Geothermal Energy for Efficient Cooling of Intake Air in Harsh Environments: A Combined Experimental-Modelling Approach
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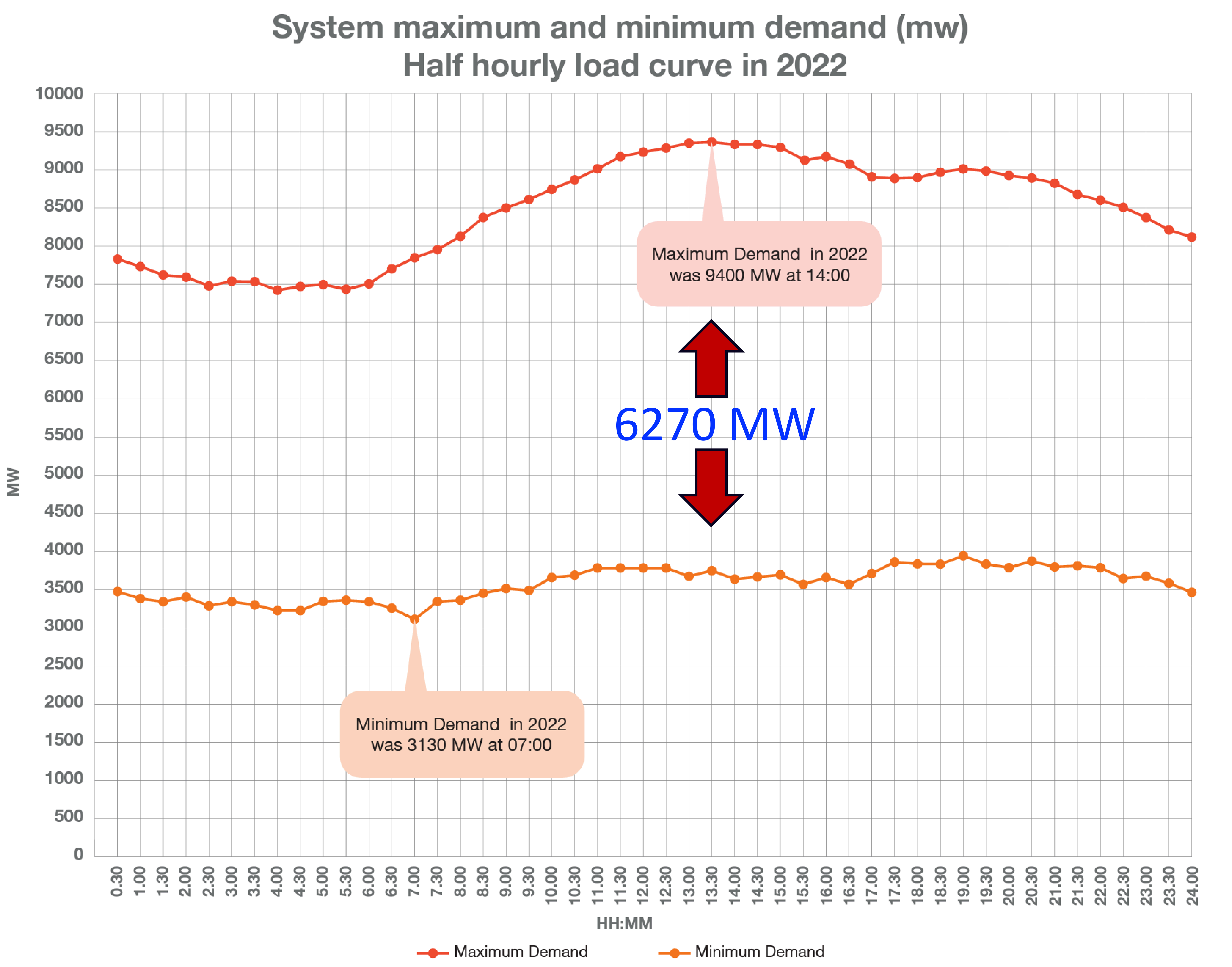
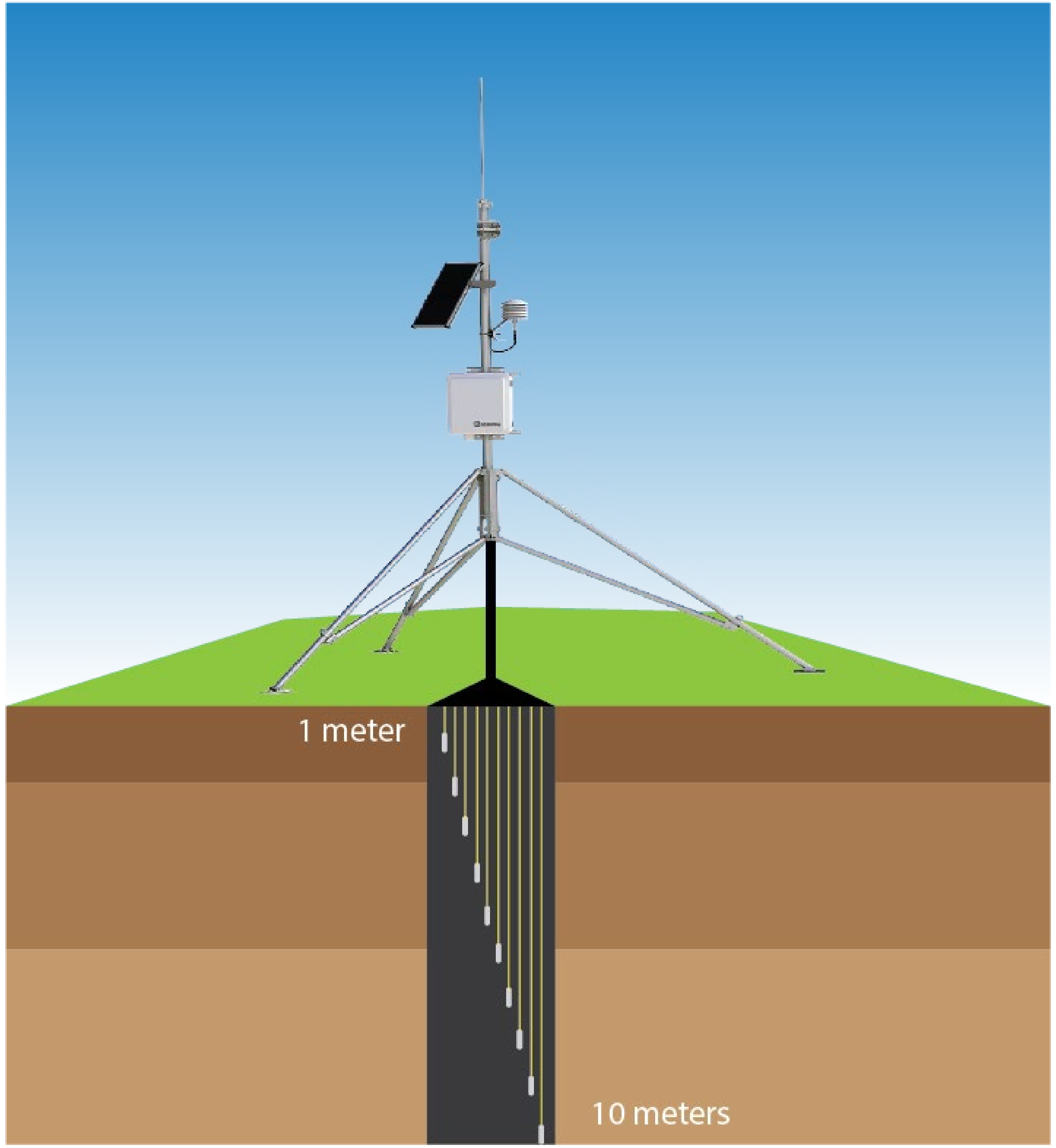
Motivation



System maximum and minimum demand (mw)
Half hourly load curve in 2022
MW
HH:MM
Maximum Demand in 2022 was 9400 MW at 14:00
6270 MW
Minimum Demand in 2022 was 3130 MW at 07:00
Maximum Demand
Minimum Demand

Motivation



Motivation

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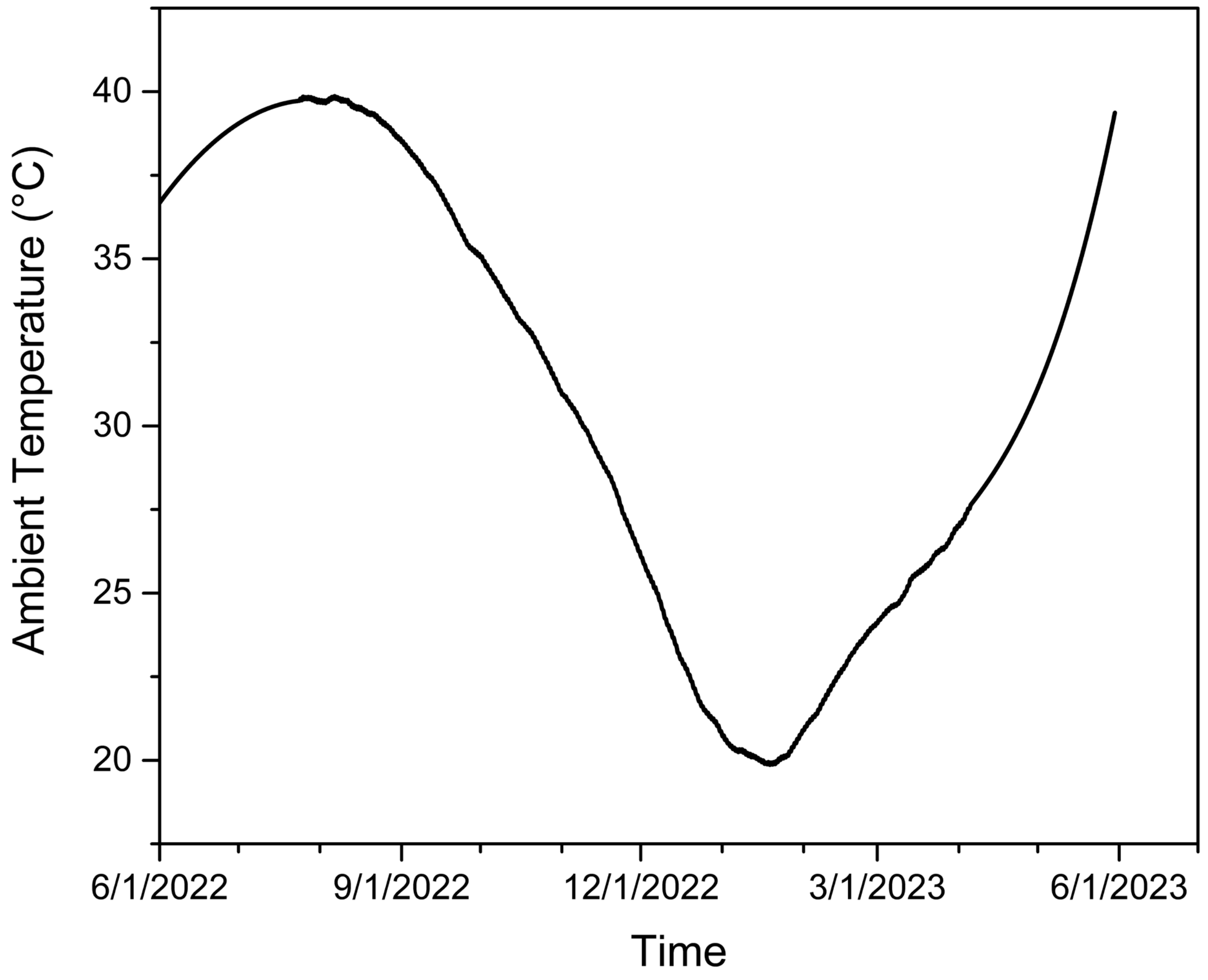
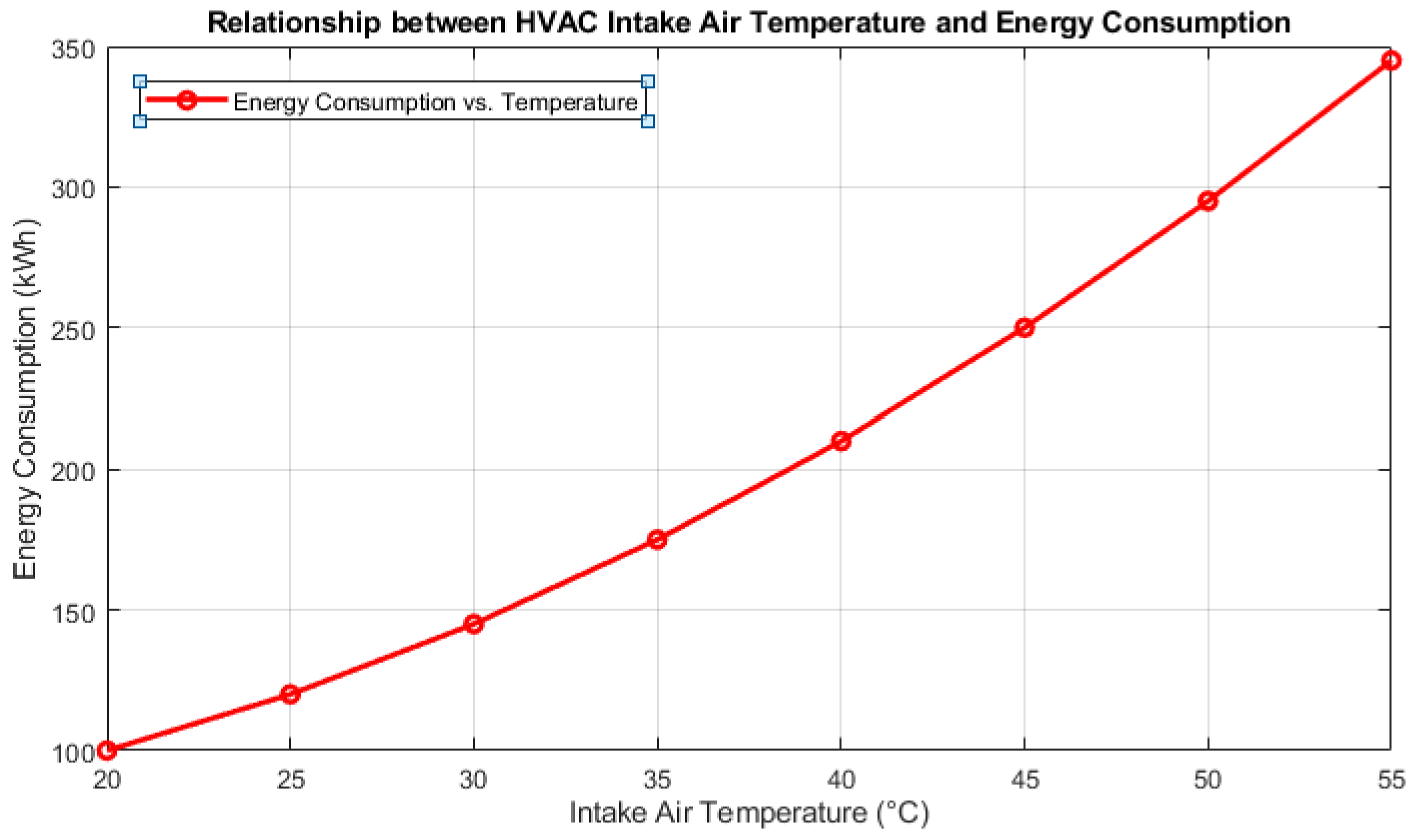
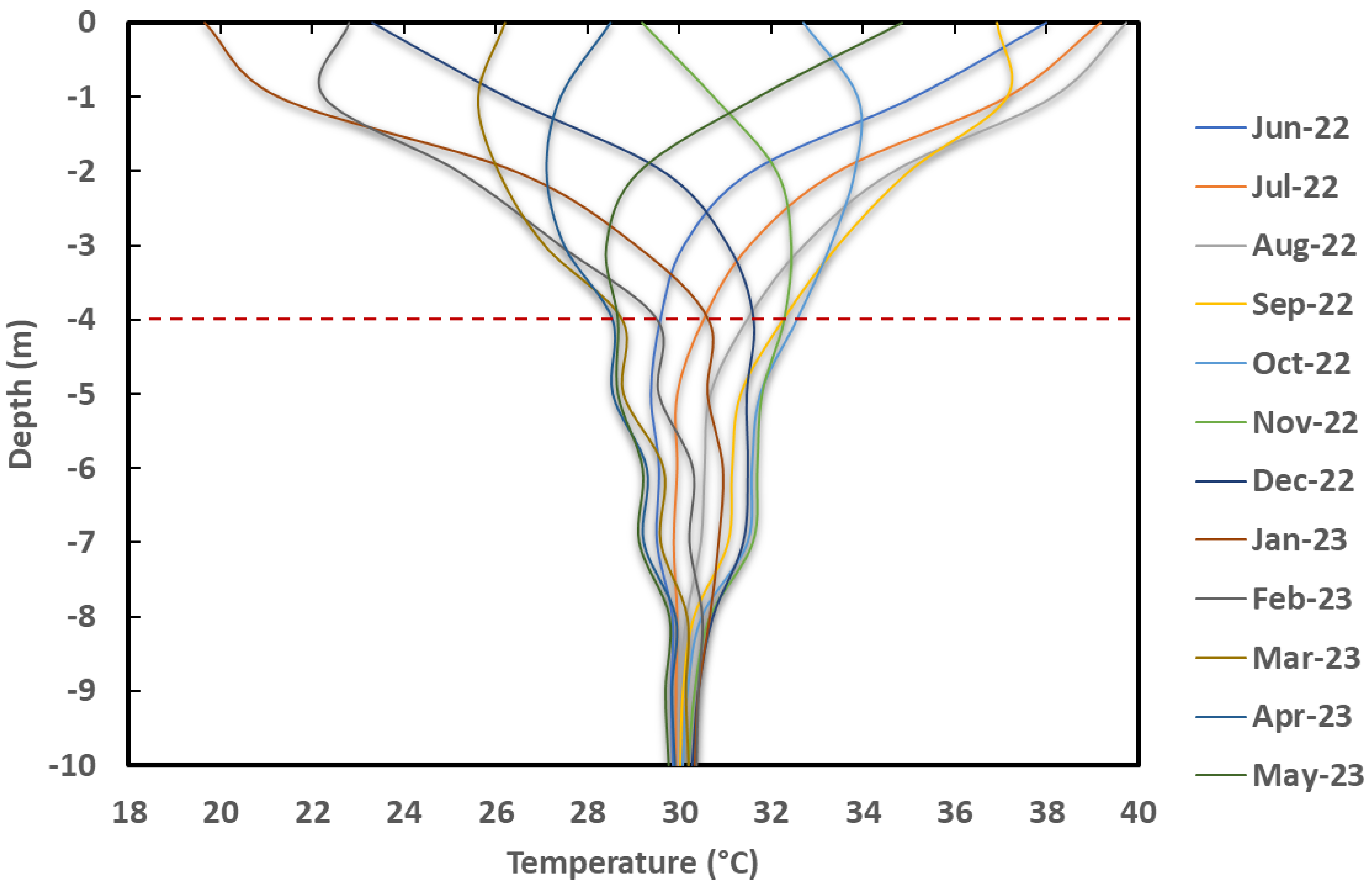


Ambient Temperature (°C)
40
35
30
25
20
6/1/2022
9/1/2022
12/1/2022
3/1/2023
6/1/2023
Time



Relationship between HVAC Intake Air Temperature and Energy Consumption
Energy Consumption vs. Temperature
Energy Consumption (kWh)
350
300
250
200
150
100
20
25
30
35
40
45
50
55
Intake Air Temperature (°C)

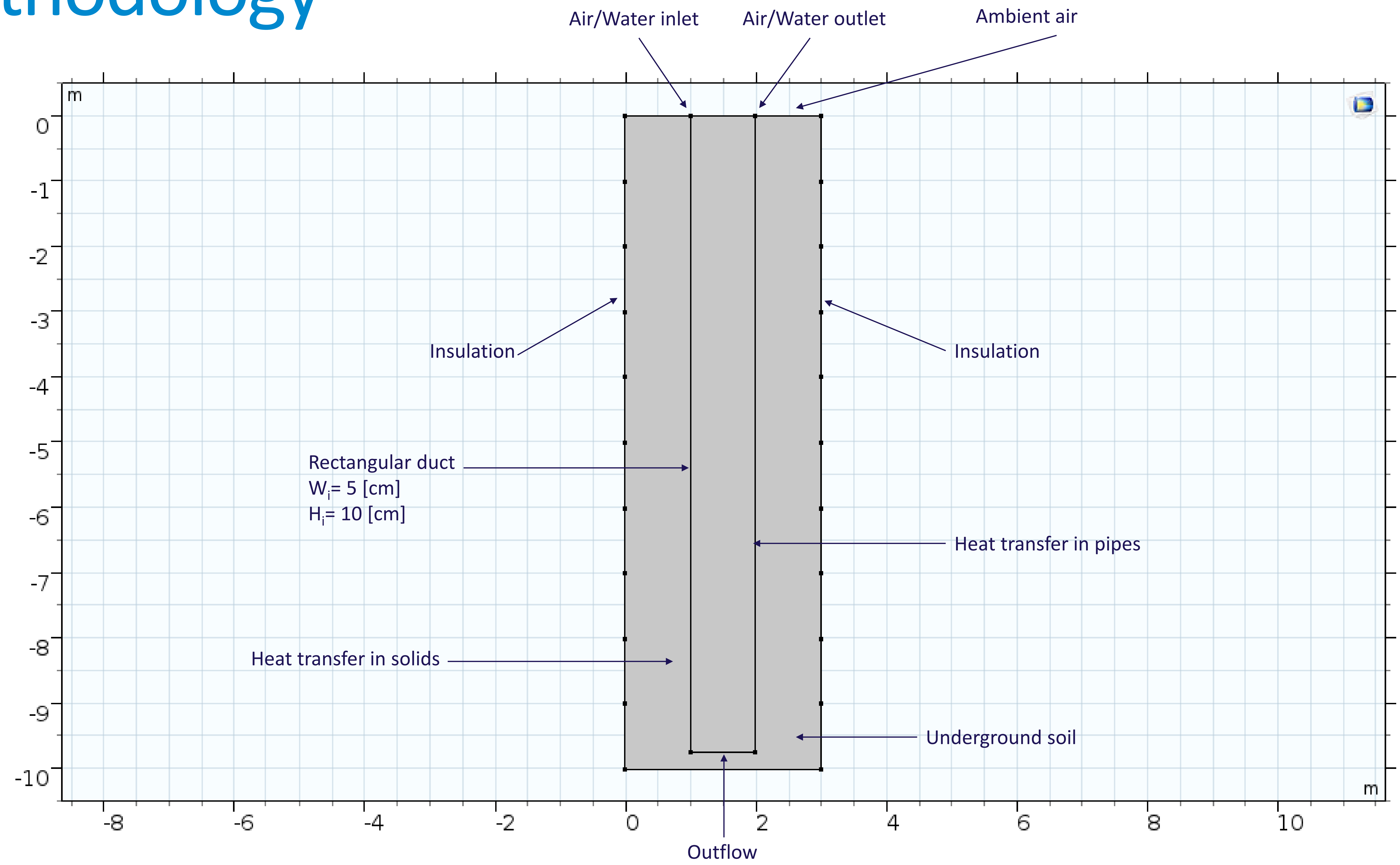


Depth (m)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
18
20
22
24
26
28
30
32
34
36
38
40
Temperature (°C)
Jun-22
Jul-22
Aug-22
Sep-22
Oct-22
Nov-22
Dec-22
Jan-23
Feb-23
Mar-23
Apr-23
May-23

Scope

- In this work we present a novel approach to enhance energy efficiency in cooling intake air for air conditioning (AC) systems in harsh environments using geothermal energy.
- Real underground temperature measurements at various depths ranging from 1-10 meters for one year.
- A 2D finite element model to simulate the heat transfer between underground soils and cooling pipes.
- The developed geothermal model captured the behavior of the underground thermal environment.
- The model was built using COMSOL Multiphysics software, version 5.3a, and utilized the Heat Transfer in Solids and Pipes Modules.
- The study is based in a Time Dependent solver with physics-based mesh.

Methodology



Methodology

Heat Transfer in Solids

$$d_z\rho C_p\frac{\partial T2}{\partial t} + d_z\rho C_p\mathbf{u}\cdot\nabla T2 + \nabla\cdot\mathbf{q} = d_zQ + q_0 + d_zQ_{ted}$$

$$\mathbf{q} = -d_zk\nabla T2$$

Heat Transfer in Pipes

$$\rho AC_p\frac{\partial T}{\partial t} + \rho AC_p u\mathbf{e}_t\cdot\nabla_tT = \nabla_t\cdot\left(Ak\nabla_tT\right) + \frac{1}{2}f_D\frac{\rho A}{d_h}|u|u^2 + Q + Q_{wall}$$

Meshing

Complete mesh

Mesh vertices: 4164

Element type: All elements

Triangular elements: 8066

Edge elements: 736

Vertex elements: 44

Domain element statistics

Number of elements: 8066

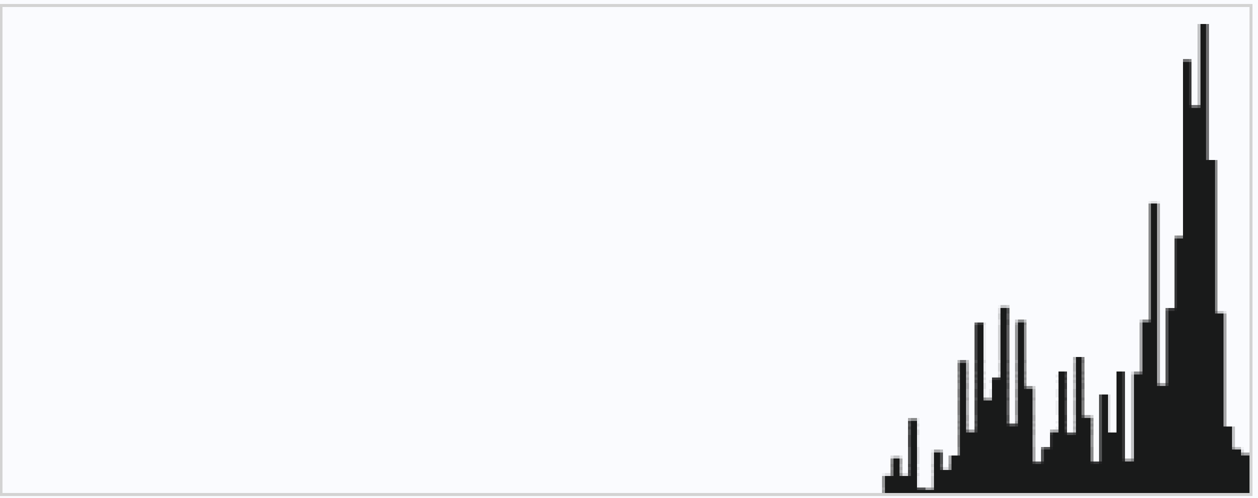
Minimum element quality: 0.7129

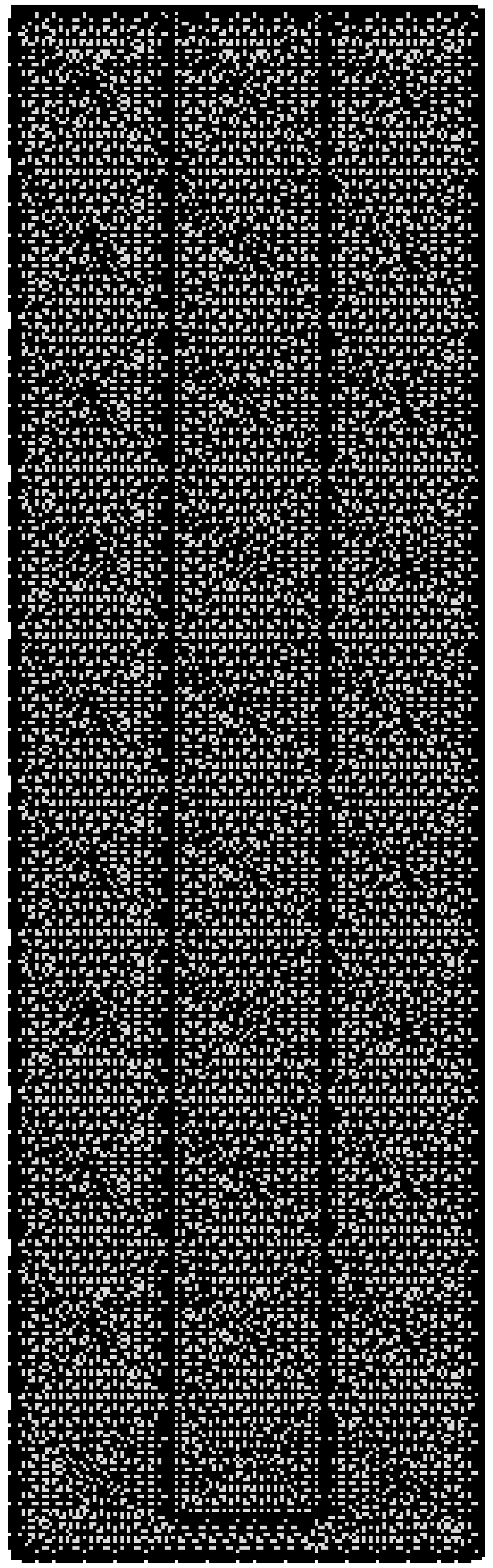
Average element quality: 0.895

Element area ratio: 0.2609

Mesh area: 30 m^2

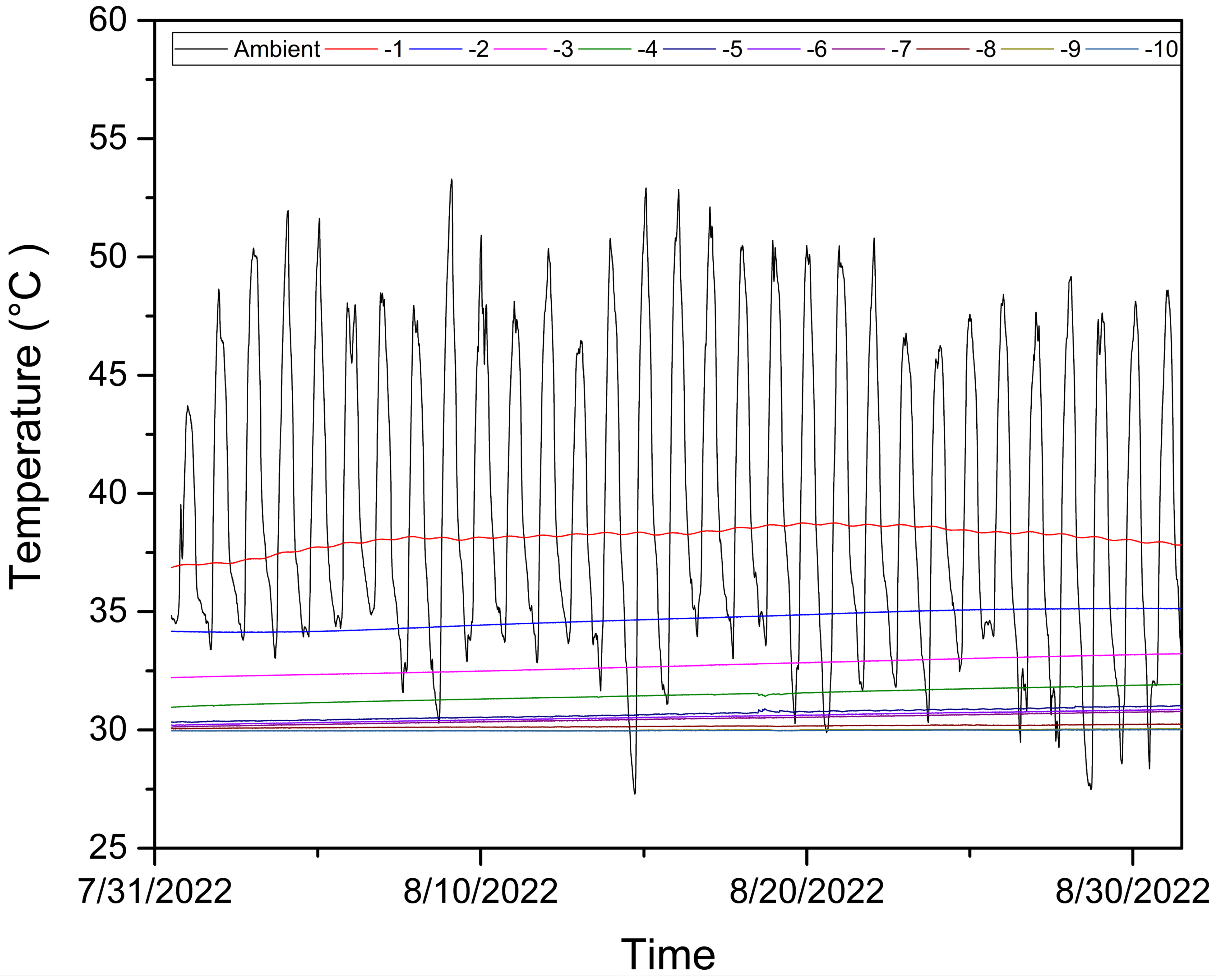
Element Quality Histogram





Methodology

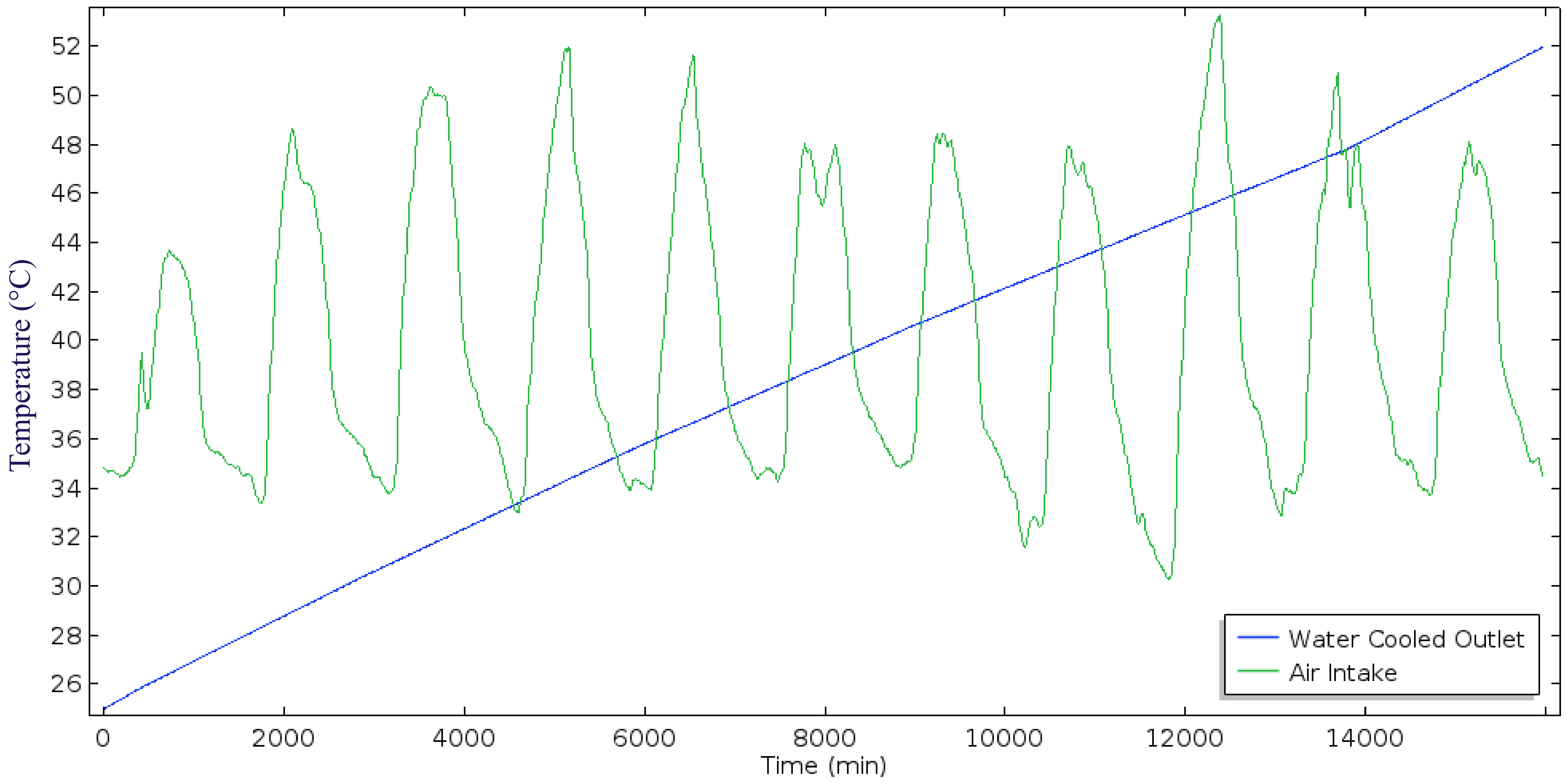
The model was tested during August-2022, a month characterized by extreme temperatures exceeding 50°C as ambient air

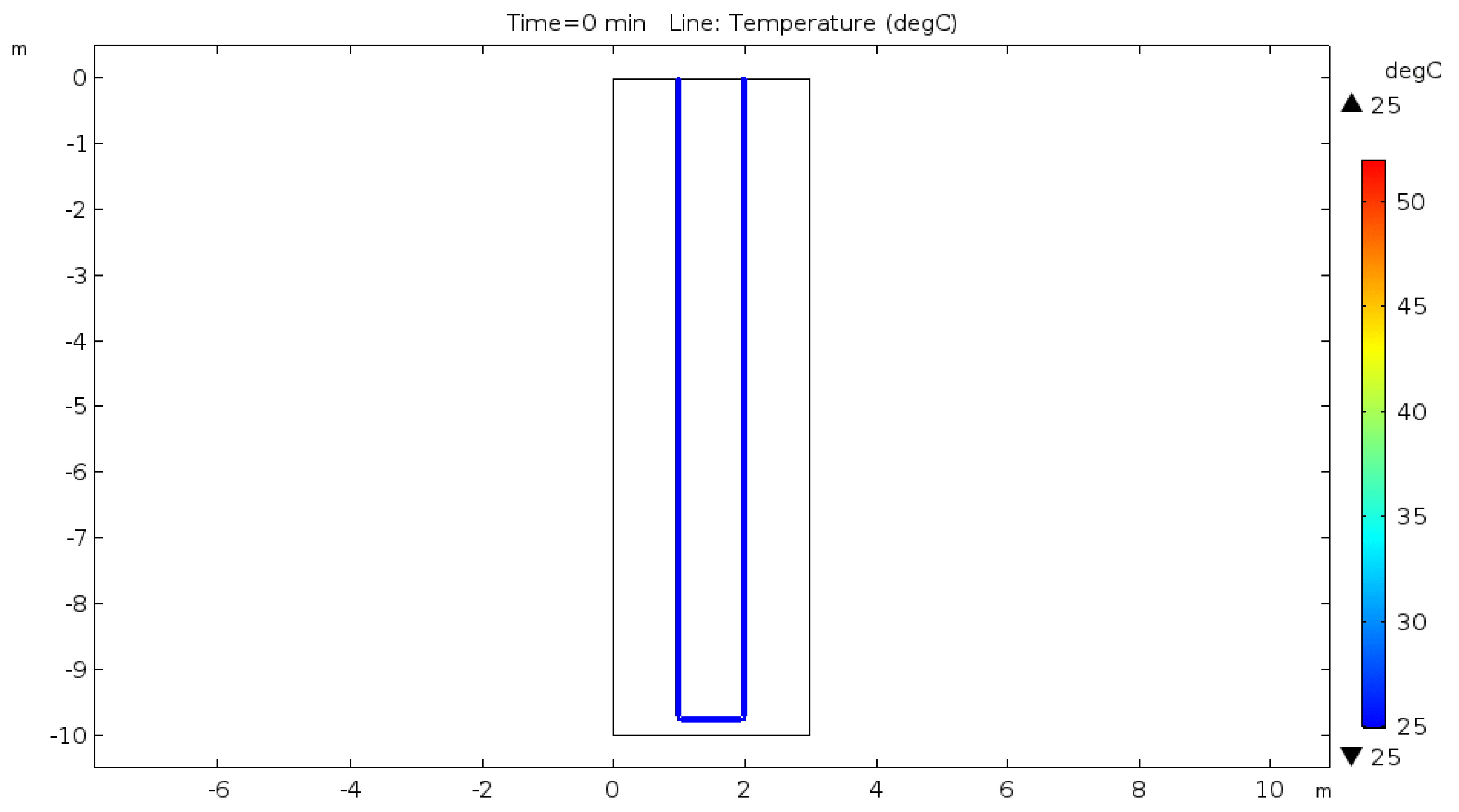


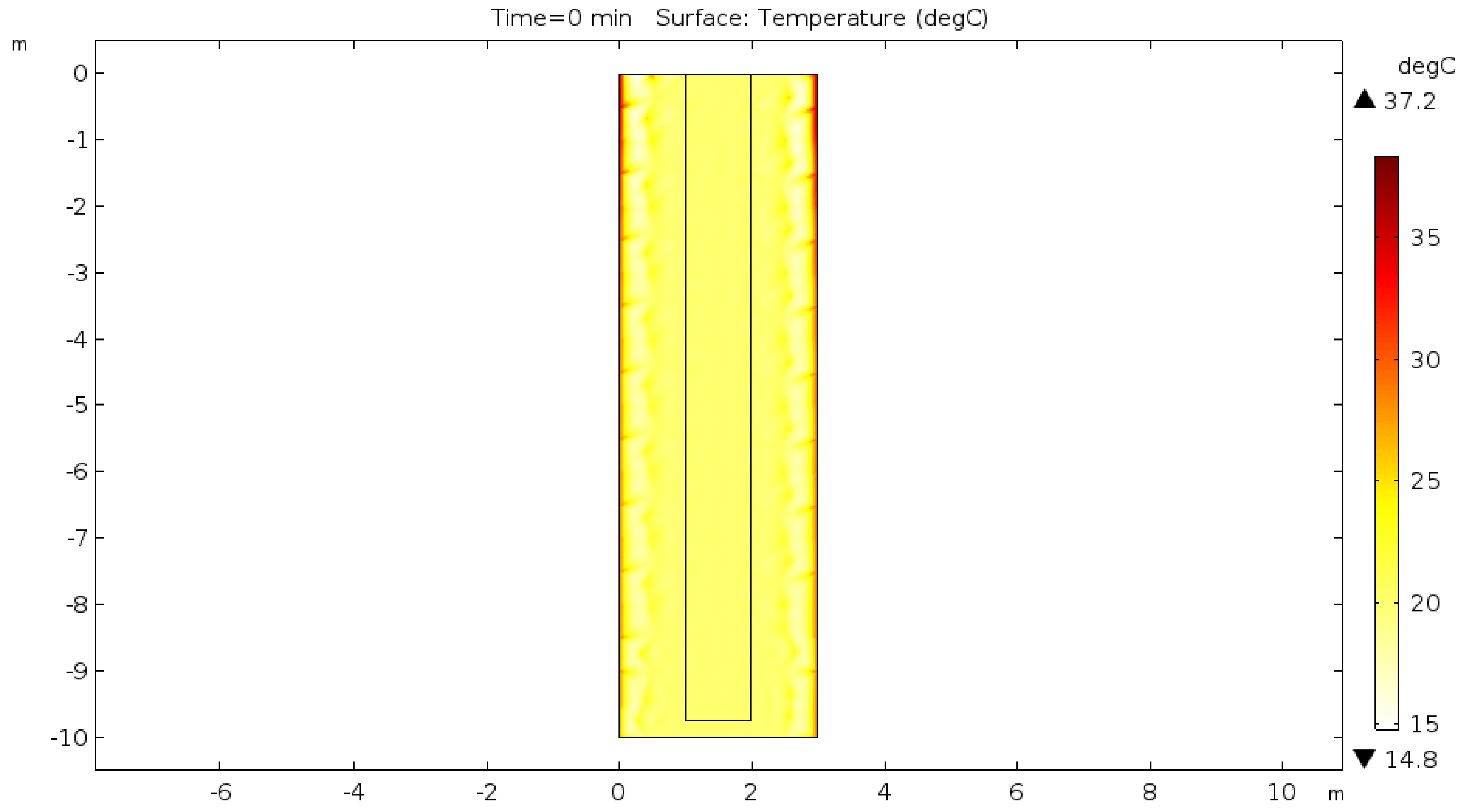
Results & Discussion

Coolant Fluid: Water

- Water inlet temperature = 25 °C
- Closed loop cooling system
- Serpentine heat exchanger with underground soil
- Cooling effective up to 4 days without makeup



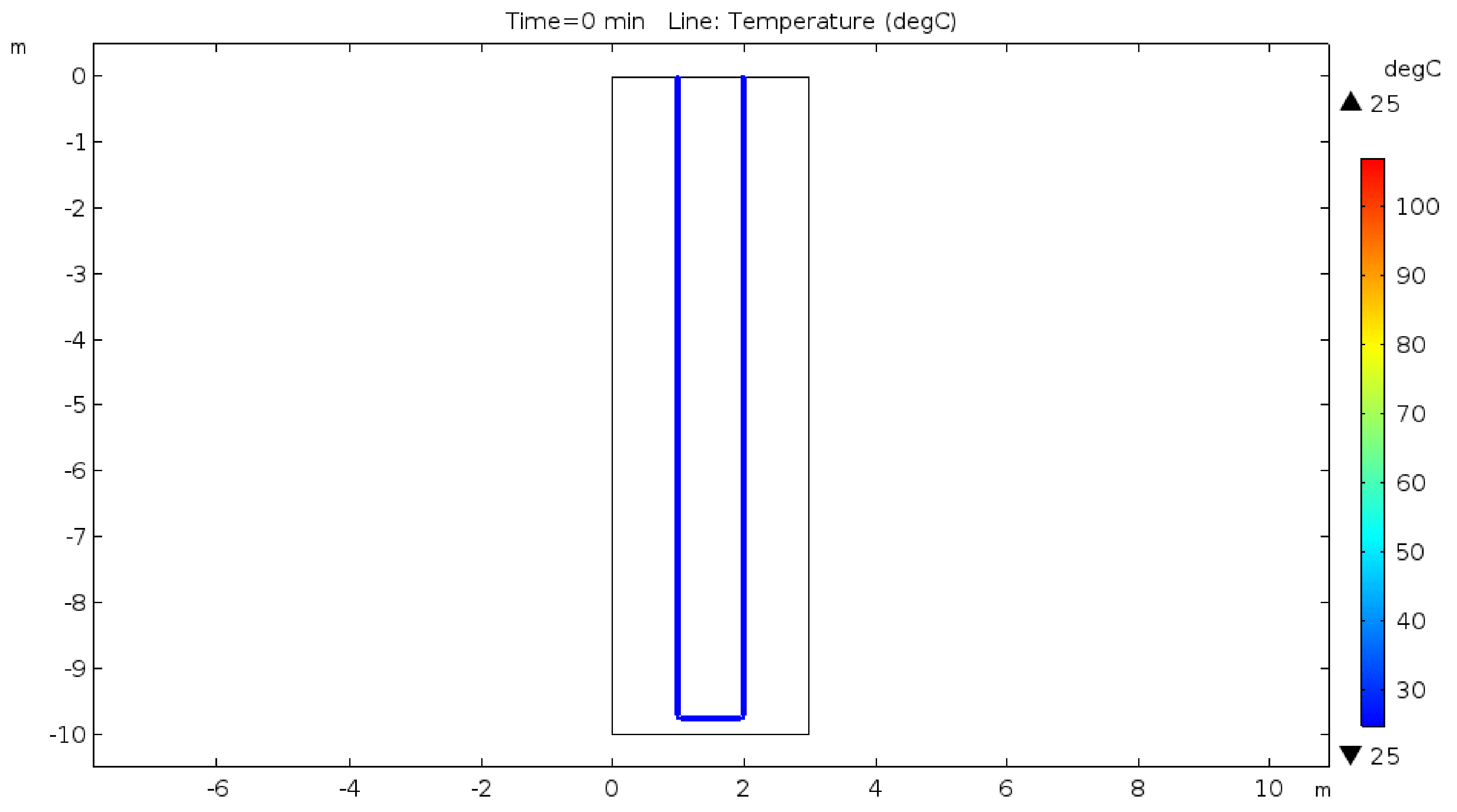


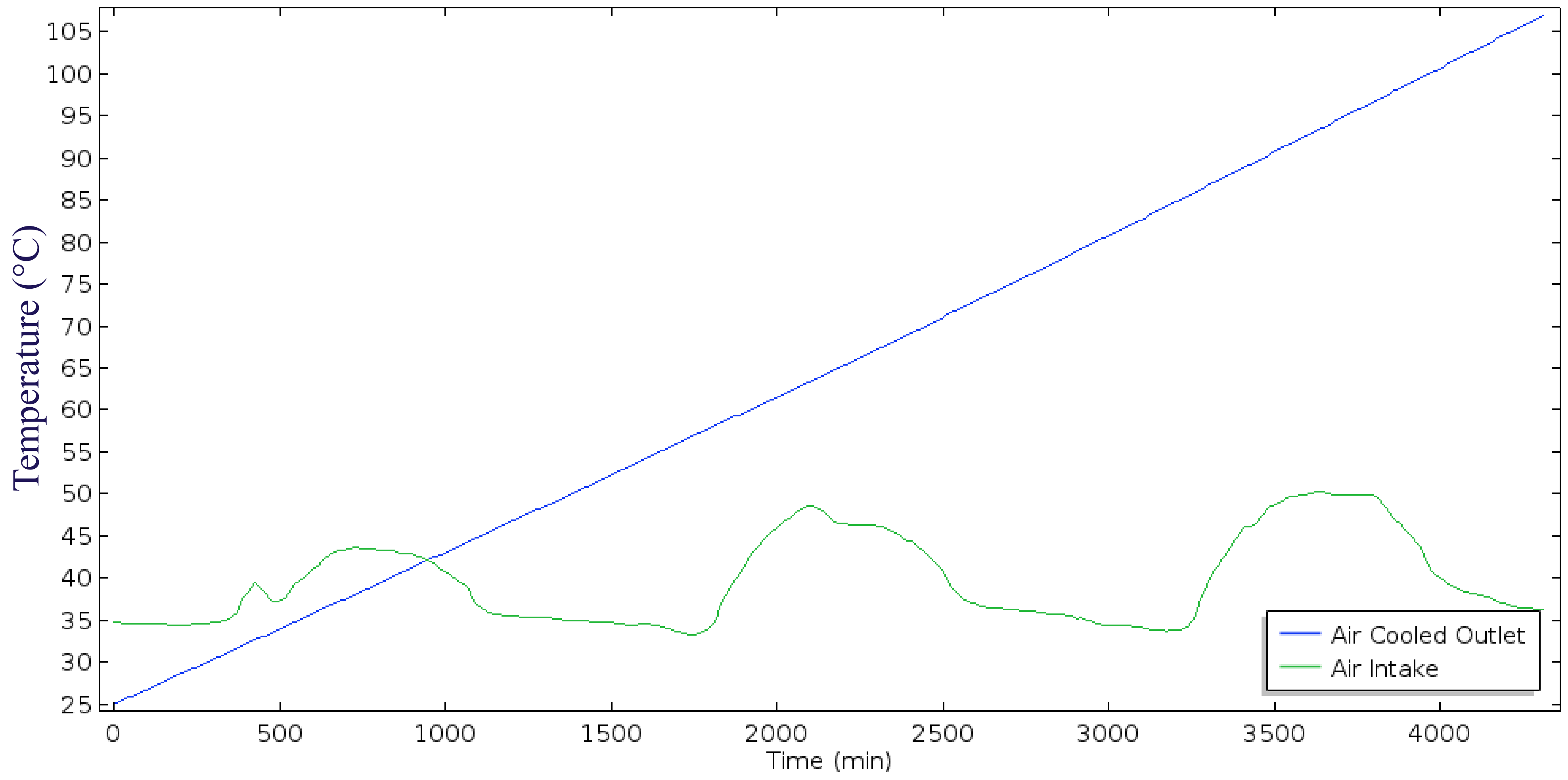


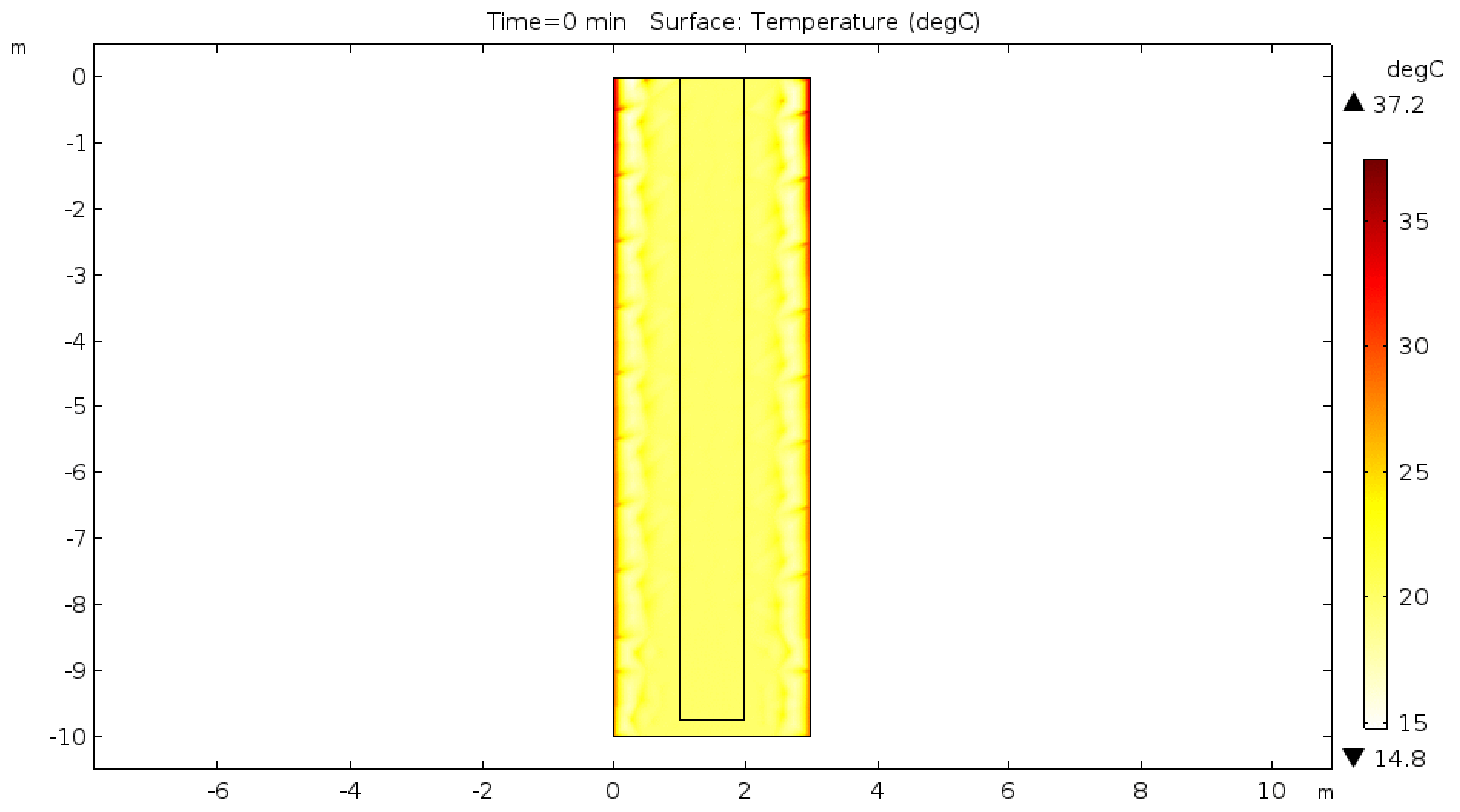
Results & Discussion

Coolant Fluid: Air

- Air inlet temperature = 25 °C
- Closed loop cooling system
- Serpentine heat exchanger with underground soil
- Cooling effective only for one day and then it turns to heating effective.







Conclusion

- By introducing water into the cooling pipes, we could efficiently exchange cooled water with the intake air of the AC system. This approach maintained a stable intake air temperature of 30°C for up to 4 days using the same circulated water.
- To avoid the cumulative effects of cooling and prevent a reverse temperature increase, the circulating water had to be replaced every 5 days.
- Alternatively, the model revealed that by introducing air into the cooling pipes and directly utilizing it as intake air, we could shave the ambient air temperature up to 10°C but only for a single day.
- To prevent the reverse temperature, increase and cumulative heat, the air needed to be replaced daily.
- Introducing water as a coolant instead of air was significantly more effective due to its relatively higher sensible heat.

Q&A