholes in series: 1

Thermal demand

Baseload heating [kWh]	Baseload cooling [kWh]	Peak heating [kW]	Peak cooling [kW]
71 808,00	0,00	272,00	0,00
70 992,00	0,00	269,55	0,00
57 528,00	0,00	218,14	0,00
40 800,00	0,00	153,95	0,00
18 360,00	12 544,00	71,81	66,40
0,00	22 960,00	0,00	120,96
0,00	30 240,00	0,00	160,00
0,00	29 568,00	0,00	156,16
4 896,00	16 688,00	17,95	87,84
26 520,00	0,00	100,10	0,00
50 184,00	0,00	189,86	0,00
66 912,00	0,00	254,05	0,00

- Domestic hot water: 128 000 kWh/year
- SCOP heating: 5
- SCOP domestic hot water: 3
- SEER cooling: 20
- Peak heating duration: 8 hours
- Peak cooling duration: 8 hours

Borefield parameters

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	149,00	150,00	1,00	0,00	0,00
0,00	6,00	149,00	150,00	1,00	0,00	0,00
0,00	12,00	149,00	150,00	1,00	0,00	0,00
0,00	18,00	149,00	150,00	1,00	0,00	0,00
6,00	0,00	149,00	150,00	1,00	0,00	0,00
6,00	6,00	149,00	150,00	1,00	0,00	0,00
6,00	12,00	149,00	150,00	1,00	0,00	0,00
6,00	18,00	149,00	150,00	1,00	0,00	0,00
12,00	0,00	149,00	150,00	1,00	0,00	0,00
12,00	6,00	149,00	150,00	1,00	0,00	0,00
12,00	12,00	149,00	150,00	1,00	0,00	0,00
12,00	18,00	149,00	150,00	1,00	0,00	0,00
18,00	0,00	149,00	150,00	1,00	0,00	0,00
18,00	6,00	149,00	150,00	1,00	0,00	0,00
18,00	12,00	149,00	150,00	1,00	0,00	0,00

18,00	18,00	149,00	150,00	1,00	0,00	0,00
24,00	0,00	149,00	150,00	1,00	0,00	0,00
24,00	6,00	149,00	150,00	1,00	0,00	0,00
24,00	12,00	149,00	150,00	1,00	0,00	0,00
24,00	18,00	149,00	150,00	1,00	0,00	0,00
30,00	0,00	149,00	150,00	1,00	0,00	0,00
30,00	6,00	149,00	150,00	1,00	0,00	0,00
30,00	12,00	149,00	150,00	1,00	0,00	0,00
30,00	18,00	149,00	150,00	1,00	0,00	0,00
36,00	0,00	149,00	150,00	1,00	0,00	0,00
36,00	6,00	149,00	150,00	1,00	0,00	0,00
36,00	12,00	149,00	150,00	1,00	0,00	0,00
36,00	18,00	149,00	150,00	1,00	0,00	0,00
42,00	0,00	149,00	150,00	1,00	0,00	0,00
42,00	6,00	149,00	150,00	1,00	0,00	0,00
42,00	12,00	149,00	150,00	1,00	0,00	0,00
42,00	18,00	149,00	150,00	1,00	0,00	0,00
48,00	0,00	149,00	150,00	1,00	0,00	0,00
48,00	6,00	149,00	150,00	1,00	0,00	0,00
48,00	12,00	149,00	150,00	1,00	0,00	0,00
48,00	18,00	149,00	150,00	1,00	0,00	0,00
54,00	0,00	149,00	150,00	1,00	0,00	0,00
54,00	6,00	149,00	150,00	1,00	0,00	0,00
54,00	12,00	149,00	150,00	1,00	0,00	0,00
54,00	18,00	149,00	150,00	1,00	0,00	0,00
60,00	0,00	149,00	150,00	1,00	0,00	0,00
60,00	6,00	149,00	150,00	1,00	0,00	0,00
60,00	12,00	149,00	150,00	1,00	0,00	0,00
60,00	18,00	149,00	150,00	1,00	0,00	0,00
66,00	0,00	149,00	150,00	1,00	0,00	0,00
66,00	6,00	149,00	150,00	1,00	0,00	0,00
66,00	12,00	149,00	150,00	1,00	0,00	0,00
66,00	18,00	149,00	150,00	1,00	0,00	0,00
72,00	0,00	149,00	150,00	1,00	0,00	0,00
72,00	6,00	149,00	150,00	1,00	0,00	0,00
72,00	12,00	149,00	150,00	1,00	0,00	0,00
72,00	18,00	149,00	150,00	1,00	0,00	0,00
78,00	0,00	149,00	150,00	1,00	0,00	0,00
78,00	6,00	149,00	150,00	1,00	0,00	0,00

78,00	12,00	149,00	150,00	1,00	0,00	0,00
78,00	18,00	149,00	150,00	1,00	0,00	0,00
84,00	0,00	149,00	150,00	1,00	0,00	0,00
84,00	6,00	149,00	150,00	1,00	0,00	0,00
84,00	12,00	149,00	150,00	1,00	0,00	0,00
84,00	18,00	149,00	150,00	1,00	0,00	0,00
90,00	0,00	149,00	150,00	1,00	0,00	0,00
90,00	6,00	149,00	150,00	1,00	0,00	0,00
90,00	12,00	149,00	150,00	1,00	0,00	0,00
90,00	18,00	149,00	150,00	1,00	0,00	0,00
96,00	0,00	149,00	150,00	1,00	0,00	0,00
96,00	6,00	149,00	150,00	1,00	0,00	0,00
96,00	12,00	149,00	150,00	1,00	0,00	0,00
96,00	18,00	149,00	150,00	1,00	0,00	0,00
102,00	0,00	149,00	150,00	1,00	0,00	0,00
102,00	6,00	149,00	150,00	1,00	0,00	0,00
102,00	12,00	149,00	150,00	1,00	0,00	0,00
102,00	18,00	149,00	150,00	1,00	0,00	0,00
108,00	0,00	149,00	150,00	1,00	0,00	0,00
108,00	6,00	149,00	150,00	1,00	0,00	0,00
108,00	12,00	149,00	150,00	1,00	0,00	0,00
108,00	18,00	149,00	150,00	1,00	0,00	0,00
114,00	0,00	149,00	150,00	1,00	0,00	0,00
114,00	6,00	149,00	150,00	1,00	0,00	0,00
114,00	12,00	149,00	150,00	1,00	0,00	0,00
114,00	18,00	149,00	150,00	1,00	0,00	0,00
120,00	0,00	149,00	150,00	1,00	0,00	0,00
120,00	6,00	149,00	150,00	1,00	0,00	0,00
120,00	12,00	149,00	150,00	1,00	0,00	0,00
120,00	18,00	149,00	150,00	1,00	0,00	0,00
126,00	0,00	149,00	150,00	1,00	0,00	0,00
126,00	6,00	149,00	150,00	1,00	0,00	0,00
126,00	12,00	149,00	150,00	1,00	0,00	0,00
126,00	18,00	149,00	150,00	1,00	0,00	0,00

5.2 Design Data - Scenario 2 (simultaneity)

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/(m³·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m²

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: 11,56 l/s
- Flow rate through borefield in injection: 8,87 l/s
- Number of boreholes in series: 1



Thermal demand

Baseload heating [kWh]	Baseload cooling [kWh]	Peak heating [kW]	Peak cooling [kW]
71 808,00	0,00	172,00	0,00
70 992,00	0,00	170,45	0,00
57 528,00	0,00	137,94	0,00
40 800,00	0,00	97,35	0,00
18 360,00	12 544,00	45,41	41,91
0,00	22 960,00	0,00	76,36
0,00	30 240,00	0,00	101,00
0,00	29 568,00	0,00	98,58
4 896,00	16 688,00	11,35	55,45
26 520,00	0,00	63,30	0,00
50 184,00	0,00	120,06	0,00
66 912,00	0,00	160,65	0,00

- Domestic hot water: 128 000 kWh/year
- SCOP heating: 5
- SCOP domestic hot water: 3
- SEER cooling: 20
- Peak heating duration: 8 hours
- Peak cooling duration: 8 hours

Borefield parameters

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	149,00	150,00	1,00	0,00	0,00
0,00	6,00	149,00	150,00	1,00	0,00	0,00
0,00	12,00	149,00	150,00	1,00	0,00	0,00
0,00	18,00	149,00	150,00	1,00	0,00	0,00
6,00	0,00	149,00	150,00	1,00	0,00	0,00
6,00	6,00	149,00	150,00	1,00	0,00	0,00
6,00	12,00	149,00	150,00	1,00	0,00	0,00
6,00	18,00	149,00	150,00	1,00	0,00	0,00
12,00	0,00	149,00	150,00	1,00	0,00	0,00
12,00	6,00	149,00	150,00	1,00	0,00	0,00
12,00	12,00	149,00	150,00	1,00	0,00	0,00
12,00	18,00	149,00	150,00	1,00	0,00	0,00
18,00	0,00	149,00	150,00	1,00	0,00	0,00
18,00	6,00	149,00	150,00	1,00	0,00	0,00
18,00	12,00	149,00	150,00	1,00	0,00	0,00

18,00	18,00	149,00	150,00	1,00	0,00	0,00
24,00	0,00	149,00	150,00	1,00	0,00	0,00
24,00	6,00	149,00	150,00	1,00	0,00	0,00
24,00	12,00	149,00	150,00	1,00	0,00	0,00
24,00	18,00	149,00	150,00	1,00	0,00	0,00
30,00	0,00	149,00	150,00	1,00	0,00	0,00
30,00	6,00	149,00	150,00	1,00	0,00	0,00
30,00	12,00	149,00	150,00	1,00	0,00	0,00
30,00	18,00	149,00	150,00	1,00	0,00	0,00
36,00	0,00	149,00	150,00	1,00	0,00	0,00
36,00	6,00	149,00	150,00	1,00	0,00	0,00
36,00	12,00	149,00	150,00	1,00	0,00	0,00
36,00	18,00	149,00	150,00	1,00	0,00	0,00
42,00	0,00	149,00	150,00	1,00	0,00	0,00
42,00	6,00	149,00	150,00	1,00	0,00	0,00
42,00	12,00	149,00	150,00	1,00	0,00	0,00
42,00	18,00	149,00	150,00	1,00	0,00	0,00
48,00	0,00	149,00	150,00	1,00	0,00	0,00
48,00	6,00	149,00	150,00	1,00	0,00	0,00
48,00	12,00	149,00	150,00	1,00	0,00	0,00
48,00	18,00	149,00	150,00	1,00	0,00	0,00
54,00	0,00	149,00	150,00	1,00	0,00	0,00
54,00	6,00	149,00	150,00	1,00	0,00	0,00
54,00	12,00	149,00	150,00	1,00	0,00	0,00
54,00	18,00	149,00	150,00	1,00	0,00	0,00
60,00	0,00	149,00	150,00	1,00	0,00	0,00
60,00	6,00	149,00	150,00	1,00	0,00	0,00
60,00	12,00	149,00	150,00	1,00	0,00	0,00
60,00	18,00	149,00	150,00	1,00	0,00	0,00
66,00	0,00	149,00	150,00	1,00	0,00	0,00
66,00	6,00	149,00	150,00	1,00	0,00	0,00
66,00	12,00	149,00	150,00	1,00	0,00	0,00
66,00	18,00	149,00	150,00	1,00	0,00	0,00
72,00	0,00	149,00	150,00	1,00	0,00	0,00
72,00	6,00	149,00	150,00	1,00	0,00	0,00
72,00	12,00	149,00	150,00	1,00	0,00	0,00
72,00	18,00	149,00	150,00	1,00	0,00	0,00
78,00	0,00	149,00	150,00	1,00	0,00	0,00
78,00	6,00	149,00	150,00	1,00	0,00	0,00

78,00	12,00	149,00	150,00	1,00	0,00	0,00
78,00	18,00	149,00	150,00	1,00	0,00	0,00
84,00	0,00	149,00	150,00	1,00	0,00	0,00
84,00	6,00	149,00	150,00	1,00	0,00	0,00
84,00	12,00	149,00	150,00	1,00	0,00	0,00
84,00	18,00	149,00	150,00	1,00	0,00	0,00
90,00	0,00	149,00	150,00	1,00	0,00	0,00
90,00	6,00	149,00	150,00	1,00	0,00	0,00
90,00	12,00	149,00	150,00	1,00	0,00	0,00
90,00	18,00	149,00	150,00	1,00	0,00	0,00
96,00	0,00	149,00	150,00	1,00	0,00	0,00
96,00	6,00	149,00	150,00	1,00	0,00	0,00
96,00	12,00	149,00	150,00	1,00	0,00	0,00
96,00	18,00	149,00	150,00	1,00	0,00	0,00
102,00	0,00	149,00	150,00	1,00	0,00	0,00
102,00	6,00	149,00	150,00	1,00	0,00	0,00
102,00	12,00	149,00	150,00	1,00	0,00	0,00
102,00	18,00	149,00	150,00	1,00	0,00	0,00
108,00	0,00	149,00	150,00	1,00	0,00	0,00
108,00	6,00	149,00	150,00	1,00	0,00	0,00
108,00	12,00	149,00	150,00	1,00	0,00	0,00
108,00	18,00	149,00	150,00	1,00	0,00	0,00
114,00	0,00	149,00	150,00	1,00	0,00	0,00
114,00	6,00	149,00	150,00	1,00	0,00	0,00
114,00	12,00	149,00	150,00	1,00	0,00	0,00
114,00	18,00	149,00	150,00	1,00	0,00	0,00
120,00	0,00	149,00	150,00	1,00	0,00	0,00
120,00	6,00	149,00	150,00	1,00	0,00	0,00
120,00	12,00	149,00	150,00	1,00	0,00	0,00
120,00	18,00	149,00	150,00	1,00	0,00	0,00
126,00	0,00	149,00	150,00	1,00	0,00	0,00
126,00	6,00	149,00	150,00	1,00	0,00	0,00
126,00	12,00	149,00	150,00	1,00	0,00	0,00
126,00	18,00	149,00	150,00	1,00	0,00	0,00

5.3 Design Data - Scenario 3 (simultaneity + PD)

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/(m³·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m²

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: 11,56 l/s
- Flow rate through borefield in injection: 8,87 l/s
- Number of boreholes in series: 1



Thermal demand

Baseload heating [kWh]	Baseload cooling [kWh]	Peak heating [kW]	Peak cooling [kW]
71 808,00	0,00	172,00	0,00
70 992,00	0,00	170,45	0,00
57 528,00	0,00	137,94	0,00
40 800,00	0,00	97,35	0,00
18 360,00	12 544,00	45,41	41,91
0,00	22 960,00	0,00	76,36
0,00	30 240,00	0,00	101,00
0,00	29 568,00	0,00	98,58
4 896,00	16 688,00	11,35	55,45
26 520,00	0,00	63,30	0,00
50 184,00	0,00	120,06	0,00
66 912,00	0,00	160,65	0,00

- Domestic hot water: 128 000 kWh/year
- SCOP heating: 5
- SCOP domestic hot water: 3
- SEER cooling: 20
- Peak heating duration: 72 hours
- Peak cooling duration: 72 hours

Borefield parameters

x [m]	y [m]	Length [m]	Depth [m]	Buried depth [m]	Tilt [°]	Orientation [°]
0,00	0,00	149,00	150,00	1,00	0,00	0,00
0,00	6,00	149,00	150,00	1,00	0,00	0,00
0,00	12,00	149,00	150,00	1,00	0,00	0,00
0,00	18,00	149,00	150,00	1,00	0,00	0,00
6,00	0,00	149,00	150,00	1,00	0,00	0,00
6,00	6,00	149,00	150,00	1,00	0,00	0,00
6,00	12,00	149,00	150,00	1,00	0,00	0,00
6,00	18,00	149,00	150,00	1,00	0,00	0,00
12,00	0,00	149,00	150,00	1,00	0,00	0,00
12,00	6,00	149,00	150,00	1,00	0,00	0,00
12,00	12,00	149,00	150,00	1,00	0,00	0,00
12,00	18,00	149,00	150,00	1,00	0,00	0,00
18,00	0,00	149,00	150,00	1,00	0,00	0,00
18,00	6,00	149,00	150,00	1,00	0,00	0,00
18,00	12,00	149,00	150,00	1,00	0,00	0,00

18,00	18,00	149,00	150,00	1,00	0,00	0,00
24,00	0,00	149,00	150,00	1,00	0,00	0,00
24,00	6,00	149,00	150,00	1,00	0,00	0,00
24,00	12,00	149,00	150,00	1,00	0,00	0,00
24,00	18,00	149,00	150,00	1,00	0,00	0,00
30,00	0,00	149,00	150,00	1,00	0,00	0,00
30,00	6,00	149,00	150,00	1,00	0,00	0,00
30,00	12,00	149,00	150,00	1,00	0,00	0,00
30,00	18,00	149,00	150,00	1,00	0,00	0,00
36,00	0,00	149,00	150,00	1,00	0,00	0,00
36,00	6,00	149,00	150,00	1,00	0,00	0,00
36,00	12,00	149,00	150,00	1,00	0,00	0,00
36,00	18,00	149,00	150,00	1,00	0,00	0,00
42,00	0,00	149,00	150,00	1,00	0,00	0,00
42,00	6,00	149,00	150,00	1,00	0,00	0,00
42,00	12,00	149,00	150,00	1,00	0,00	0,00
42,00	18,00	149,00	150,00	1,00	0,00	0,00
48,00	0,00	149,00	150,00	1,00	0,00	0,00
48,00	6,00	149,00	150,00	1,00	0,00	0,00
48,00	12,00	149,00	150,00	1,00	0,00	0,00
48,00	18,00	149,00	150,00	1,00	0,00	0,00
54,00	0,00	149,00	150,00	1,00	0,00	0,00
54,00	6,00	149,00	150,00	1,00	0,00	0,00
54,00	12,00	149,00	150,00	1,00	0,00	0,00
54,00	18,00	149,00	150,00	1,00	0,00	0,00
60,00	0,00	149,00	150,00	1,00	0,00	0,00
60,00	6,00	149,00	150,00	1,00	0,00	0,00
60,00	12,00	149,00	150,00	1,00	0,00	0,00
60,00	18,00	149,00	150,00	1,00	0,00	0,00
66,00	0,00	149,00	150,00	1,00	0,00	0,00
66,00	6,00	149,00	150,00	1,00	0,00	0,00
66,00	12,00	149,00	150,00	1,00	0,00	0,00
66,00	18,00	149,00	150,00	1,00	0,00	0,00
72,00	0,00	149,00	150,00	1,00	0,00	0,00
72,00	6,00	149,00	150,00	1,00	0,00	0,00
72,00	12,00	149,00	150,00	1,00	0,00	0,00
72,00	18,00	149,00	150,00	1,00	0,00	0,00
78,00	0,00	149,00	150,00	1,00	0,00	0,00
78,00	6,00	149,00	150,00	1,00	0,00	0,00

78,00	12,00	149,00	150,00	1,00	0,00	0,00
78,00	18,00	149,00	150,00	1,00	0,00	0,00
84,00	0,00	149,00	150,00	1,00	0,00	0,00
84,00	6,00	149,00	150,00	1,00	0,00	0,00
84,00	12,00	149,00	150,00	1,00	0,00	0,00
84,00	18,00	149,00	150,00	1,00	0,00	0,00
90,00	0,00	149,00	150,00	1,00	0,00	0,00
90,00	6,00	149,00	150,00	1,00	0,00	0,00
90,00	12,00	149,00	150,00	1,00	0,00	0,00
90,00	18,00	149,00	150,00	1,00	0,00	0,00
96,00	0,00	149,00	150,00	1,00	0,00	0,00
96,00	6,00	149,00	150,00	1,00	0,00	0,00
96,00	12,00	149,00	150,00	1,00	0,00	0,00
96,00	18,00	149,00	150,00	1,00	0,00	0,00
102,00	0,00	149,00	150,00	1,00	0,00	0,00
102,00	6,00	149,00	150,00	1,00	0,00	0,00
102,00	12,00	149,00	150,00	1,00	0,00	0,00
102,00	18,00	149,00	150,00	1,00	0,00	0,00
108,00	0,00	149,00	150,00	1,00	0,00	0,00
108,00	6,00	149,00	150,00	1,00	0,00	0,00
108,00	12,00	149,00	150,00	1,00	0,00	0,00
108,00	18,00	149,00	150,00	1,00	0,00	0,00
114,00	0,00	149,00	150,00	1,00	0,00	0,00
114,00	6,00	149,00	150,00	1,00	0,00	0,00
114,00	12,00	149,00	150,00	1,00	0,00	0,00
114,00	18,00	149,00	150,00	1,00	0,00	0,00
120,00	0,00	149,00	150,00	1,00	0,00	0,00
120,00	6,00	149,00	150,00	1,00	0,00	0,00
120,00	12,00	149,00	150,00	1,00	0,00	0,00
120,00	18,00	149,00	150,00	1,00	0,00	0,00
126,00	0,00	149,00	150,00	1,00	0,00	0,00
126,00	6,00	149,00	150,00	1,00	0,00	0,00
126,00	12,00	149,00	150,00	1,00	0,00	0,00
126,00	18,00	149,00	150,00	1,00	0,00	0,00

5.4 Design Data - Scenario 4 (hourly)

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/(m³·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m²

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: 19,11 l/s
- Flow rate through borefield in injection: 14,07 l/s
- Number of boreholes in series: 1

Thermal demand

- Type of load: Hourly building load
- Domestic hot water: 128 000 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	149,00	150,00	1,00	0,00	0,00
0,00	6,00	149,00	150,00	1,00	0,00	0,00
0,00	12,00	149,00	150,00	1,00	0,00	0,00
0,00	18,00	149,00	150,00	1,00	0,00	0,00
6,00	0,00	149,00	150,00	1,00	0,00	0,00
6,00	6,00	149,00	150,00	1,00	0,00	0,00
6,00	12,00	149,00	150,00	1,00	0,00	0,00
6,00	18,00	149,00	150,00	1,00	0,00	0,00
12,00	0,00	149,00	150,00	1,00	0,00	0,00
12,00	6,00	149,00	150,00	1,00	0,00	0,00
12,00	12,00	149,00	150,00	1,00	0,00	0,00
12,00	18,00	149,00	150,00	1,00	0,00	0,00
18,00	0,00	149,00	150,00	1,00	0,00	0,00
18,00	6,00	149,00	150,00	1,00	0,00	0,00
18,00	12,00	149,00	150,00	1,00	0,00	0,00
18,00	18,00	149,00	150,00	1,00	0,00	0,00
24,00	0,00	149,00	150,00	1,00	0,00	0,00
24,00	6,00	149,00	150,00	1,00	0,00	0,00
24,00	12,00	149,00	150,00	1,00	0,00	0,00
24,00	18,00	149,00	150,00	1,00	0,00	0,00
30,00	0,00	149,00	150,00	1,00	0,00	0,00
30,00	6,00	149,00	150,00	1,00	0,00	0,00
30,00	12,00	149,00	150,00	1,00	0,00	0,00
30,00	18,00	149,00	150,00	1,00	0,00	0,00
36,00	0,00	149,00	150,00	1,00	0,00	0,00
36,00	6,00	149,00	150,00	1,00	0,00	0,00
36,00	12,00	149,00	150,00	1,00	0,00	0,00
36,00	18,00	149,00	150,00	1,00	0,00	0,00
42,00	0,00	149,00	150,00	1,00	0,00	0,00
42,00	6,00	149,00	150,00	1,00	0,00	0,00
42,00	12,00	149,00	150,00	1,00	0,00	0,00
42,00	18,00	149,00	150,00	1,00	0,00	0,00
48,00	0,00	149,00	150,00	1,00	0,00	0,00
48,00	6,00	149,00	150,00	1,00	0,00	0,00
48,00	12,00	149,00	150,00	1,00	0,00	0,00
48,00	18,00	149,00	150,00	1,00	0,00	0,00
54,00	0,00	149,00	150,00	1,00	0,00	0,00
54,00	6,00	149,00	150,00	1,00	0,00	0,00

54,00	12,00	149,00	150,00	1,00	0,00	0,00
54,00	18,00	149,00	150,00	1,00	0,00	0,00
60,00	0,00	149,00	150,00	1,00	0,00	0,00
60,00	6,00	149,00	150,00	1,00	0,00	0,00
60,00	12,00	149,00	150,00	1,00	0,00	0,00
60,00	18,00	149,00	150,00	1,00	0,00	0,00
66,00	0,00	149,00	150,00	1,00	0,00	0,00
66,00	6,00	149,00	150,00	1,00	0,00	0,00
66,00	12,00	149,00	150,00	1,00	0,00	0,00
66,00	18,00	149,00	150,00	1,00	0,00	0,00
72,00	0,00	149,00	150,00	1,00	0,00	0,00
72,00	6,00	149,00	150,00	1,00	0,00	0,00
72,00	12,00	149,00	150,00	1,00	0,00	0,00
72,00	18,00	149,00	150,00	1,00	0,00	0,00
78,00	0,00	149,00	150,00	1,00	0,00	0,00
78,00	6,00	149,00	150,00	1,00	0,00	0,00
78,00	12,00	149,00	150,00	1,00	0,00	0,00
78,00	18,00	149,00	150,00	1,00	0,00	0,00
84,00	0,00	149,00	150,00	1,00	0,00	0,00
84,00	6,00	149,00	150,00	1,00	0,00	0,00
84,00	12,00	149,00	150,00	1,00	0,00	0,00
84,00	18,00	149,00	150,00	1,00	0,00	0,00
90,00	0,00	149,00	150,00	1,00	0,00	0,00
90,00	6,00	149,00	150,00	1,00	0,00	0,00
90,00	12,00	149,00	150,00	1,00	0,00	0,00
90,00	18,00	149,00	150,00	1,00	0,00	0,00
96,00	0,00	149,00	150,00	1,00	0,00	0,00
96,00	6,00	149,00	150,00	1,00	0,00	0,00
96,00	12,00	149,00	150,00	1,00	0,00	0,00
96,00	18,00	149,00	150,00	1,00	0,00	0,00
102,00	0,00	149,00	150,00	1,00	0,00	0,00
102,00	6,00	149,00	150,00	1,00	0,00	0,00
102,00	12,00	149,00	150,00	1,00	0,00	0,00
102,00	18,00	149,00	150,00	1,00	0,00	0,00
108,00	0,00	149,00	150,00	1,00	0,00	0,00
108,00	6,00	149,00	150,00	1,00	0,00	0,00
108,00	12,00	149,00	150,00	1,00	0,00	0,00
108,00	18,00	149,00	150,00	1,00	0,00	0,00
114,00	0,00	149,00	150,00	1,00	0,00	0,00

114,00	6,00	149,00	150,00	1,00	0,00	0,00
114,00	12,00	149,00	150,00	1,00	0,00	0,00
114,00	18,00	149,00	150,00	1,00	0,00	0,00
120,00	0,00	149,00	150,00	1,00	0,00	0,00
120,00	6,00	149,00	150,00	1,00	0,00	0,00
120,00	12,00	149,00	150,00	1,00	0,00	0,00
120,00	18,00	149,00	150,00	1,00	0,00	0,00
126,00	0,00	149,00	150,00	1,00	0,00	0,00
126,00	6,00	149,00	150,00	1,00	0,00	0,00
126,00	12,00	149,00	150,00	1,00	0,00	0,00
126,00	18,00	149,00	150,00	1,00	0,00	0,00



5.5 Design Data - Scenario 5 (hourly - simultaneity)

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/(m³·K)
- Ground surface temperature: 9,6 °C
- Ground flux: 0,07 W/m²

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: 12,38 l/s
- Flow rate through borefield in injection: 8,91 l/s
- Number of boreholes in series: 1

Thermal demand

- Type of load: Hourly building load
- Domestic hot water: 128 000 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	149,00	150,00	1,00	0,00	0,00
0,00	6,00	149,00	150,00	1,00	0,00	0,00
0,00	12,00	149,00	150,00	1,00	0,00	0,00
0,00	18,00	149,00	150,00	1,00	0,00	0,00
6,00	0,00	149,00	150,00	1,00	0,00	0,00
6,00	6,00	149,00	150,00	1,00	0,00	0,00
6,00	12,00	149,00	150,00	1,00	0,00	0,00
6,00	18,00	149,00	150,00	1,00	0,00	0,00
12,00	0,00	149,00	150,00	1,00	0,00	0,00
12,00	6,00	149,00	150,00	1,00	0,00	0,00
12,00	12,00	149,00	150,00	1,00	0,00	0,00
12,00	18,00	149,00	150,00	1,00	0,00	0,00
18,00	0,00	149,00	150,00	1,00	0,00	0,00
18,00	6,00	149,00	150,00	1,00	0,00	0,00
18,00	12,00	149,00	150,00	1,00	0,00	0,00
18,00	18,00	149,00	150,00	1,00	0,00	0,00
24,00	0,00	149,00	150,00	1,00	0,00	0,00
24,00	6,00	149,00	150,00	1,00	0,00	0,00
24,00	12,00	149,00	150,00	1,00	0,00	0,00
24,00	18,00	149,00	150,00	1,00	0,00	0,00
30,00	0,00	149,00	150,00	1,00	0,00	0,00
30,00	6,00	149,00	150,00	1,00	0,00	0,00
30,00	12,00	149,00	150,00	1,00	0,00	0,00
30,00	18,00	149,00	150,00	1,00	0,00	0,00
36,00	0,00	149,00	150,00	1,00	0,00	0,00
36,00	6,00	149,00	150,00	1,00	0,00	0,00
36,00	12,00	149,00	150,00	1,00	0,00	0,00
36,00	18,00	149,00	150,00	1,00	0,00	0,00
42,00	0,00	149,00	150,00	1,00	0,00	0,00
42,00	6,00	149,00	150,00	1,00	0,00	0,00
42,00	12,00	149,00	150,00	1,00	0,00	0,00
42,00	18,00	149,00	150,00	1,00	0,00	0,00
48,00	0,00	149,00	150,00	1,00	0,00	0,00
48,00	6,00	149,00	150,00	1,00	0,00	0,00
48,00	12,00	149,00	150,00	1,00	0,00	0,00
48,00	18,00	149,00	150,00	1,00	0,00	0,00
54,00	0,00	149,00	150,00	1,00	0,00	0,00
54,00	6,00	149,00	150,00	1,00	0,00	0,00

54,00	12,00	149,00	150,00	1,00	0,00	0,00
54,00	18,00	149,00	150,00	1,00	0,00	0,00
60,00	0,00	149,00	150,00	1,00	0,00	0,00
60,00	6,00	149,00	150,00	1,00	0,00	0,00
60,00	12,00	149,00	150,00	1,00	0,00	0,00
60,00	18,00	149,00	150,00	1,00	0,00	0,00
66,00	0,00	149,00	150,00	1,00	0,00	0,00
66,00	6,00	149,00	150,00	1,00	0,00	0,00
66,00	12,00	149,00	150,00	1,00	0,00	0,00
66,00	18,00	149,00	150,00	1,00	0,00	0,00
72,00	0,00	149,00	150,00	1,00	0,00	0,00
72,00	6,00	149,00	150,00	1,00	0,00	0,00
72,00	12,00	149,00	150,00	1,00	0,00	0,00
72,00	18,00	149,00	150,00	1,00	0,00	0,00
78,00	0,00	149,00	150,00	1,00	0,00	0,00
78,00	6,00	149,00	150,00	1,00	0,00	0,00
78,00	12,00	149,00	150,00	1,00	0,00	0,00
78,00	18,00	149,00	150,00	1,00	0,00	0,00
84,00	0,00	149,00	150,00	1,00	0,00	0,00
84,00	6,00	149,00	150,00	1,00	0,00	0,00
84,00	12,00	149,00	150,00	1,00	0,00	0,00
84,00	18,00	149,00	150,00	1,00	0,00	0,00
90,00	0,00	149,00	150,00	1,00	0,00	0,00
90,00	6,00	149,00	150,00	1,00	0,00	0,00
90,00	12,00	149,00	150,00	1,00	0,00	0,00
90,00	18,00	149,00	150,00	1,00	0,00	0,00
96,00	0,00	149,00	150,00	1,00	0,00	0,00
96,00	6,00	149,00	150,00	1,00	0,00	0,00
96,00	12,00	149,00	150,00	1,00	0,00	0,00
96,00	18,00	149,00	150,00	1,00	0,00	0,00
102,00	0,00	149,00	150,00	1,00	0,00	0,00
102,00	6,00	149,00	150,00	1,00	0,00	0,00
102,00	12,00	149,00	150,00	1,00	0,00	0,00
102,00	18,00	149,00	150,00	1,00	0,00	0,00
108,00	0,00	149,00	150,00	1,00	0,00	0,00
108,00	6,00	149,00	150,00	1,00	0,00	0,00
108,00	12,00	149,00	150,00	1,00	0,00	0,00
108,00	18,00	149,00	150,00	1,00	0,00	0,00
114,00	0,00	149,00	150,00	1,00	0,00	0,00

114,00	6,00	149,00	150,00	1,00	0,00	0,00
114,00	12,00	149,00	150,00	1,00	0,00	0,00
114,00	18,00	149,00	150,00	1,00	0,00	0,00
120,00	0,00	149,00	150,00	1,00	0,00	0,00
120,00	6,00	149,00	150,00	1,00	0,00	0,00
120,00	12,00	149,00	150,00	1,00	0,00	0,00
120,00	18,00	149,00	150,00	1,00	0,00	0,00
126,00	0,00	149,00	150,00	1,00	0,00	0,00
126,00	6,00	149,00	150,00	1,00	0,00	0,00
126,00	12,00	149,00	150,00	1,00	0,00	0,00
126,00	18,00	149,00	150,00	1,00	0,00	0,00





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