Software within building physics and ground heat storage

EED WEB ENGINE

Earth Energy Designer web engine

September 5, 2019

The latest version of this document is available at
https://buildingphysics.com/download/eedwebengine.pdf

BLOCON

www.buildingphysics.com

Contents

1. EED web engine

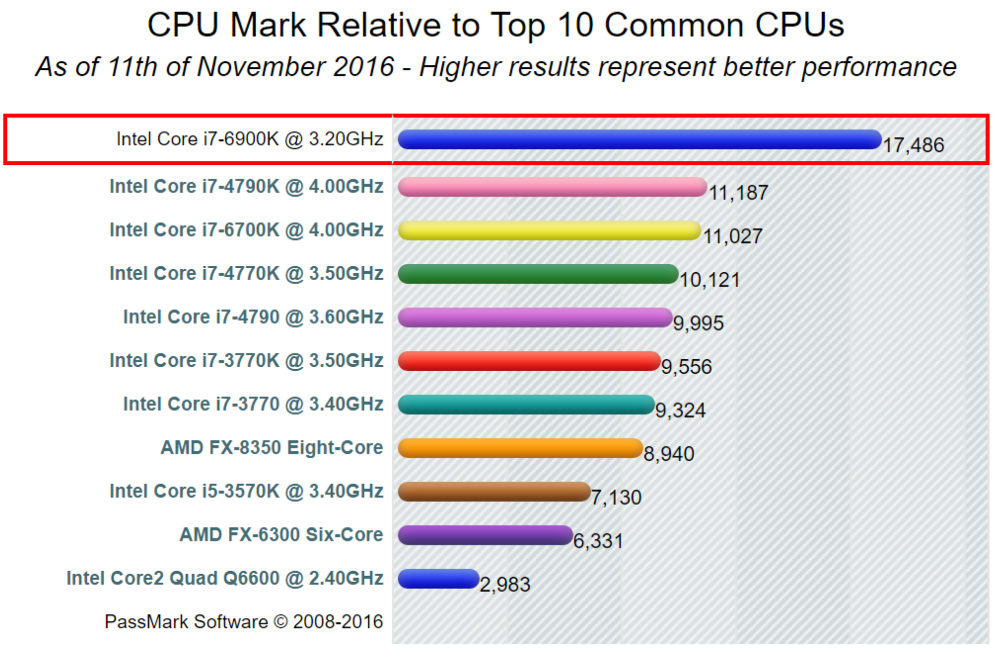
The EED web engine is a simple yet powerful solution that allows users to quickly make calculations without the standard EED desktop application.

All that is needed from the user is basically to put an input file in a drop-box/Google drive/Onedrive folder and then the engine will read that file, calculate it, and produce an output file with results.

There are many advantages using the EED Web Engine:

- Easy to use. Access it from anywhere.
- Extreme calculation performance. We use powerful cpu/gpu:s allowing quick simulations and optimizations for both monthly and hourly values for loads. A monthly calculation for 25 years takes typically 0.02 seconds, and an hourly calculation for 25 years only about one second!
- Run multiple batch jobs allowing e.g. parameter studies.
- Allows for integration development to be used with other software within building simulation such as TRNSYS, EnergyPlus, DesignBuilder and OpenStudio (based on EnergyPlus), and other software that needs a Ground Source Heat Pump (GSHP) module.

A high-end cpu (I7-6900K) is currently used on the server. The graph below shows the relative performance of the I7-6900K compared to the 10 other common cpu:s in terms of the “PassMark CPU Mark” benchmark test.



2. Using the EED web engine

2.1 Introduction and quick start

No installation of software is needed. The only thing you need is a Dropbox account (or Google drive/Onedrive account). We will share a folder with you that constantly will be monitored by a dedicated EED web engine. In essence, the steps are simple:

- Place the EED input file(s) in this folder. If you want to make hourly calculations using load files these files should also be put here.
- Make a text file called **run.txt** and specify on each row the input file name and what kind of calculation that will be executed (solve mean fluid temperatures F9 or solve required bore hole length F10). (Optimization F11 will be added later on).

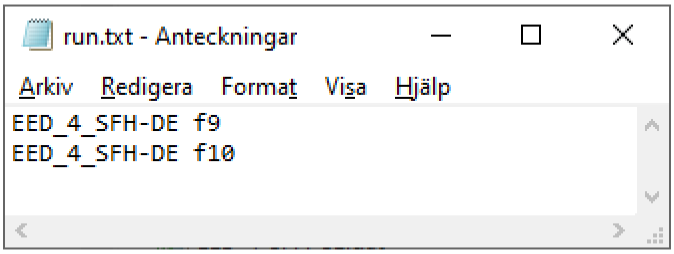
Example: (see example 1 in the tutorial https://buildingphysics.com/download/exampleseed.pdf)

- Place the EED input file EED_4_SFH-DE in your dropbox folder.
- Create a text file **run.**txt with the following rows

  EED_4_SFH-DE f9

  EED_4_SFH-DE f10

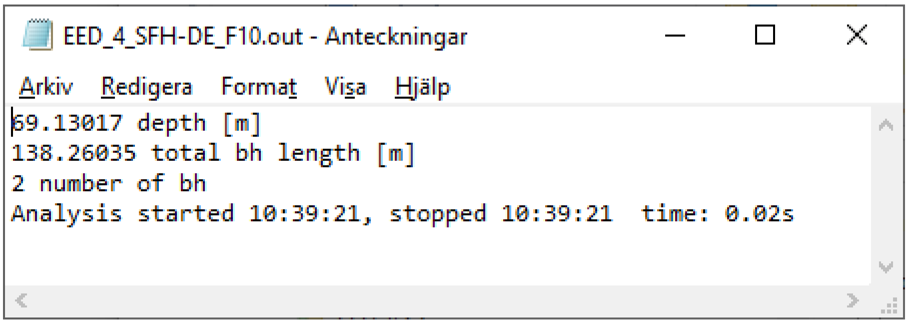
  Below is an example where Notepad is used as an editor:



- When run.txt is saved the EED web engine will instantly “consume” it and create some output files:

  F9 will create EED_4_SFH-DE.OUT (same as the “design data” window in EED, see Appendix 1) and EED_4_SFH-DE_Tf.OUT (mean fluid temperatures).

  F10 will create EED_4_SFH-DE_F10.OUT (as shown below)



- After all rows in **run.txt** have been processed, the file will be renamed to **runned.txt**.

- A log file log.txt will also be created/appended to with info about simulation:

```
log.txt - Anteckningar
Arkiv  Redigera  Format  Visa  Hjälp
2019-09-03 10:42:31 EED_4_SFH-DE.dat      F9  [M] => *.out + *_Tf.out     cpu:0.06s  sims:1/1000
2019-09-03 10:42:32 EED_4_SFH-DE.dat      F10 [M] => *_F10.out            cpu:0.021s sims:2/1000
```

Description of log.txt:

date and time when simulation is started
input file name
F9: mean fluid temperatures are solved
F10: required borehole length is solved
[M] or **[H]:** indicates if calculation has been made for monthly or hourly load values (this is set in the input data file)
Files created: e.g. the F9 simulation of EED_4_SFH-DE.dat will create EED_4_SFH-DE.out and EED_4_SFH-DE_Tf.out (this contains monthly mean fluid temperatures). The F10 simulation of EED_4_SFH-DE.dat will create EED_4_SFH-DE_F10.dat
cpu time: how long time the calculation takes for the EED web engine server
sims: used/max simulations for the account

The following run.txt file will run all files in the tutorial at

https://buildingphysics.com/download/exampleseed.pdf

```
run.txt - Anteckningar
Arkiv  Redigera  Format  Visa  Hjälp
EED_4_SFH-DE f9
EED_4_SFH-DE f10
EED_4_SFH-SE f9
EED_4_SFH-SE f10
EED_4_SFH-GR f9
EED_4_SFH-GR f10
EED_4_OFFICE-S f9
EED_4_OFFICE-S f10
EED_4_OFFICE-L f10
EED_4_OFFICE-L f9
```

The following log.txt will be created when simulations are done:

```
log.txt - Anteckningar
Arkiv Redigera Format Visa Hjälp
2019-08-30 10:27:43 EED_4_SFH-DE.dat     F9  [M] => *.out + *_Tf.out    cpu:0,03s  sims:1/1000
2019-08-30 10:27:44 EED_4_SFH-DE.dat     F10 [M] => *_F10.out           cpu:0,02s  sims:2/1000
2019-08-30 10:58:41 EED_4_SFH-DE.dat     F9  [M] => *.out + *_Tf.out    cpu:0,03s  sims:3/1000
2019-08-30 10:58:41 EED_4_SFH-DE.dat     F10 [M] => *_F10.out           cpu:0,02s  sims:4/1000
2019-08-30 10:58:42 EED_4_SFH-SE.dat     F9  [M] => *.out + *_Tf.out    cpu:0,036s sims:5/1000
2019-08-30 10:58:42 EED_4_SFH-SE.dat     F10 [M] => *_F10.out           cpu:0,011s sims:6/1000
2019-08-30 10:58:42 EED_4_SFH-GR.dat     F9  [M] => *.out + *_Tf.out    cpu:0,027s sims:6/1000
2019-08-30 10:58:43 EED_4_SFH-GR.dat     F10 [M] => *_F10.out           cpu:0,011s sims:7/1000
2019-08-30 10:58:43 EED_4_OFFICE-S.dat   F9  [M] => *.out + *_Tf.out    cpu:0,033s sims:8/1000
2019-08-30 10:58:44 EED_4_OFFICE-S.dat   F10 [M] => *_F10.out           cpu:0,022s sims:9/1000
2019-08-30 10:58:45 EED_4_OFFICE-L.dat   F10 [H] => No solution found   cpu:1s     sims:9/1000
2019-08-30 10:58:46 EED_4_OFFICE-L.dat   F9  [H] => *.out + *_Tf.out    cpu:1s     sims:10/1000
```

Note that the file EED_4_OFFICE-L.dat (that has a load file) only takes one second to process for 25 years of hourly values.

2.2 Details of the EED web engine process

Your account file folder will constantly be monitored by a dedicated EED web engine. As soon as the file **run.txt** exists in this folder it will be read and processed. The file run.txt will be renamed to **running.txt** and when all the simulations are made it will be renamed again to **runned.txt**.

The above process makes it suitable to programmatically run multiple simulations. An advanced user can for example write a software program/script that creates the EED input data file(s) and the run.txt file, and then read output results when simulations are done.

The EED engine will ignore rows that starts with "%" (see second row below). Comments can be written at the end of each row (see third row below).

```
run.txt - Anteckningar
Arkiv Redigera Format Visa Hjälp
EED_4_SFH-DE f9
%EED_4_SFH-DE f10
EED_4_SFH-SE f9 comments ok here
```

2.3 Input files

The input file (*.dat) is the same as the one that is used by the desktop version of EED. An example is shown in Appendix 1.

The user can edit an input file in a text editor (such as Notepad) or make a script/software program that creates this file.

Note that data is given on each row and sometimes followed by a comment for the variable, such as

```
2.20000 ThermCondGround
```

Note that the comment does not need to be given, hence this row is ok:

```
2.20000
```

Tip: Check that an input file is ok by opening it in the EED desktop version.

Load files

Option for monthly or hourly calculations is set by row

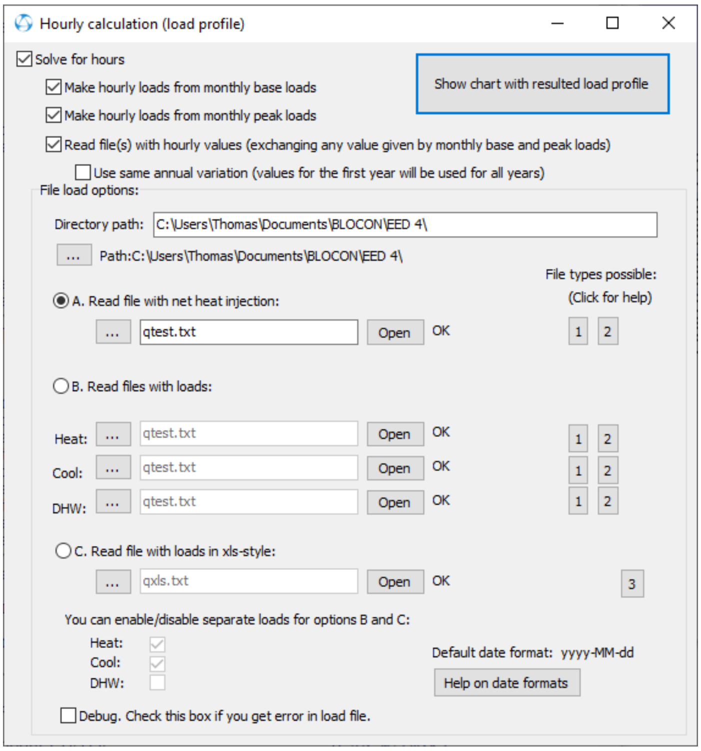
```
0 CB_SolveHours (yes=1,no=0)
```

Option to use a load file is set by row

```
1 CB_readqifile (yes=1,no=0)
```

And “file load option” is set by row

```
0 File option index (0=A, 1=B, 2=C)
```



Note that all paths used in the input file will be ignored. It is assumed that all load files (like qtest.txt in example above) is in the root of the Dropbox user folder.

Make script/software to create input files

Assume that you need to make some parametric studies (e.g. see effects on different borehole spacings or loads). This can be made by

1. Start with an input file saved by the desktop version

2. Make a script/software utility that reads the input file and changes some data (e.g. the borehole spacings) and then creates new input files.

3. Create the file run.txt

4. Read the output file(s) (when the file runned.txt exists)

If iterations are needed for some calculations, the above lines can be repeated.

2.4 Output files

A calculation for mean fluid temperatures (F9) will create a text file with design data (filename.out) and a text file with fluid temperatures (filename_Tf.out) that contains monthly or hourly values depending of what is specified in the input file.

```
EED_4_SFH-DE.OUT - Anteckningar
Arkiv  Redigera  Format  Visa  Hjälp

EED 4.20 - www.buildingphysics.com - license for info@blocon.se
  Input file:EED_4_SFH-DE.dat
  This output file: EED_4_SFH-DE.OUT  Date: 2019-09-03 Time: 10:55:58

MEMORY NOTES FOR PROJECT
[]


QUICK FACTS
  Cost                                         -
  Number of boreholes                          2
  Borehole depth                               100 m
  Total borehole length                        200 m


                 D E S I G N    D A T A
                 ======================

GROUND

  Ground thermal conductivity                  2.2 W/(m·K)
  Ground heat capacity                         2.3 MJ/(m³·K)
  Ground surface temperature                   9.2 °C
  Geothermal heat flux                         0.07 W/m²

BOREHOLE

  Configuration:                               1 ("2 : 1 x 2 line")
  Borehole depth                               100 m
  Borehole spacing                             6 m
```

Example EED_4_SFH-DE.out with design data

```
EED_4_SFH-DE_Tf.out - Anteckningar
Arkiv  Redigera  Format  Visa  Hjälp

month          T
     1        6.32
     2        6.25
     3        6.43
     4         6.5
     5        6.66
     6        7.41
     7        7.41
     8        7.41
     9           5
    10        4.14
    11        3.42
    12        2.64
    13         2.4
    14        2.33
    15        2.84
    16        3.34
```

Example EED_4_SFH-DE_Tf.out with monthly mean temperatures for 25 years (25*12=300 values).

EED_4_OFFICE-L_Tf.out - Anteckningar

Arkiv Redigera Format Visa Hjälp

```
hour          T
     0         11.2
     1         11.2
     2         7.84
     3         7.38
     4         6.98
     5         6.77
     6          6.7
     7         6.74
     8         7.36
     9         7.61
    10         7.87
    11         8.07
    12         8.29
    13         8.27
```

Example EED_4_OFFICE-L_Tf.out with hourly mean temperatures for 25 years (25*8760=219000 values).

A calculation for required borehole length (F10) will create filename_F10.dat with the following data:

EED_4_SFH-DE_F10.out - Anteckningar

Arkiv Redigera Format Visa Hjälp

```
69.13017 depth [m]
138.26035 total bh length [m]
2 number of bh
Analysis started 10:55:58, stopped 10:55:58  time: 0.024s
```

Example EED_4_SFH-DE_F10.out

Note that the decimal point used is "." In the output files.

2.5 Errors

The log file will indicate if there is any error due to bad input files, missing load files, etc.

log.txt - Anteckningar

Arkiv Redigera Format Visa Hjälp

```
2019-09-05 09:53:34 ex1.dat                F9  [M] => *.out + *_Tf.out     cpu:0.057s sims:34/1000
2019-09-05 09:53:39 EED_4_OFFICE-L.dat     F10 [H] => No solution found    cpu:4s     sims:34/1000
2019-09-05 09:53:43 ex2.dat                F10 [H] => *_F10.out            cpu:4s     sims:35/1000
2019-09-05 09:53:43 ex3.dat                error: bad input file no version           sims:35/1000
2019-09-05 09:53:44 ex4.dat                F9  [M] => *.out + *_Tf.out     cpu:0.044s sims:36/1000
2019-09-05 09:53:44 ex5.dat                error: bad input file                      sims:36/1000
2019-09-05 09:53:44 testreynolds.dat       F9  [M] => *.out + *_Tf.out     cpu:0.049s sims:37/1000
2019-09-05 09:53:44 ex5_corrupted.dat      error: bad input file                      sims:37/1000
```

Note that the counter for simulations will not be increased if there is an error.

Even though there is no error, there might be warnings indicated in the output file:

```
TESTREYNOLDS.OUT - Anteckningar
Arkiv  Redigera  Format  Visa  Hjälp
EED 4.20 - www.buildingphysics.com - license for info@blocon.se
  Input file:testreynolds.dat
  This output file: TESTREYNOLDS.OUT  Date: 2019-08-30 Time: 12:32:42

MEMORY NOTES FOR PROJECT
[]

*** CAUTION! SOLUTION HAS WARNINGS! ***

No solution found! Depth not changed.

 Warning! Flow is not turbulent. Re=1981,4.

QUICK FACTS
  Cost                                        -
  Number of boreholes                         1
  Borehole depth                              110 m
  Total borehole length                       110 m
```

If required borehole length cannot be found for an F10 calculation it will be indicated by -1:

```
EED_4_OFFICE-L_F10.out - Anteckningar
Arkiv  Redigera  Format  Visa  Hjälp
-1 No solution found: EED_4_OFFICE-L.dat error in calculation
```

2.6 Account details

An account for using the EED engine requires a perpetual or annual license of EED v4. The cost is the same as for “EED on the WEB”, see

https://buildingphysics.com/wp-content/uploads/prices.pdf

A typical cost is 1€ per simulation.The subscription is valid for one year. Please contact us for a free test account.

The log file (log.txt) will show used and max simulations for the account.

2.7 Comments on speed

Even though the calculations are very fast there is an overhead cost regarding speed due to the sync process in the Dropbox folder that can be a few seconds. There is a response time (latency) between your device and our server and a file transfer time that depends on internet speed and bandwidth. In addition to the factors described above, the following also play a role in sync speeds:

- Traffic/Packet shaping and Bandwidth limits: ISPs and other organizations set limits on the amount of network traffic allotted to a service or to prioritize bandwidth for certain services over others.
- Network Congestion: Too much traffic on a particular network (congestion) impacts connection speed.
- Virus scanning/security software may affect speed.

See also
https://help.dropbox.com/sv-se/installs-integrations/sync-uploads/faster-sync

If faster overall calculation times is needed we would be able to develop a **web service/Restful API server/client** on a consultant basis.

3. Appendix 1

Example 1 input file file EED_4_SFH-DE.dat:

```
& Version=4.19
SI=yes
Comment 1
Comment 2
Comment 3
Comment 4
Comment 5
2.20000 ThermCondGround
2299999.95232 HeatCap
9.20000 InitGroundSurfTemp
0.07000 GeothermalHeatFlux
1 RecNum
2 : 1 x 2 line
100.00000 BHDepth
6.00000 B
0.15240 BoreholeDiam
DOUBLE-U
0.00200 BhVolFlow m3/s
1 Volflow index
1 Volflow factor
0.05000 PipeDiam
0.00460 PipeThick
0.22000 PipeThCond
0.10000 LinOutDiam
0.00400 LinThick
0.40000 LinThCond
0.00000 mc
0.03200 UPipeDiam
0.00300 UPipeThick
0.42000 UPipeThCond
0.08000 UPipeShankSpace
1.60000 ThermCondFill
4.79999989271164E-0001 hc_thermcond
3.79500000000000E+0003 hc_heatcap
1.05200000000000E+0003 hc_dens
5.20000001415610E-0003 hc_visc
-1.40000000000000E+0001 hc_freeze
1 calculate_borehole_resistance (yes=1,no=0)
10 multipoles
7.26550593972206E-0002 bore_rb
2.33945712447166E-0001 bore_ra
1.00000001490116E-0001 bore_rb_const
5.00000000000000E-0001 bore_ra_const
1 internal_heat_transfer (yes=1,no=0)
0 baseloadenergy_mode (yes=1,no=0)
10.80000 annual_heat_load
4.20000 SPF_Heat
0 direct (yes=1,no=0)
2.51100 monthly heat load  1
2.39760 monthly heat load  2
2.02500 monthly heat load  3
1.60380 monthly heat load  4
1.03680 monthly heat load  50.00000 monthly heat load  6
0.00000 monthly heat load  7
0.00000 monthly heat load  8
0.98820 monthly heat load  9
1.40940 monthly heat load 10
1.89540 monthly heat load 11
2.33280 monthly heat load 12
0.15500 monthly heat factor  1
0.14800 monthly heat factor  2
0.12500 monthly heat factor  3
0.09900 monthly heat factor  4
0.06400 monthly heat factor  5
0.00000 monthly heat factor  6
0.00000 monthly heat factor  7
0.00000 monthly heat factor  8
0.06100 monthly heat factor  9
0.08700 monthly heat factor 10
```

```
0.11700 monthly heat factor 11
0.14400 monthly heat factor 12
0.00000 annual_cool_load
3.00000 SPF_Cool
0 direct (yes=1,no=0)
0.00000 monthly cool load  1
0.00000 monthly cool load  2
0.00000 monthly cool load  3
0.00000 monthly cool load  4
0.00000 monthly cool load  5
0.00000 monthly cool load  6
0.00000 monthly cool load  7
0.00000 monthly cool load  8
0.00000 monthly cool load  9
0.00000 monthly cool load 10
0.00000 monthly cool load 11
0.00000 monthly cool load 12
0.00000 monthly cool factor  1
0.00000 monthly cool factor  2
0.00000 monthly cool factor  3
0.00000 monthly cool factor  4
0.00000 monthly cool factor  5
0.00000 monthly cool factor  6
0.00000 monthly cool factor  7
0.00000 monthly cool factor  8
0.00000 monthly cool factor  9
0.00000 monthly cool factor 10
0.00000 monthly cool factor 11
0.00000 monthly cool factor 12
9.50000000000000E+0000 monthly heat peak load  1
9.50000000000000E+0000 monthly heat peak load  2
9.50000000000000E+0000 monthly heat peak load  3
9.50000000000000E+0000 monthly heat peak load  4
9.50000000000000E+0000 monthly heat peak load  5
9.50000000000000E+0000 monthly heat peak load  6
9.50000000000000E+0000 monthly heat peak load  7
9.50000000000000E+0000 monthly heat peak load  8
9.50000000000000E+0000 monthly heat peak load  9
9.50000000000000E+0000 monthly heat peak load 10
9.50000000000000E+0000 monthly heat peak load 11
9.50000000000000E+0000 monthly heat peak load 12
1.20000000000000E+0001 monthly heat duration  1
1.20000000000000E+0001 monthly heat duration  2
8.00000000000000E+0000 monthly heat duration  3
6.00000000000000E+0000 monthly heat duration  4
4.00000000000000E+0000 monthly heat duration  5
1.50000000000000E+0000 monthly heat duration  6
1.50000000000000E+0000 monthly heat duration  7
1.50000000000000E+0000 monthly heat duration  8
4.00000000000000E+0000 monthly heat duration  9
6.00000000000000E+0000 monthly heat duration 10
8.00000000000000E+0000 monthly heat duration 11
1.20000000000000E+0001 monthly heat duration 12
0.00000000000000E+0000 monthly cool peak load  1
0.00000000000000E+0000 monthly cool peak load  2
0.00000000000000E+0000 monthly cool peak load  3
0.00000000000000E+0000 monthly cool peak load  4
0.00000000000000E+0000 monthly cool peak load  5
0.00000000000000E+0000 monthly cool peak load  6
0.00000000000000E+0000 monthly cool peak load  7
0.00000000000000E+0000 monthly cool peak load  8
0.00000000000000E+0000 monthly cool peak load  9
0.00000000000000E+0000 monthly cool peak load 10
0.00000000000000E+0000 monthly cool peak load 11
0.00000000000000E+0000 monthly cool peak load 12
0.00000000000000E+0000 monthly cool duration  1
0.00000000000000E+0000 monthly cool duration  2
0.00000000000000E+0000 monthly cool duration  3
0.00000000000000E+0000 monthly cool duration  4
0.00000000000000E+0000 monthly cool duration  5
0.00000000000000E+0000 monthly cool duration  6
0.00000000000000E+0000 monthly cool duration  7
0.00000000000000E+0000 monthly cool duration  8
0.00000000000000E+0000 monthly cool duration  9
0.00000000000000E+0000 monthly cool duration 10
0.00000000000000E+0000 monthly cool duration 11
0.00000000000000E+0000 monthly cool duration 12
-3.50000000000000E+0000 tfluid_min_required
```

```
1.50000000000000E+0001 tfluid_max_required
1 include_peak_load (yes=1,no=0)
25 max_number_of_cycles
9 start_month
123
89
88
88
4
-1
-1
-1
13
22
-1
4.00000 annual DHW
3.50000 SPF DHW
0 Config min
797 Config max
 3.00000000000000E+0001 Land area width
 2.00000000000000E+0001 Land area height
5 Spacing min
100 Spacing max
 5.00000000000000E+0001 Depth min
 3.00000000000000E+0002 Depth max
2000 Borehole num max
1 detail (yes=1,no=0)
1 round off (yes=1,no=0)
0 Also list cases with warnings (yes=1,no=0)
2 Step
0 Sort index
EUR
 0.00000000000000E+0000 Cost fix
 0.00000000000000E+0000 Cost fix per bh
 0.00000000000000E+0000 Cost drilling per m
 0.00000000000000E+0000 Cost soil drilling per bh
 0.00000000000000E+0000 Cost soil drilling per m
 0.00000000000000E+0000 depth soil drilling
 0.00000000000000E+0000 Cost ditch per m
qtest.txt
qtest.txt
qtest.txt
qtest.txt
qxls.txt
0 Show results after
0 CB_SolveHours (yes=1,no=0)
1 CB_UseInitialBase (yes=1,no=0)
1 CB_UseInitialPeak (yes=1,no=0)
0 CB_readqifile (yes=1,no=0)
0 CB_UseAnnualVariation (yes=1,no=0)
1 CB_useheat (yes=1,no=0)
1 CB_usecool (yes=1,no=0)
0 CB_usedhw (yes=1,no=0)
0 File option index
C:\Users\BS\Documents\BLOCON\EED 4\
```

Example 1 output file EED_4_SFH-DE.out:

```
EED 4.20 - www.buildingphysics.com - license for info@blocon.se
  Input file:EED_4_SFH-DE.dat
  This output file: EED_4_SFH-DE.OUT  Date: 2019-09-03 Time: 10:55:58

MEMORY NOTES FOR PROJECT
[]


QUICK FACTS
  Cost                                        -
  Number of boreholes                         2
  Borehole depth                              100 m
  Total borehole length                       200 m


                 D E S I G N   D A T A
                 ======================

GROUND

  Ground thermal conductivity                 2.2 W/(m·K)
  Ground heat capacity                        2.3 MJ/(m³·K)
  Ground surface temperature                  9.2 °C
  Geothermal heat flux                        0.07 W/m²

BOREHOLE

  Configuration:                              1 ("2 : 1 x 2 line")
  Borehole depth                              100 m
  Borehole spacing                            6 m
  Borehole installation                       Double-U
  Borehole diameter                           152 mm
  U-pipe diameter                             32 mm
  U-pipe thickness                            3 mm
  U-pipe thermal conductivity                 0.42 W/(m·K)
  U-pipe shank spacing                        80 mm
  Filling thermal conductivity                1.6 W/(m·K)
  Contact resistance pipe/filling             0 (m·K)/W

THERMAL RESISTANCES

  Borehole thermal resistances are calculated.
  Number of multipoles                        10
  Internal heat transfer between upward and downward channel(s) is considered.

HEAT CARRIER FLUID

  Thermal conductivity                        0.48 W/(m·K)
  Specific heat capacity                      3795 J/(Kg·K)
  Density                                     1052 Kg/m³
  Viscosity                                   0.0052 Kg/(m·s)
  Freezing point                              -14 °C
  Flow rate per borehole                      2 l/s

BASE LOAD

  Annual DHW load                             4 MWh
  Annual heating load (DHW excluded)          10.8 MWh
  Annual cooling load                         0 MWh

  Seasonal performance factor (DHW)           3.5
  Seasonal performance factor (heating)       4.2
  Seasonal performance factor (cooling)       3

  Monthly energy profile [MWh]
  Month     Factor   Heat load   Factor   Cool load   Ground load
   JAN      0.155       2.01        0         0          1.51
   FEB      0.148       1.93        0         0          1.46
   MAR      0.125       1.68        0         0          1.27
   APR      0.099        1.4        0         0          1.05
   MAY      0.064       1.02        0         0          0.76
   JUN          0       0.33        0         0          0.24
   JUL          0       0.33        0         0          0.24
   AUG          0       0.33        0         0          0.24
   SEP      0.061       0.99        0         0          0.74
```

OCT	0.087	1.27	0	0	0.95
NOV	0.117	1.6	0	0	1.2
DEC	0.144	1.89	0	0	1.42
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Total	1	14.8	0	0	11.1

PEAK LOAD

Monthly peak powers [kW]

Month	Peak heat	Duration	Peak cool	Duration [h]
JAN	9.5	12	0	0
FEB	9.5	12	0	0
MAR	9.5	8	0	0
APR	9.5	6	0	0
MAY	9.5	4	0	0
JUN	9.5	1.5	0	0
JUL	9.5	1.5	0	0
AUG	9.5	1.5	0	0
SEP	9.5	4	0	0
OCT	9.5	6	0	0
NOV	9.5	8	0	0
DEC	9.5	12	0	0

Number of simulation years 25
First month of operation SEP

C A L C U L A T E D   V A L U E S
==================================
* Monthly calculation *

Total borehole length 200 m

THERMAL RESISTANCES

Borehole therm. res. internal 0.23 (m·K)/W

Reynolds number 9907
Thermal resistance fluid/pipe 0.00531 (m·K)/W
Thermal resistance pipe material 0.07868 (m·K)/W
Contact resistance pipe/filling 0 (m·K)/W

Borehole therm. res. fluid/ground 0.07266 (m·K)/W

Effective borehole thermal res. 0.07288 (m·K)/W

SPECIFIC HEAT EXTRACTION RATE [W/m]

Month	Base load	Peak heat	Peak cool
JAN	10.4	36.2	0
FEB	9.97	36.2	0
MAR	8.68	36.2	0
APR	7.21	36.2	0
MAY	5.24	36.2	0
JUN	1.63	36.2	0
JUL	1.63	36.2	0
AUG	1.63	36.2	0
SEP	5.07	36.2	0
OCT	6.53	36.2	0
NOV	8.22	36.2	0
DEC	9.75	36.2	0

BASE LOAD: MEAN FLUID TEMPERATURES (at end of month) [°C]

Year	1	2	5	10	25
JAN	10.8	6.87	6.17	5.86	5.56
FEB	10.8	6.87	6.21	5.9	5.6
MAR	10.8	7.2	6.57	6.27	5.97
APR	10.8	7.63	7.04	6.75	6.45
MAY	10.8	8.26	7.7	7.41	7.12
JUN	10.8	9.46	8.93	8.65	8.35
JUL	10.8	9.58	9.06	8.79	8.5
AUG	10.8	9.64	9.15	8.88	8.59
SEP	9.15	8.57	8.1	7.83	7.55
OCT	8.54	8.03	7.58	7.31	7.03
NOV	7.85	7.4	6.96	6.7	6.42
DEC	7.22	6.8	6.38	6.12	5.84

BASE LOAD: YEAR 25
Minimum mean fluid temperature 5.56 °C at end of JAN
Maximum mean fluid temperature 8.59 °C at end of AUG

PEAK HEAT LOAD: MEAN FLUID TEMPERATURES (at end of month) [°C]

Year	1	2	5	10	25
JAN	10.8	2.4	1.7	1.39	1.08
FEB	10.8	2.33	1.67	1.37	1.06
MAR	10.8	2.84	2.21	1.91	1.61
APR	10.8	3.34	2.75	2.45	2.16
MAY	10.8	4.13	3.57	3.28	2.99
JUN	10.8	6.08	5.54	5.26	4.97
JUL	10.8	6.19	5.68	5.4	5.11
AUG	10.8	6.26	5.77	5.49	5.21
SEP	5	4.42	3.95	3.68	3.39
OCT	4.14	3.64	3.18	2.92	2.64
NOV	3.42	2.97	2.53	2.27	1.99
DEC	2.64	2.22	1.8	1.55	1.26

PEAK HEAT LOAD: YEAR 25
Minimum mean fluid temperature 1.06 °C at end of FEB
Maximum mean fluid temperature 5.21 °C at end of AUG

PEAK COOL LOAD: MEAN FLUID TEMPERATURES (at end of month) [°C]

Year	1	2	5	10	25
JAN	10.8	6.87	6.17	5.86	5.56
FEB	10.8	6.87	6.21	5.9	5.6
MAR	10.8	7.2	6.57	6.27	5.97
APR	10.8	7.63	7.04	6.75	6.45
MAY	10.8	8.26	7.7	7.41	7.12
JUN	10.8	9.46	8.93	8.65	8.35
JUL	10.8	9.58	9.06	8.79	8.5
AUG	10.8	9.64	9.15	8.88	8.59
SEP	9.15	8.57	8.1	7.83	7.55
OCT	8.54	8.03	7.58	7.31	7.03
NOV	7.85	7.4	6.96	6.7	6.42
DEC	7.22	6.8	6.38	6.12	5.84

PEAK COOL LOAD: YEAR 25
Minimum mean fluid temperature 5.56 °C at end of JAN
Maximum mean fluid temperature 8.59 °C at end of AUG