



Deploying Egypt's shallow geothermal potential for sustainable cooling and air conditioning in real estate developments (Pilot Study)



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Acknowledgment

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INTRODUCTION

Geo-cooling

AIM OF WORK

Geo-cooling

METHODOLOGY

Geo-cooling

Results

Geo-cooling

Cairo University

Geo-cooling

El-Alamein

Geo-cooling

Acoustics

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Prototype

Geo-cooling

Thank You

Geo-cooling

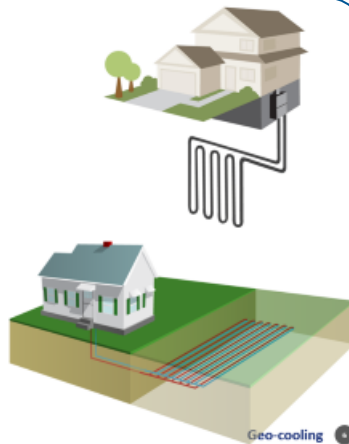
Geothermal heat pump systems utilize a series of underground pipes, an electric compressor and a heat exchanger to absorb and transfer heat. In the summer, the system removes heat from the house/building and returns it to the Earth. In the winter, the geothermal pump absorbs heat from the ground and transfers it into the house/building.

Vertical

The heat is taken deeper than the horizontal method, temperature decrease till 6 m and remain constant then start increasing by 2-4 C every 100 m

Horizontal

Trenches are dug (1.8m) deep, into which a network of ducts pass.



INTRODUCTION

Geothermal heat pump systems utilize a series of underground pipes, an electric compressor and a heat exchanger to absorb and transfer heat. In the summer, the system removes heat from the house/building and returns it to the Earth. In the winter, the geothermal pump absorbs heat from the ground and transfers it into the house/building.

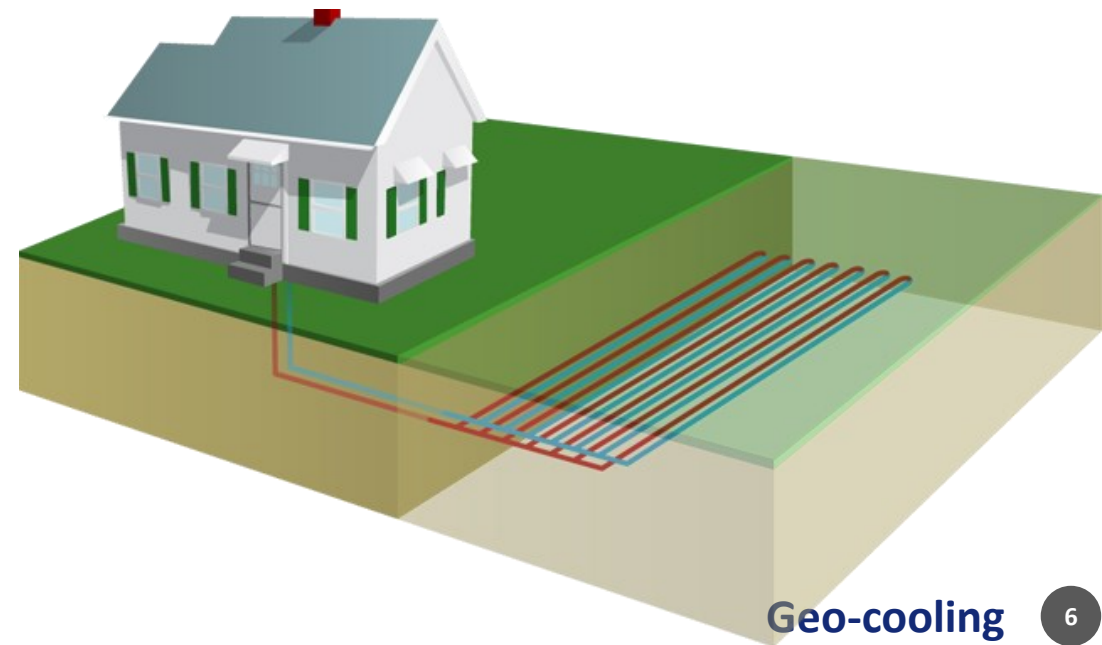


Vertical

The heat is taken deeper than the horizontal method, temperature decrease **till 6 m** and remain constant then start increasing by **2-4 C** every **100 m**

Horizontal

Trenches are dug **(1.8m)** deep, into which a network of ducts pass.



Project Aspects



Energy consumption

70% of building energy consumption for Air-conditioning



Thermal Comfort

Comes 3rd in Egypt Priorities according to regional priority credit in LEED rating sys



Sustainability

New Green- buildings For sustainable developments



Cost

Efficient systems to reduce total cost of energy consumption



Greener Future

Reducing carbon footprint to reduce the Environmental impact

Geo-cooling

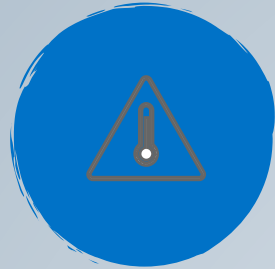
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*Cooling & Heating
Load calculations*



Closed GSHP Design



*Finite Element
Simulation*



Life Cycle Assessment



METHODOLOGY

Cooling & Heating Load calculations



❑ Operation Theory:

Every building needs a specific amount of cooling to be comfortable. Defining several factors for calculating the building cooling loads, including:

- *Daytime heat gain*
- *Building Orientation*
- *Levels of insulation from top to bottom*
- *Floor plan*
- *Number and types of windows and doors*
- *Number of occupants*
- *Square footage*

❑ Analytical Procedure:

Cooling load calculation methodologies consider heat transfer by conduction, convection, and radiation can be found **in ASHRAE handbooks, ISO Standard 11855, European Standard (EN) 15243, and EN 15255**

Design of cooling loads assume steady periodic conditions (i.e., *design day's weather, occupancy, and heat gain conditions* are identical to those for preceding days such that the loads repeat on **an identical 24 h cyclical basis**).

❑ HAP Software:

Hourly **A**nalysis **P**rogram (HAP) is a computer tool produced by Carrier.

The aim of this program is to assist in designing HVAC systems for commercial buildings.

Closed GSHP Design



Factors affecting the orientation of GSHP Design
Economic Evaluation
System Performance
Accessed Area for Digging and Implementation

Software used: GHX_Design_Toolbox

First, cooling and heating loads are entered as an input data before defining the closed loop system parameters.

Second, according to the selection of closed loop GSHP, soil parameters as well as other parameters are being defined.

I. For Vertical GSHP

II. For Horizontal GSHP

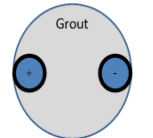
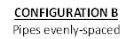
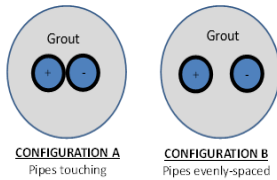
Closed GSHP Design



I. For Vertical GSHP

Input Data in Yellow Fields

SI Units	
Pipe Details:	
Nominal Diameter:	DN32 mm
SDR:	SDR11
Pipe k:	0.4 W/(m-K)
Pipe OD:	45.000 mm
Pipe ID:	37.000 mm
u-tube center to borehole center Spacing:	22.50 mm
Borehole Details:	
Borehole Dia.	152.00 mm
Borehole Depth	40 m
Fluid Details:	
Heat Transfer Fluid:	Water
Flow Rate per Borehole:	21.00 Lpm
Design Temperature of Fluid:	24.5 °C
Freeze Point:	-7.3 °C
Density:	1025.80 kg/m ³
Specific Heat:	3929.00 J/(kg-°C)
Thermal Conductivity:	0.61 W/(m-K)
Viscosity:	4.05E-03 kg/(m-s)
Grout Details:	
Thermal Conductivity:	1.42 W/(m-K)
Ground Details:	
Thermal Conductivity:	1.10 W/(m-K)



Select Pipe Configuration: Configuration A

$$R'_b = 0.1407 \text{ m}^2\text{-C/W}$$

Calculations	
Mass Flow Rate =	3.59E-01 kg/s
Re =	3,051 -
Pr =	26.24 -
friction factor (f) =	0.04530 -
Nu =	53.435 -
h =	875.7 W/(m ² -°C)
R' _{g, convective, component} =	0.00982 m ² -C/W
R' _{g, conductive, component} =	0.07788 m ² -C/W
R' _g =	0.08771 m ² -C/W
β =	0.782 -
α =	0.127 -
R' ₁ =	0.32865
R' ₂ =	0.13991
R' _{1,2} =	0.7962
R' _{eff1} =	0.1407
R' _{eff2} =	0.1407

II. For Horizontal GSHP

Input Data in Yellow Fields

SI Units	
Pipe Details:	
Nominal Diameter:	DN20 mm
SDR:	SDR9
Pipe k:	0.19 W/(m-K)
Pipe OD:	25.670 mm
Pipe ID:	20.743 mm
Pipe center-to-center spacing:	450.00 mm
Trench Details:	
Width:	500.00 mm
Fluid Details:	
Heat Transfer Fluid:	Water
Flow Rate per Circuit:	216.00 Lpm
Design Temperature of Fluid:	18.4 °C
Freeze Point:	0 °C
Density:	998.54 kg/m ³
Specific Heat:	4188.09 J/(kg-°C)
Thermal Conductivity:	0.60 W/(m-K)
Viscosity:	1.04E-03 kg/(m-s)
Trench Backfill:	
Thermal Conductivity:	1.10 W/(m-K)

Calculations

Mass Flow Rate =	3.59E+00 kg/s
Re =	211,531 -
Pr =	7.33 -
friction factor (f) =	0.01544 -
Nu =	1175.165 -
h =	33746.0 W/(m ² -°C)
R' _{g, convective, component} =	0.00045 m ² -C/W
R' _{g, conductive, component} =	0.21052 m ² -C/W
R' _g =	0.21097 m ² -C/W
eccentricity parameter (b) =	0.45 -
R' _{g'} =	0.2490 m ² -C/W
R' _s =	1.3585 m ² -C/W

R'_{trench} = 0.2490 m²-C/W

Finite Element Simulation



□ CFD Methodology :

A 3D model was designed using Autodesk Fusion360 and imported to COMSOL Multiphysics

For Cairo University	For Prototype
3D symmetrical model to simulate a single U-tube borehole for a Vertical GSHP	Full 3D Model to simulate the prototype (horizontal ground heat exchanger configuration) with soil domain dimensions
<i>soil domain dimensions</i> considering model as a cylinder of 5 m radius and 45 m depth	<i>soil domain dimensions</i> Considering model as a cuboid of (L x W x H) = (1.2 x 2.4 x 0.75) m
Study Type: Steady State	Study Type: Steady State/Transient
Model Physics: Coupling both <i>heat and mass transfer in the soil</i> and <i>fluid flow</i>	

Assumptions:

- Negligible ground water movement was present within the soil domain
- Soil properties are function to change in ground temperature throughout the simulation time

Life Cycle Assessment



According to **ISO 14040 standards**, LCA is defined as the collection and evaluation of the inputs and outputs for determining possible environmental impacts of a product, process, or system during its life cycle.

The main parts of the LCA are the following:

- a) Discuss the purpose and definition of the scope of application of this approach.
- b) Make an inventory of the inputs and outputs of the system.
- c) Assess all types of impacts on the environment.
- d) Interpret the results and evaluate the impacts.



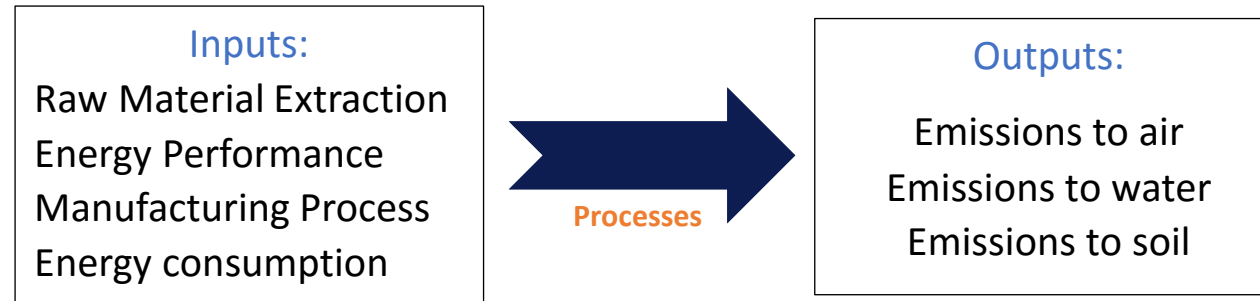
LCA Report Scope Objective

<i>Goal / Scoping:</i>	Evaluate LCA comparing potential environmental impacts of geothermal heat pumps relative to conventional HVAC system
<i>Application:</i>	Basis for decisions on geothermal heat pumps installation
<i>Functional Unit:</i>	One unit of a heat pump (e.g., 1 KWhth of the process)
<i>System Boundaries:</i>	<ul style="list-style-type: none">- Geothermal Heat pumps operational energy- All manufacturing processes contributing significantly to the life cycle impacts are considered.- Scope is based on <i>Cradle-to-gate</i>

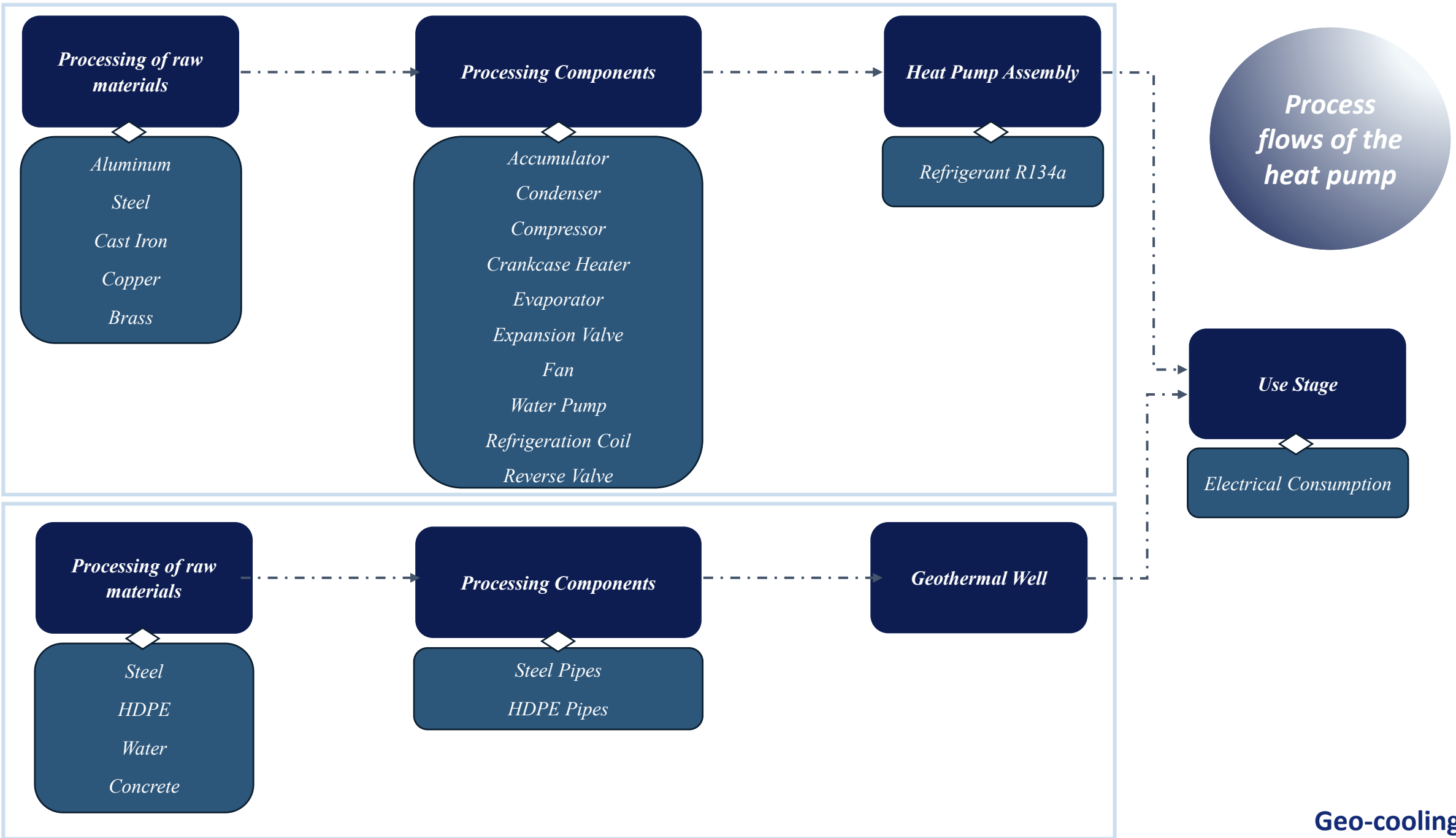
Life Cycle Assessment



Life Cycle Inventory Analysis



Emissions produced by the processes during extraction of materials, manufacture, operation, and end-of-life stage of the system has been considered





LCA Impact Assessment Method

This process will allow to obtain environmental indicators from the list of emissions and consumed resources caused by the heat pump system during its life cycle so it can become easier to comprehend. For this transformation it has been used one method which is ***Environmental Footprint v3.0***

Environmental Footprint v3.0 was performed for those impact categories:

Climate change, ozone depletion, Ionizing radiation, Photochemical ozone formation, Particulate matter, Human toxicity (non-cancer/cancer), Acidification, Ecotoxicity freshwater, land use, water use.



Cairo University

Designing a cooling geothermal plant for computer laboratory



El-Alamein

Designing geothermal cooling plants for El-Alamein Real estates



Acoustics

Substitution of One Chiller capacity using geothermal heat pump



Prototype

Enhancing the performance of a cooling water dispenser



Results



Cairo University

Site Parameters

RVC	Area
Location	The Department of Mining, Metallurgical and Petroleum Engineering (Building No. 70), is located on the ground floor.
Air Conditioning Area	Len = 10.634611, Long = 11.308603
Cell Area	Area (m ²) = 41.231 m ²
Operational Conditions	<ul style="list-style-type: none"> Maximum 800 computer units Annual Occupancy = 18 "h" according to ASHRAE standard design Operating hours: 1.00 am to 10.00 pm (10 hours)
System used	GSHP

Geo-cooling 1

Cooling and Heating Load Results



Monthly Load during operating hours (24 hrs) for each month

Peak Load during operating hours for each month



ANNUAL LOADS DURING OPERATING HOURS


Total Annual Energy Required = 34118 + 1761 = **15814.6 kWh**

Total Energy Required in 10 years (10YR) = 15814 x 10 = **158140 kWh** = **43% 218.8 kWh**

Geo-cooling 2

Closed Loop GSHP Design Parameters

System type:
A closed loop Ground Source Heat pump is used which is a Water to Air heat pump.



From Geo-Planet Graphs:

- Heat pump cooling efficiency (EEF) = 5.5 (100/18)
- Heat pump heating efficiency (COVS) = 4.3

As a thermal property test provided the following information for soil data:

- Ground temperature (T_g) = 23.5°C
- Ground conductivity (k_g) = 2.5 W/m·K
- Ground diffusivity (α_g) = 0.075 m²/s = 0.077 m²/day
- Borehole fill conductivity (k_b) = 2.5 W/m·K

From Pipe Selection for ground source heat pumps:

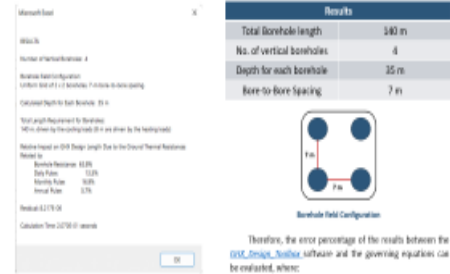
- Size: Vertical U-tube = 22 mm, 152 mm (0.152 m) borehole diameter
- Material: DR 11, HDPE

From Pipe Spacing:


- 2 x 2 square grid (4 vertical bore) with 7 m borehole separation

Geo-cooling 3

Closed Loop GSHP Design Results



Results	
Total borehole length	140 m
No. of vertical boreholes	4
Depth for each borehole	35 m
Bore-to-bore spacing	7 m



Borehole Field Configuration

Therefore, the error percentage of the results between the `GSHP_design_toolbox Software` and the governing equations can be evaluated, where:

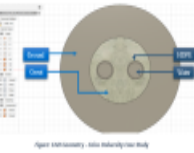
$$\% \text{ Error} = \frac{140 - 144}{140} \times 100 = -2.86 \%$$

Geo-cooling 4

CFD Parameters

Input Values:

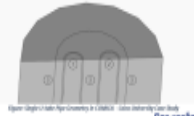
Geometry in 3D space	
Material: Fluid	Water (3000 K)
Velocity at Inlet	$u = 0.0003 \text{ m/s}$
Temperature at inlet	$T_{in} = 24.6 \text{ }^\circ\text{C}$
Average Pressure at outlet	$P_{out} = 0 \text{ (Fully developed)}$



Input boundary: inlet velocity (m/s) field

Boundaries:

Name	Type	No. assigned
Inlet 1	Boundary	1
Outlet 1	Boundary	2
Wall 1	Boundary	3



Input: Inlet velocity (m/s) field

Geo-cooling 5

<i>P.O.C</i>	<i>Data</i>
<i>Location:</i>	<ul style="list-style-type: none"> - The department of Mining, Metallurgical and Petroleum Engineering Department (Building No. 32). - It is located on the ground floor.
<i>Site Geological Data:</i>	Lat.: 30.0244932, Long.: 31.2099024
<i>Lab Area</i>	Area (m ²) ≈ 47.25 m ²
<i>Operational Conditions:</i>	<ul style="list-style-type: none"> - Six people & Six computer units. - Demand Temperature = 24 °C according to ASHRAE standard design. - Operating hours: 7:00 am to 10:00 pm (16 hours)
<i>Software used</i>	HAP



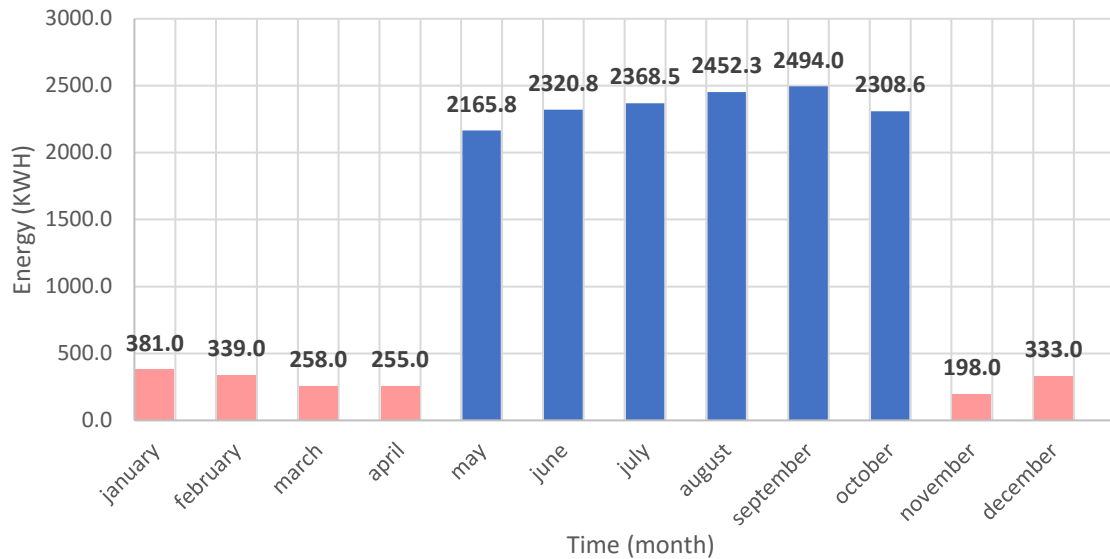
Figure 1: Lab Site from Google



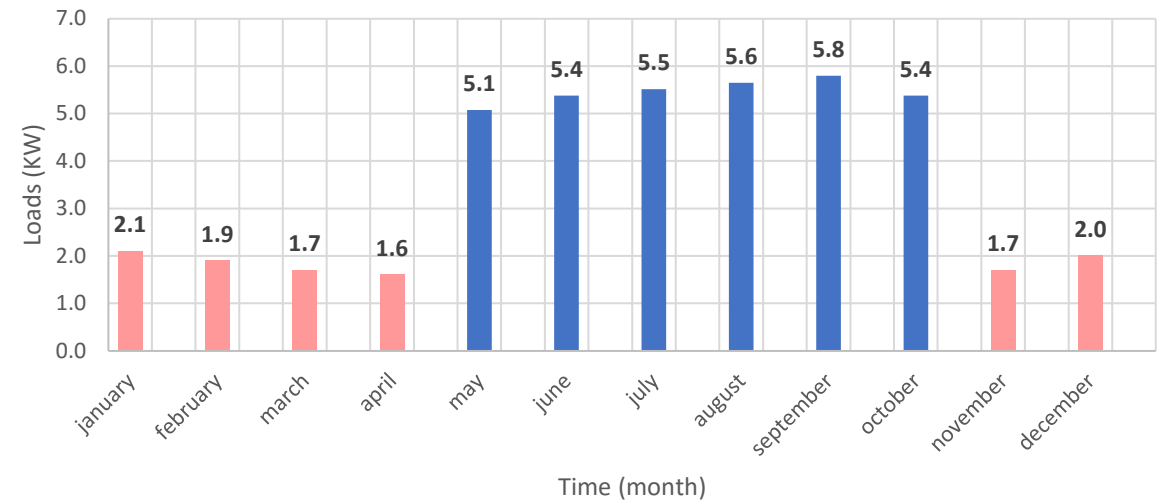
Figure 2: Visit to the lab (Inside)

Cooling and Heating Load Results

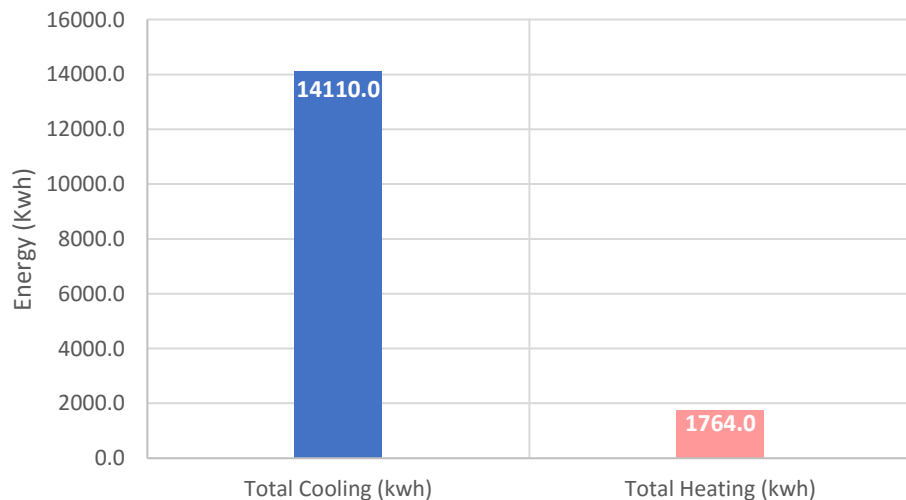
Monthly Load during operating hours (16 hr.) for each month



Peak Load during operating hours for each month



ANNUAL LOADS DURING OPERATING HOURS



*Total Annual Energy Required = 14110 + 1764 = **15874 KWH***
*Total Energy Required in 30 years (KWH) = **15874 × 30 = 476,220 KWH***

Closed Loop GSHP Design Parameters

➤ System type:

A closed loop Ground Source Heat pump is used which is a Water-to-Air heat pump.



From Eco- Forest Graphs:

- Heat pump cooling efficiency (EER) = 5.5 Btu/Wh
- Heat pump heating efficiency (COP_h) = 6.3

➤ A thermal property test provided the following information for soil data:

Ground temperature (t_g) = 23.5°C

Ground conductivity (k_g) = 2.5 W/m · K

Ground diffusivity (α_g) = 0.892 mm²/s = 0.077 m²/day

Borehole fill conductivity (k_b) = 2.5 W/m · K

➤ From Pipe Selection for ground source heat pumps:

- **Size:** Vertical U-tube = 32 mm, 152 mm (0.152 m) borehole diameter
- **Material:** DR 11, HDPE

➤ From Pipe Spacing:

- 2 × 2 square grid (4 vertical bores) with 7 m borehole separation

Closed Loop GSHP Design Results

Microsoft Excel

RESULTS:

Number of Vertical Boreholes: 4

Borehole Field Configuration:
Uniform Grid of 2 x 2 boreholes, 7-m bore-to-bore spacing.

Calculated Depth for Each Borehole: 35 m

Total Length Requirement for Boreholes:
140 m, driven by the cooling loads (8 m are driven by the heating loads)

Relative Impact on GHX Design Length Due to the Ground Thermal Resistances
Related to:

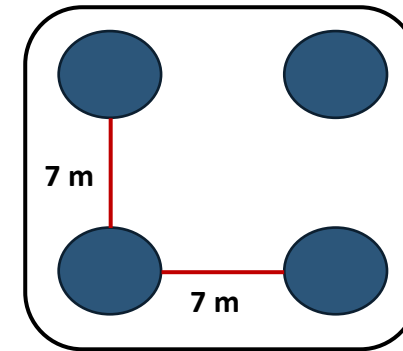
- Borehole Resistance: 63.8%
- Daily Pulse: 13.5%
- Monthly Pulse: 16.9%
- Annual Pulse: 5.7%

Residual: 8.217E-06

Calculation Time: 2.070E-01 seconds

OK

Results	
Total Borehole length	140 m
No. of vertical boreholes	4
Depth for each borehole	35 m
Bore-to-Bore Spacing	7 m



Borehole field Configuration

Therefore, the error percentage of the results between the [GHX Design Toolbox](#) software and the governing equations can be evaluated, where:

$$\% \text{ Error} = \frac{140 - 144}{140} \times 100 = -2.86 \%$$

CFD Parameters

Input Values:

Geometry in 3D space	
Material: Fluid	Water (Built-In)
Velocity at inlet	$u = 0.0683 \text{ m/s}$
Temperature at inlet	$T_{in} = 29.6 \text{ }^\circ\text{C}$
Average Pressure at outlet	$P_{av} = 0, (\text{Fully developed})$

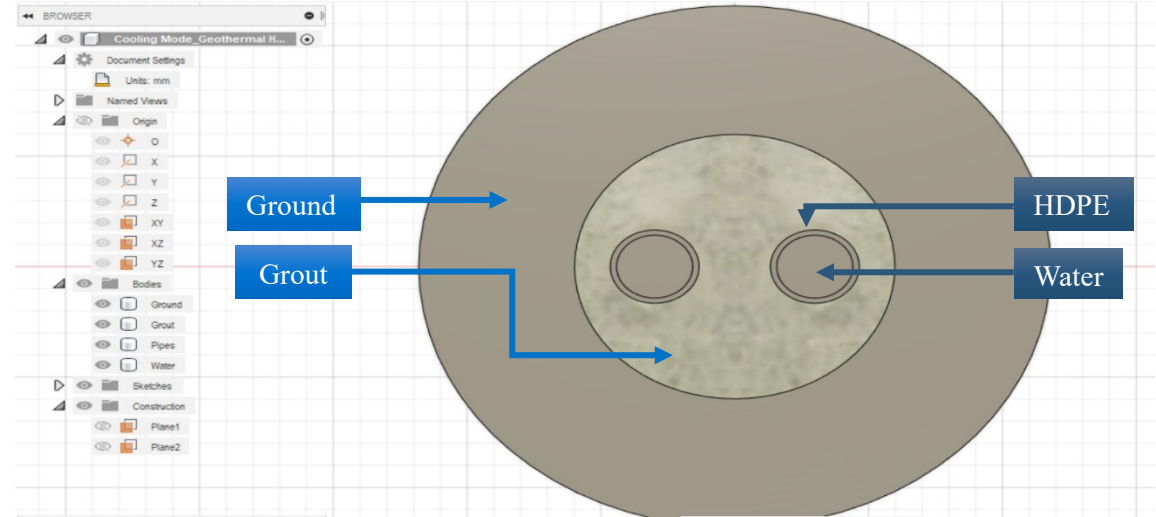


Figure: CAD Geometry - Cairo University Case Study

Boundaries:

Name	Type	No. Assigned
Inlet 1	Boundary	1
Outlet 1	Boundary	2
Wall 1	Boundary	3

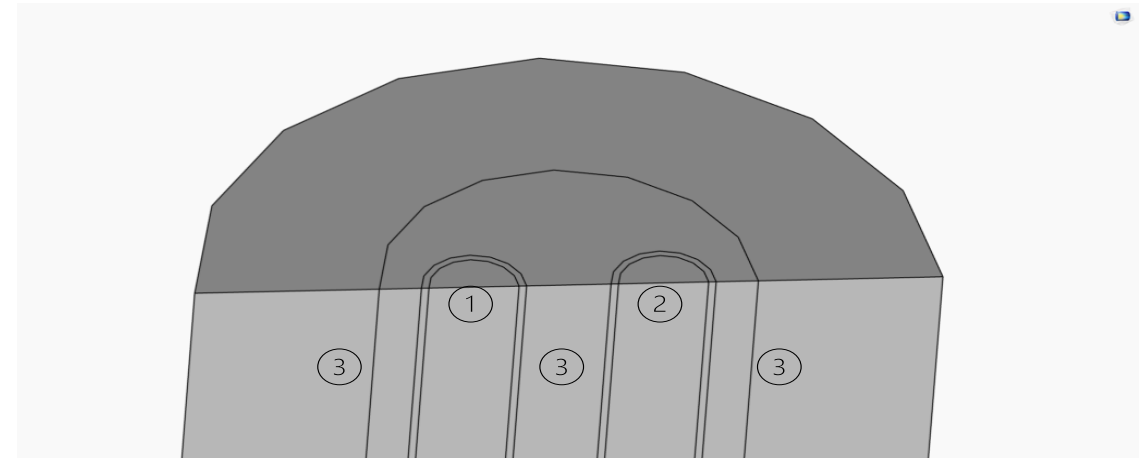


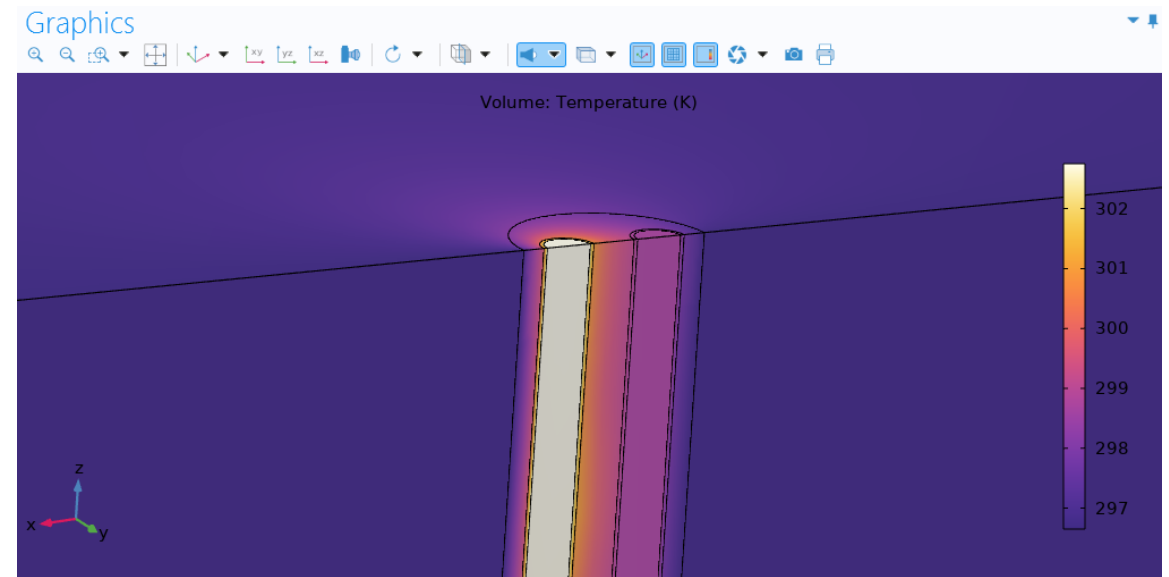
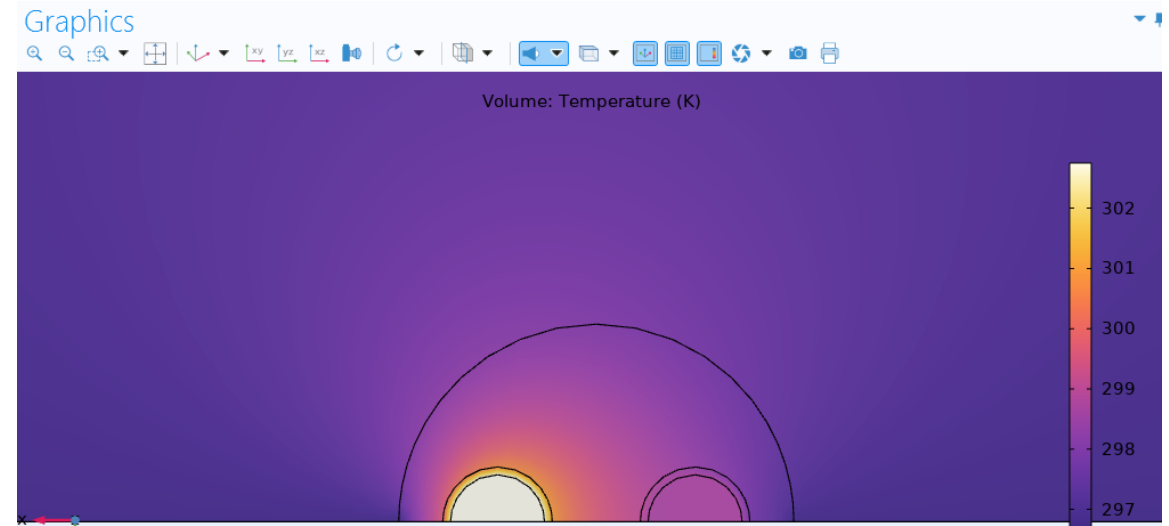
Figure: Single U-tube Pipe Geometry in COMSOL - Cairo University Case Study

From a steady state analysis:

$$\therefore T_{out} = 25.53 \text{ } ^\circ\text{C} \text{ (From simulation)}$$

$$\therefore T_{ground} = 23.5 \text{ } ^\circ\text{C} \text{ (Input)}$$

$$\begin{aligned} \therefore \text{Effectiveness } (\theta) &= \frac{T_{in} - T_{out}}{T_{in} - T_{ground}} \\ &= \frac{29.6 - 25.53}{29.6 - 23.5} \times 100 = \mathbf{66.72 \%} \end{aligned}$$



Cost Assessment Results

Geothermal heat pump Cost Evaluation

Drilling Cost (LE)	182,000
Unit Cost (LE)	276,308
Initial Cost = 182,000 + 276,308 = 458,308 LE	
Operation & Maintenance Cost = 6835.3 LE	

Air-Conditioning Cost Evaluation

No. of Ac units	1
SHARP Ac unit selection	3 hp
Initial Cost = 27,500 + 1000 = 28,500 LE	
Operation & Maintenance Cost = 15,230 LE	

Ecoforest EcoGEO Basic 1-6kW PRO



Nuenta are pleased to offer the EcoGeo PRO from Ecoforest. This state of the art Ground Source Heat Pump is Inverter driven, providing an output of between 1- 6 kW. This is the smallest model in the Ecoforest range and is ideal for properties that have a lower heating demand. This inverter driven technology reduces the need for larger buffer storage, which reduces the overall footprint of the installation.

New natural refrigerant R290 allowing 70°C Heat/DHW

Passive and Active cooling options are available on request.

- R290 Refrigerant
- Copeland Scroll Compressor With Inverter Technology
- Carel Electronic Expansion Valve
- Variable Speed And High Efficiency Grundfos Circulation Pumps
- Alfa Laval Plate Heat Exchangers
- Carel Micro PC Control
- Sound Insulation Kit 36-45dB

£8,126.71
(£9,752.05 inc. VAT)

For specific delivery times please contact us on: 01543 466642

Additional Options
Please select

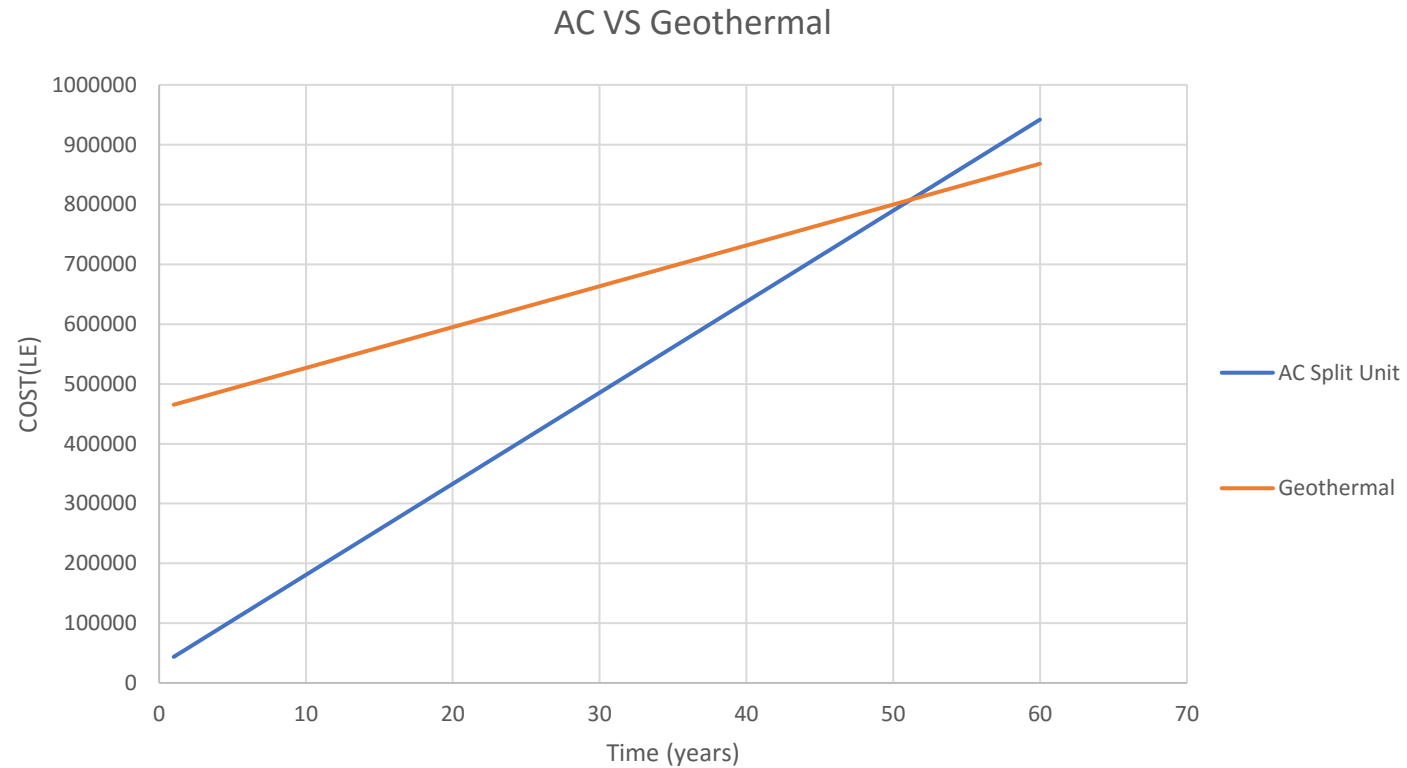
Quantity: - 1 +

Add to cart

Figure: GSHP Specifications - Cairo University Case study

SHARP Ac units	Cost
1.5 hp	20,450 EGP
3 hp	27,500 EGP
4 hp	42,610 EGP

Cost Assessment Results

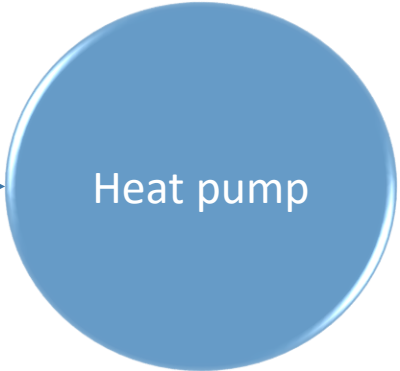


The payback period is 51 years if installing Geothermal heat pumps instead of conventional air conditioning. **(Not feasible)**

LIFE CYCLE ASSESSMENT

CAIRO UNIVERSITY

Inputs



Aluminum



Copper



Aluminum



Aluminum



Steel

Cast iron

Iron sinter

Aluminum

low-alloyed steel

Electricity consumed



Brass



Refrigerant R134a

Copper

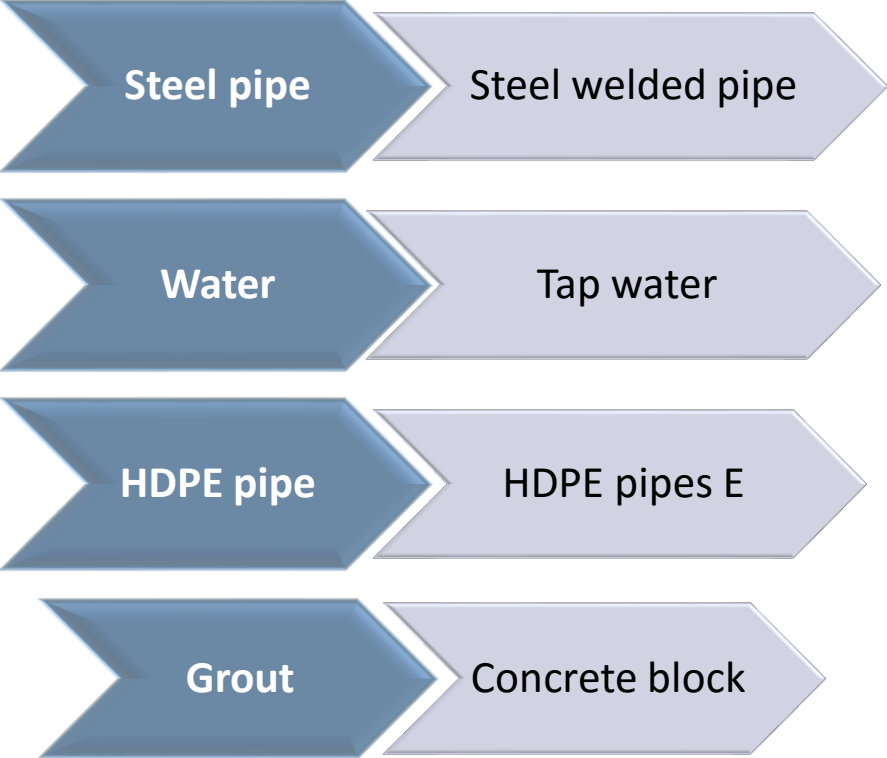
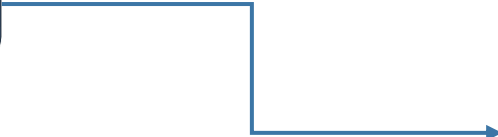


Copper

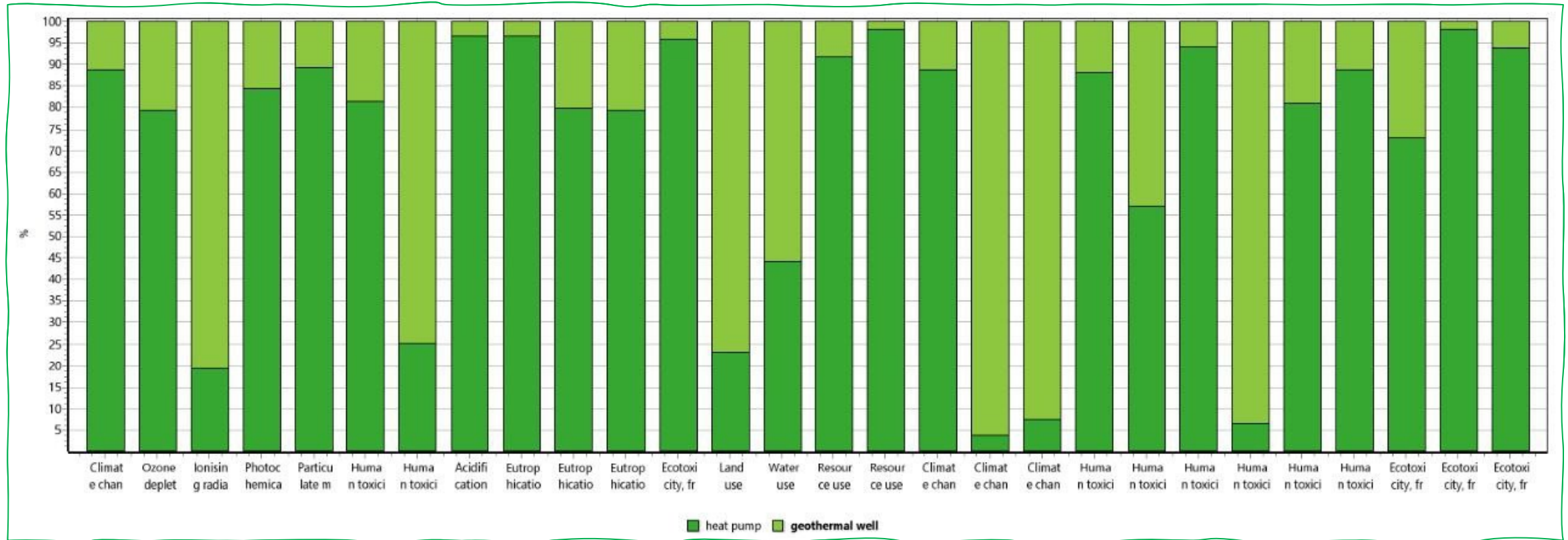


Brass

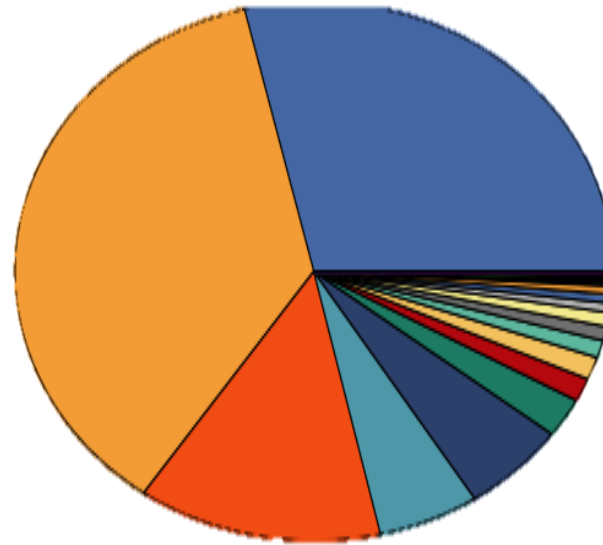
Inputs



LCA Results



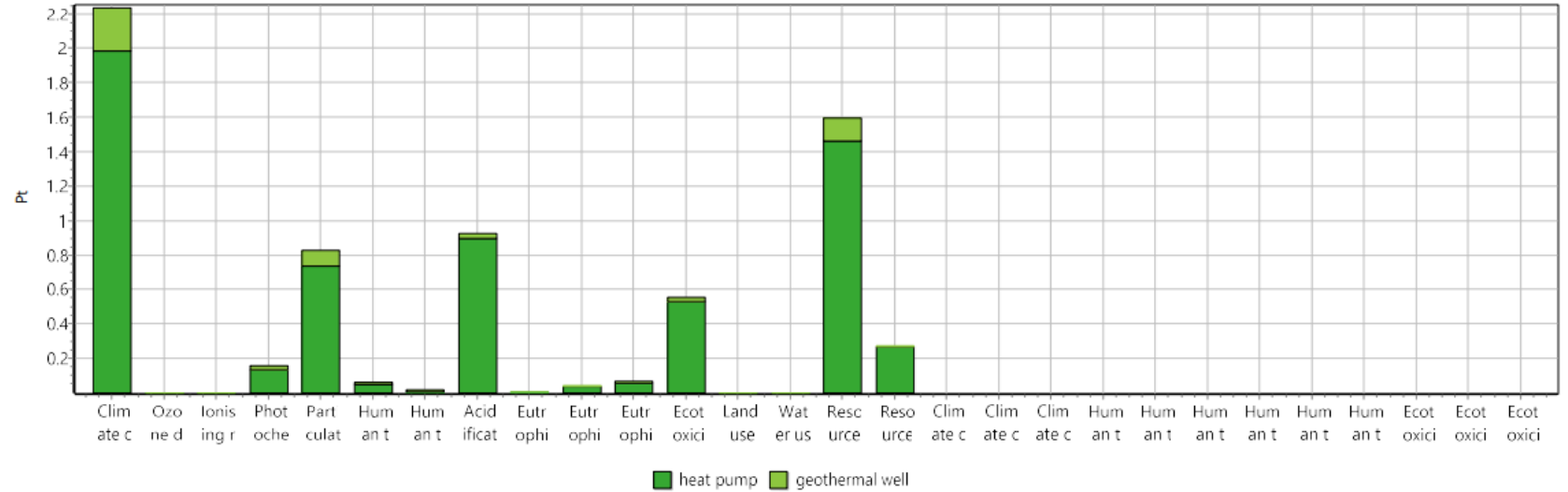
Heat pump vs geothermal well contribution for each category (characterization)



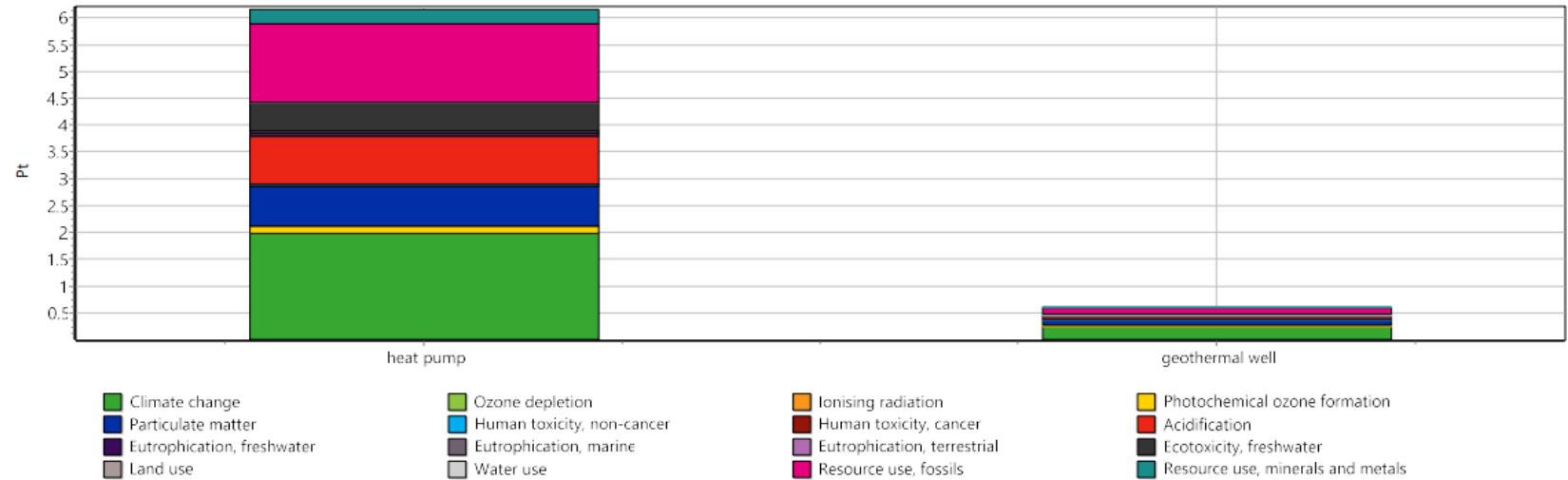
- Natural gas, at extraction site/US
- Natural gas, processed, at plant/US
- Copper, anode {GLO}| market for copper, anode | APOS, S
- Concrete block {BR}| market for concrete block | APOS, S
- HDPE pipes E
- Crude oil, at production/RNA
- Brass {CH}| market for brass | APOS, S
- Gasoline, combusted in equipment/US
- Residual fuel oil, combusted in industrial boiler/US
- Transport, ocean freighter, residual fuel oil powered/US
- Electricity, natural gas, at power plant/US
- Steel welded pipe/EU
- Natural gas, combusted in industrial boiler/US
- Electricity, bituminous coal, at power plant/US
- Transport, combination truck, diesel powered/US
- Water pump, 22kW {GLO}| market for water pump, 22kW | APOS, S
- Bituminous coal, at mine/US
- Diesel, combusted in industrial boiler/US
- Electricity, lignite coal, at power plant/US
- Transport, train, diesel powered/US

About 75% of the emissions is produced by the electrical consumption of the compressor. This electrical consumption is consumed by the natural gas power plants as most of the power plants in Egypt are Natural gas.

Comparative
between two
processes to EF 3.0
Method (adapted)
V1.03/EF 3.0
normalization &
weighting set
/Weighting



EF 3.0 Method (adapted) V1.03 / EF 3.0 normalization and weighting set / Weighting set 1 p 'the process';



EF 3.0 Method (adapted) V1.03 / EF 3.0 normalization and weighting set / Single score for 1 p 'the process';

Top 5 processes contributing for each category

No	Process	Project	Unit	Total	heat pump	geothermal well
	Total of all processes		kg CO2 eq	8.59E4	7.63E4	9.61E3
1	Electricity, natural gas, at power plant/US	USLCI	kg CO2 eq	5.91E4	5.91E4	x
2	Natural gas, at extraction site/US	USLCI	kg CO2 eq	1.05E4	1.05E4	x
3	Steel welded pipe/EU	Industry data	kg CO2 eq	8.95E3	x	8.95E3
4	Natural gas, combusted in industrial boiler/US	USLCI	kg CO2 eq	3.13E3	3.13E3	x
5	Natural gas, processed, at plant/US	USLCI	kg CO2 eq	1.68E3	1.68E3	x



Climate change

No	Process	Project	Unit	Total	heat pump	geothermal well
	Total of all processes		kg CFC11 eq	0.000157	0.000125	3.24E-5
1	Refrigerant R134a {GLO} market for APOS, S	Ecoinvent 3 -	kg CFC11 eq	0.000118	0.000118	x
2	Concrete block {BR} market for concrete block APOS, S	Ecoinvent 3 -	kg CFC11 eq	3.24E-5	x	3.24E-5
3	Copper, anode {GLO} market for copper, anode APOS, S	Ecoinvent 3 -	kg CFC11 eq	3.29E-6	3.29E-6	x
4	Water pump, 22kW {GLO} market for water pump, 22kW APOS, S	Ecoinvent 3 -	kg CFC11 eq	2E-6	2E-6	x
5	Brass {CH} market for brass APOS, S	Ecoinvent 3 -	kg CFC11 eq	1.04E-6	1.04E-6	x



Ozone depletion

No	Process	Project	Unit	Total	heat pump	geothermal well
	Total of all processes		kBq U-235 eq	57.7	11.2	46.5
1	Steel welded pipe/EU	Industry data	kBq U-235 eq	31.9	x	31.9
2	Concrete block {BR} market for concrete block APOS, S	Ecoinvent 3 -	kBq U-235 eq	14.6	x	14.6
3	Copper, anode {GLO} market for copper, anode APOS, S	Ecoinvent 3 -	kBq U-235 eq	6.01	6.01	x
4	Water pump, 22kW {GLO} market for water pump, 22kW APOS, S	Ecoinvent 3 -	kBq U-235 eq	2.67	2.67	x
5	Brass {CH} market for brass APOS, S	Ecoinvent 3 -	kBq U-235 eq	1.68	1.68	x



Ionizing radiation

No	Process	Project	Unit	Total	heat pump	geothermal well
	Total of all processes		kg NMVOC eq	136	115	21.5
1	Natural gas, processed, at plant/US	USLCI	kg NMVOC eq	50.4	50.4	x
2	Electricity, natural gas, at power plant/US	USLCI	kg NMVOC eq	50.4	50.4	x
3	Steel welded pipe/EU	Industry data	kg NMVOC eq	18.7	x	18.7
4	Transport, combination truck, diesel powered/US	USLCI	kg NMVOC eq	3.41	3.41	x
5	Natural gas, combusted in industrial boiler/US	USLCI	kg NMVOC eq	2.75	2.75	x



Photochemical ozone formation

Geo-cooling

Top 5 processes contributing for each category

No	Process	Project	Unit	Total	heat pump	geothermal well
	Total of all processes		disease inc.	0.00549	0.00489	0.000593
1	Natural gas, processed, at plant/US	USLCI	disease inc.	0.00452	0.00452	x
2	Steel welded pipe/EU	Industry data	disease inc.	0.000554	x	0.000554
3	Electricity, natural gas, at power plant/US	USLCI	disease inc.	0.000275	0.000275	x
4	Electricity, bituminous coal, at power plant/US	USLCI	disease inc.	4.93E-5	4.93E-5	x
5	Concrete block (BR) market for concrete block APOS, S	Ecoinvent 3 -	disease inc.	2.97E-5	x	2.97E-5



Particulate matter

No	Process	Project	Unit	Total	heat pump	geothermal well
	Total of all processes		mol H+ eq	827	799	27.9
1	Natural gas, processed, at plant/US	USLCI	mol H+ eq	740	740	x
2	Electricity, natural gas, at power plant/US	USLCI	mol H+ eq	35.4	35.4	x
3	Steel welded pipe/EU	Industry data	mol H+ eq	24.3	x	24.3
4	Electricity, bituminous coal, at power plant/US	USLCI	mol H+ eq	8.83	8.83	x
5	Copper, anode (GLO) market for copper, anode APOS, S	Ecoinvent 3 -	mol H+ eq	7.56	7.56	x



Acidification

No	Process	Project	Unit	Total	heat pump	geothermal well
	Total of all processes		Pt	1.25E4	2.89E3	9.64E3
1	Concrete block (BR) market for concrete block APOS, S	Ecoinvent 3 -	Pt	6.88E3	x	6.88E3
2	Steel welded pipe/EU	Industry data	Pt	2.77E3	x	2.77E3
3	Copper, anode (GLO) market for copper, anode APOS, S	Ecoinvent 3 -	Pt	2.42E3	2.42E3	x
4	Water pump, 22kW (GLO) market for water pump, 22kW APOS, S	Ecoinvent 3 -	Pt	231	231	x
5	Brass (CH) market for brass APOS, S	Ecoinvent 3 -	Pt	173	173	x



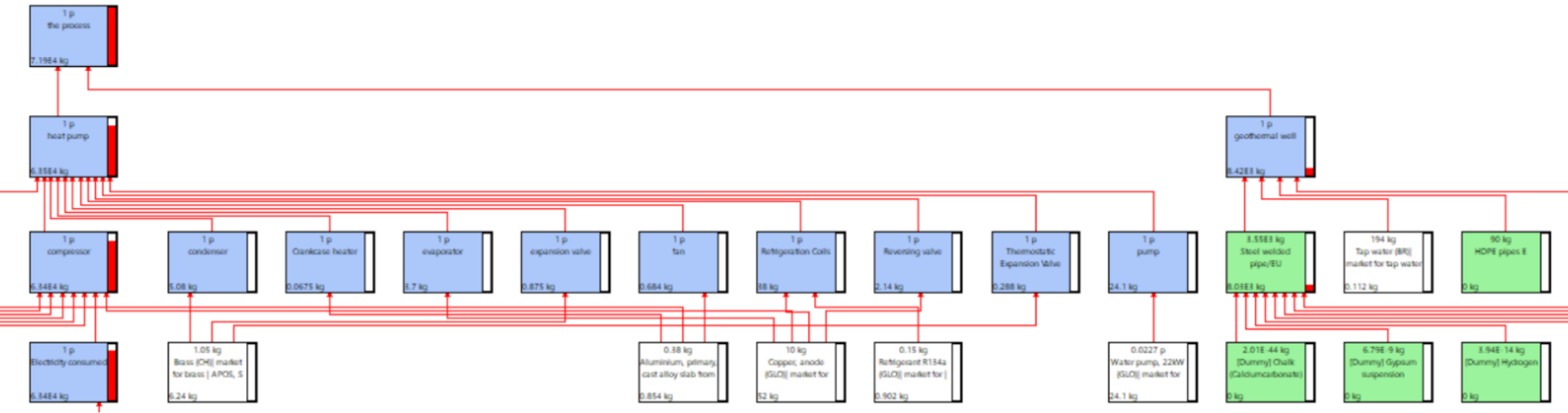
Land use

No	Process	Project	Unit	Total	heat pump	geothermal well
	Total of all processes		m3 depriv.	378	167	211
1	HDPE pipes E	Industry data	m3 depriv.	180	x	180
2	Copper, anode (GLO) market for copper, anode APOS, S	Ecoinvent 3 -	m3 depriv.	120	120	x
3	Concrete block (BR) market for concrete block APOS, S	Ecoinvent 3 -	m3 depriv.	24.4	x	24.4
4	Aluminum, secondary, ingot, at plant/RNA	USLCI	m3 depriv.	20.3	20.3	x
5	Water pump, 22kW (GLO) market for water pump, 22kW APOS, S	Ecoinvent 3 -	m3 depriv.	13.1	13.1	x



Water use

LCA Detailed Flowchart



- **Effect on Climate Change:**

- Total CO_2 produced = 71,900 kg CO_2 ,While the rest of emissions in (kg CO_2 eq.) = 14,000 kg
- Total heating load injected / produced from the ground= 565,920 kWhth

$$\text{GHG produced} = \frac{71,900 + 14,000}{565,920} = \mathbf{0.1517 \text{ kgCO}_2\text{eq./kWhth}}$$

From references, Heat pump system designed and implemented in Cairo university rock laboratory has GHG production = ***0.1517 kgCO₂eq./kWhth*** which is below average for India, Singapore and China references and is in range for Europe standards. ***This shows how this heat pump system is environmental-friendly.***



El-Alamein

Gate Towers Site Parameters

Gate Towers Site Specifications	
Location	El-Alamein city, North coast, Egypt
Area, m ²	204.8 m ² / Floor
Current use	Hotel (Residential Use)

View rendering



Design Results

ecoGEO HP 15-70

El-Alamein Gate Towers Results	
No. of total geopipes selected	2
Maximum capacity of one heat pump	70 kW

View rendering

Design Results

Vertical GSHP Results		Horizontal GSHP Results	
Total trench length	1042 m	Total trench length	1337 m
No. of vertical boreholes	2	Trench configuration	20' @ 10' spacing
Length for each borehole	521 m	Each trench length	35.5 m
Bore-to-bore Spacing	7 m	Bore-to-Bore Spacing	7 m

View rendering

Gate Towers Site Parameters

The view is a map from building that is allowed you look for good land use.

View rendering



Design Results

Results	
Total trench length	450 m
No. of vertical boreholes	1
Depth for each borehole	75 m
Bore-to-bore spacing	75 m

- 30% of boreholes = 8 boreholes 12 x 8
- Each borehole 75 m depth
- Spacing = 7 m
- Land area required = 7 x 12 = 84 m²

The land area required for geothermal/heating building system represents about 8% of total land area.

View rendering

Cost Assessment Results

Geothermal heat pump Cost Evaluation	
Drilling Cost (\$)	180,000
Loop Cost (\$)	275,000
Initial Cost = 180,000 + 275,000 = 455,000 (\$)	
Operation & Maintenance Cost = 10,000 (\$)	

Horizontal heat pump + PV Cost Evaluation	
Drilling Cost (\$)	180,000
Loop Cost (\$)	120,000
Initial Cost = 180,000 + 120,000 = 300,000 (\$)	
Operation & Maintenance Cost = 10,000 (\$)	

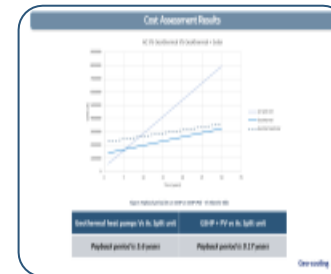
View rendering

Cost Assessment Results

Year	Year	Year	Year	Year	Year	Year
1	2	3	4	5	6	7
1	2	3	4	5	6	7
1	2	3	4	5	6	7
1	2	3	4	5	6	7
1	2	3	4	5	6	7
1	2	3	4	5	6	7

No. of Geopipes		Payback Period	
No. of Geopipes	2	Payback Period	1.7 years
Initial Cost	455,000 (\$)	Payback Period	1.7 years
Operation & Maintenance Cost	10,000 (\$)		

View rendering



CO₂ Emission Savings (GSHP vs AC)

AC	GSHP	CO ₂ Emission (kg per kWh)
AC (1000 kWh)	GSHP (1000 kWh)	400
10000	10000	
100000	100000	

Then, CO₂ Emission Savings per year (t CO₂/yr):

CO₂ Emission Savings = 10,000,000 - 11,700,000 = 1,700,000 g CO₂/yr

5.4 t CO₂/yr 1000 kWh 100%

View rendering

Gate Towers Site Parameters

Gate Towers Site Specifications

Location	El-Alamein city, North coast, Egypt DMS: 30° 51' 26" N, 28° 51' 19" E
Area, m ²	594.8 m ² / Floor
Current use	Hotel (Residential Use)

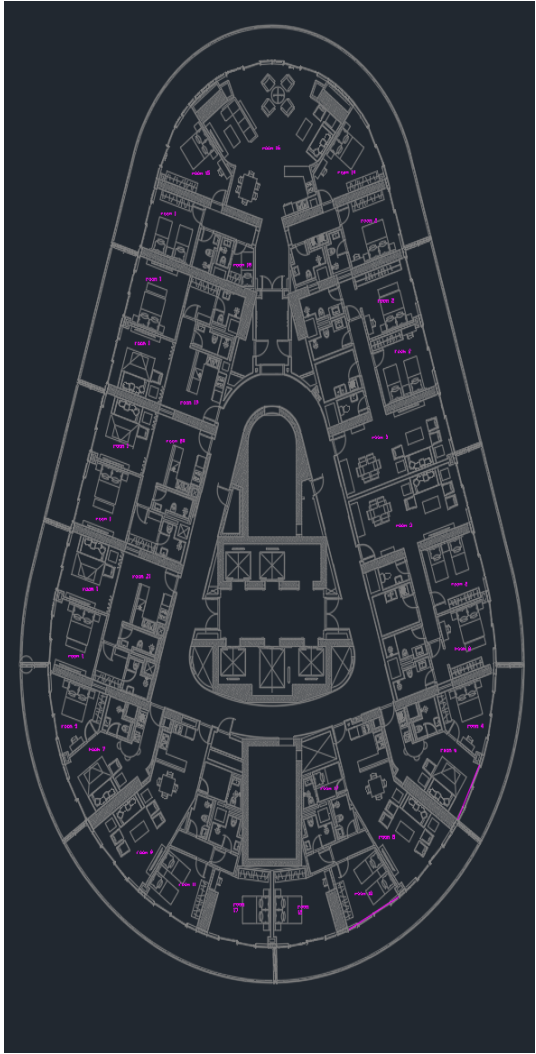
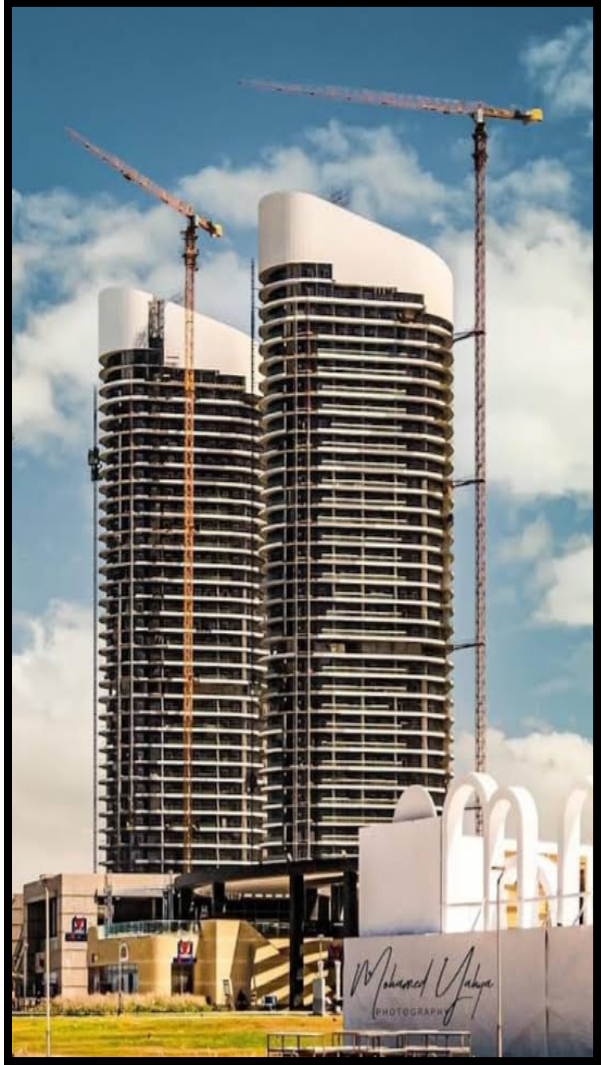
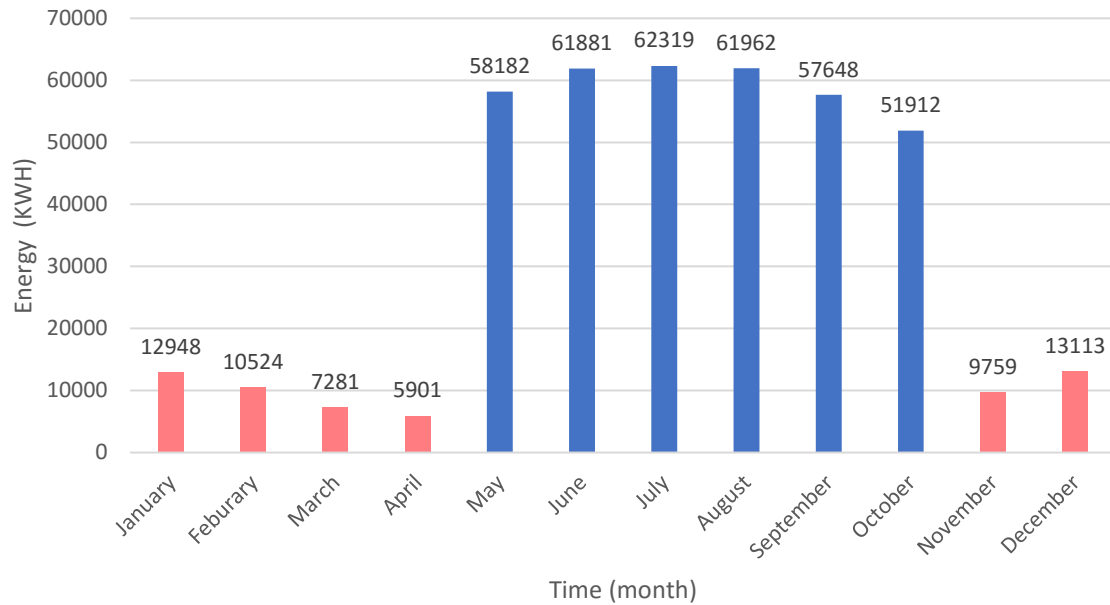


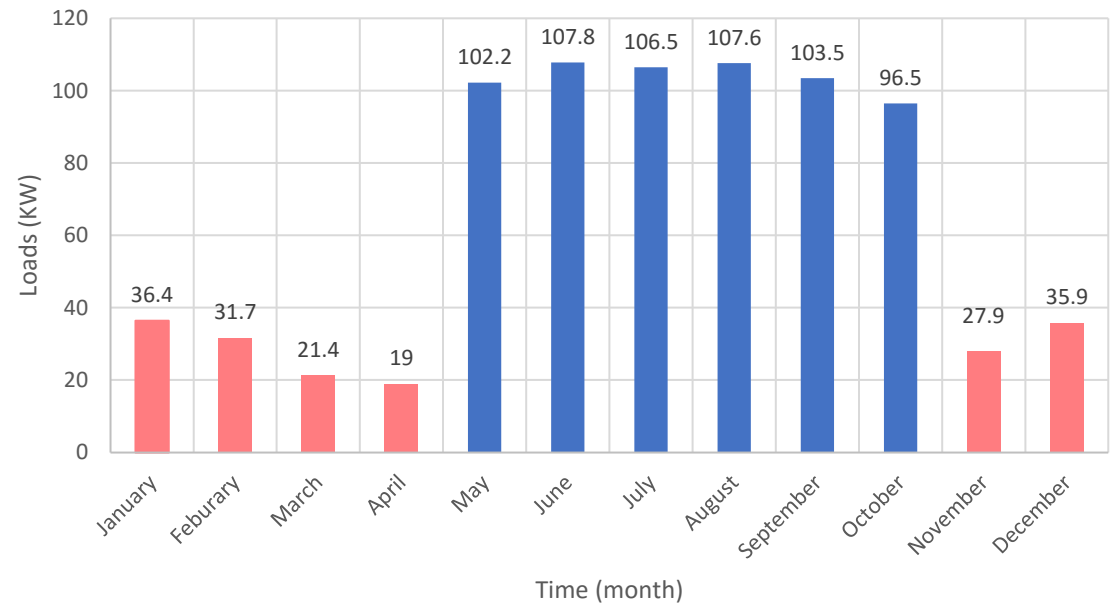
Figure : Plan view of one floor

Cooling and Heating Load Results

Monthly Load during operating hours for each month



Peak Load during operating hours for each month



Maximum Peak Load = **107.8 KW** @ June

Design Results

El-Alamein Gate Towers Results	
No. of heat pumps selected	2
Maximum capacity of one heat pump	70 kW

ecoGEO HP 15-70

- Modulating thermal power control within a wide range (25-100%) and modulating flow rate control of both brine and production circuits (20-100%).
- Inverter technology and scroll compressor.
- Integrated management of up to 5 different emission temperatures, 2 buffer tanks (heating and cooling), 1 DHW tank, 1 pool and hourly control of DHW recirculation.
- Management of aérothermal collection modulating units, in case of air source or hybrid configurations by means of the ecoSMART e-source.
- Integrated management of external On/Off or modulating auxiliary systems, such as electrical heaters, On/Off boilers or modulating boilers.
- Management of cascade systems up to 6 units by means of the ecoSMART Supervisor.
- Integrated management of simultaneous cooling/heating systems according to scheme.
- Free cooling (Passive cooling) management.
- Integrated active cooling in models 3.
- Three-phase version available.
- Compatible with ecoSMART e-manager and ecoSMART e-system.
- Integrated energy meters to measure the electrical consumption, the heating/cooling thermal power, the COP and the monthly and annual SPF.

SPECIFICATIONS ecoGEO HP 15-70		UNITS	HP1	HP3
APPLICATION	Place of installation	-	Indoors	
	Type of brine system ¹	-	Ground source / Air source / Hybrid source	
	DHW with external tank	-	✓	✓
	Heating and Pool	-	✓	✓
	External Passive cooling management	-	✓	✓
	Integrated Active cooling	-	-	✓
PERFORMANCE	Modulation range of the compressor	%	25 to 100	
	Heating power output ¹ , B0W35	kW	17,1 to 59,6	
	COP ¹ , B0W35	-	4,5	
	Active cooling power output ¹ , B35W7	kW	-	15,1 to 61,5
	EER ¹ , B35W7	-	-	4,5
	Max. DHW temperature without / with support	°C	60 / 70	
OPERATION LIMITS	Noise power emission level ³	db	53 to 71	
	Energy label / rjs / SCOP W35 average climate control	-	A+++ / 180% / 4,71	
	Energy label / rjs / SCOP W55 average climate control	-	A++ / 139% / 3,67	
	Distribution / Set heating outlet temperature range ²	°C	10 to 60 / 20 to 60	
	Distribution / Set cooling outlet temperature range ²	°C	5 to 35 / 7 to 25	
	Brine inlet temperature range in heating applications ²	°C	-20 to 35	
WORKING FLUIDS	Brine inlet temperature range in cooling applications ²	°C	10 to 60	
	Minimum / Maximum refrigerant circuit pressure	bar	2 / 45	
	Production / Pre-load circuit pressure	bar	0,5 to 5,0	
	Brine / Pre-load circuit pressure	bar	0,5 to 5,0	
	R410A Refrigerant load	kg	4,7	5,5
	Compressor oil type / load	kg	POE / 3,6	
CONTROL ELECTRICAL DATA	Nominal primary flow rate, B0W35 ¹ (ΔT = 3 °C)	l/h	3230 to 13195	
	Nominal secondary flow rate, B0W35 ¹ (ΔT = 5 °C)	l/h	2465 to 10265	
	1/N/PE 230 V / 50-60 Hz ⁵	-	✓	
	Maximum recommended external protection ⁷	-	C1A	
	Transformer primary circuit fuse	A	0,63	
	Transformer secondary circuit fuse	A	4,0	
ELECTRICAL DATA: THREE-PHASE	3/N/PE 400 V / 50-60Hz ⁵	-	✓	
	Maximum recommended external protection ⁷	-	C50A	
	Maximum consumption ² , B0W35	kW / A	14,3 / 23,2	
	Maximum consumption ² , B0W55	kW / A	20,4 / 32,3	
DIMENSIONS/WEIGHT	Minimum / Maximum starting current ⁴	A	7,5 / 11,8	
	Correction of cosine Ø	-	0,96-1	
	Height x width x depth	mm	1063x870x785	
	Empty weight (without assembly)	kg	320	325

1. In compliance with EN 14511, this includes the consumption of the circulation pumps and the compressor driver.
 2. With variable speed circulating pumps, managed by the ecoGEO HP heat pump.
 3. According to EN 12102.
 4. Starting current depends on working condition of the hydraulic circuits.
 5. The admissible voltage range for proper operation of the heat pump is ±10%.
 6. Maximum consumption can vary significantly according to working conditions, or if the compressor's range of operation is restricted.
 7. External protection exclusively regarding the ecoGEO heat pump controller electrical consumption. This protection should be updated in case of using the controller single-phase electrical supply to wire other equipments depending on the features of such equipments.
 8. In case of air source or hybrid source configuration, it is required to combine the ecoGEO HP heat pump with the ecoSMART e-source.
 Note: primary circuit and secondary circuit circulation pumps not included.

Design Results

RESULTS:

Number of Vertical Boreholes: 16

Borehole Field Configuration:

Uniform Grid of 4 x 4 boreholes, 7-m bore-to-bore spacing.

Calculated Depth for Each Borehole: 99 m

Total Length Requirement for Boreholes:

1584 m, driven by the cooling loads (240 m are driven by the heating loads)

Relative Impact on GHX Design Length Due to the Ground Thermal Resistances Related to:

Borehole Resistance: 63.6%
 Daily Pulse: 12.7%
 Monthly Pulse: 16.6%
 Annual Pulse: 7.1%

Residual: 5.384E-06

Calculation Time: 2.578E-01 seconds

- Vertical GSHP Results:**

Results	
Total Borehole length	1584 m
No. of vertical boreholes	16
Depth for each borehole	99 m
Bore-to-Bore Spacing	7 m

RESULTS:

Trench Configuration: 20 @ 3.0 m spacing

Calculated Length for Each Trench: 78.9 m

Total Length Requirement for Trenches:

1579 m, driven by the cooling loads (-80 m are driven by the heating loads)

Relative Impact on GHX Design Length Due to the Ground Thermal Resistances Related to:

Trench Resistance: 67.3%
 Daily Pulse: .5%
 Monthly Pulse: 3.4%
 Annual Pulse: 28.9%

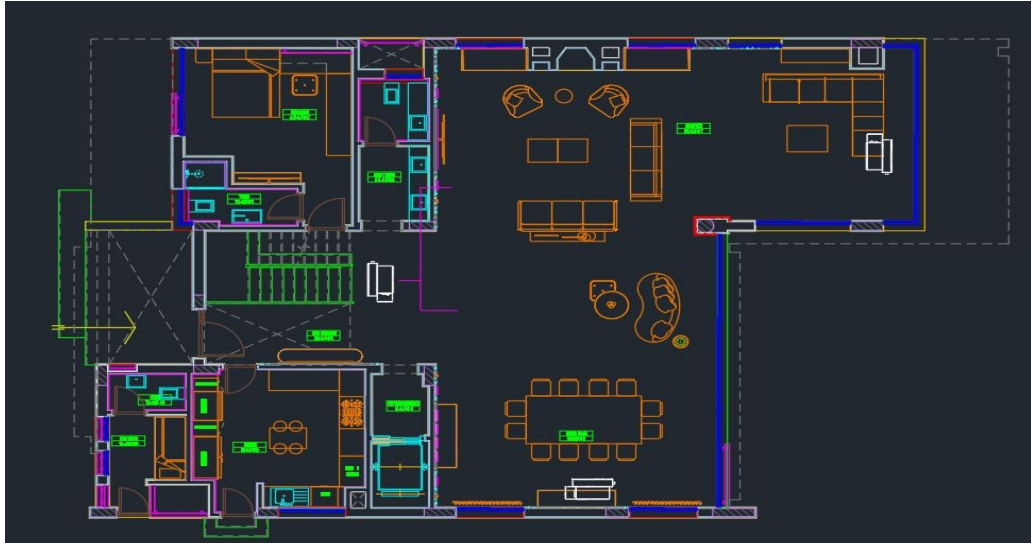
Residual: 8.429E-06

Calculation Time: 6.797E-01 seconds

- Horizontal GSHP Results:**

Results	
Total Trench length	1579 m
Trench Configuration	20 @ 3m spacing
Each Trench Length	78.9 m
Bore-to-Bore Spacing	7 m

Gate Towers Site Parameters



Ground Floor Plan View



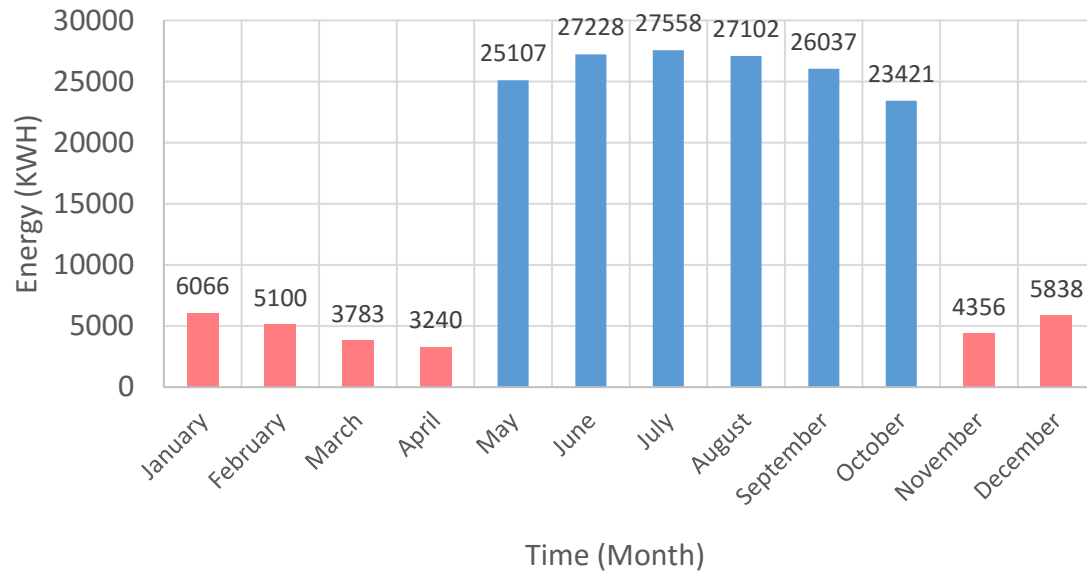
First Floor Plan View



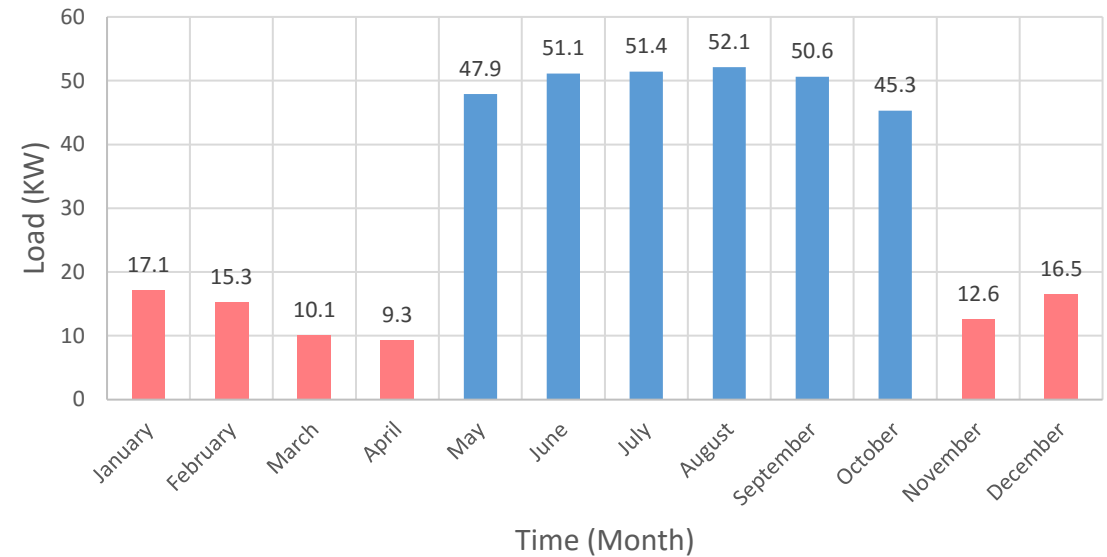
The Villa is a **two-floor building** that is allocated overlooks the north coast at Palm Hills.

Cooling and Heating Load Results

Monthly Load during operating loads for each month



Peak Load during operating loads for each month



Maximum Peak Load = **52.1 KW** @ Aug

Design Results

Microsoft Excel

RESULTS:

Number of Vertical Boreholes: 6

Borehole Field Configuration:

Uniform Grid of 2 x 3 boreholes, 7-m bore-to-bore spacing.

Calculated Depth for Each Borehole: 75 m

Total Length Requirement for Boreholes:

450 m, driven by the cooling loads (114 m are driven by the heating loads)

Relative Impact on GHX Design Length Due to the Ground Thermal Resistances
Related to:

Borehole Resistance: 48.2%

Daily Pulse: 33.6%

Monthly Pulse: -26.1%

Annual Pulse: 44.3%

Residual: 4.698E-06

Calculation Time: 2.578E-01 seconds

Results	
Total Borehole length	450 m
No. of vertical boreholes	6
Depth for each borehole	75 m
Bore-to-Bore Spacing	7 m

- *No. of boreholes = 6 boreholes (2 × 3)*
- *Each borehole 75 m depth*
- *Spacing = 7 m*
- *Land area required = 7 × 14 = 98 m²*

The land area required for geothermal heating/cooling system represents about **46% of total land area**.

Cost Assessment Results


Geothermal heat pump Cost Evaluation

Drilling Cost (LE)	585,000
Unit Cost (LE)	773,600
Initial Cost = 585,000+ 773,600 = 1,358,600 LE	
Operation & Maintenance Cost = 62,628 LE	

Geothermal heat pump + PV Cost Evaluation

PV Initial Cost (LE)	665,215.2
Unit Cost (LE)	184,782
Initial Cost = 1,358,600 + 665,215.2 + 184,782= 2,208,596 LE	
Operation & Maintenance Cost = 45,585 LE	

Ecoforest EcoGEO HP 15-70 kW



Description **Models**

Nuenta are please to offer the EcoGEO High Power range from Ecoforest. This state of the art Ground Source Heat Pump is Inverter driven, providing between 15-70 kW output. The EcoGeo 15 - 70 kw is not only suitable for a commercial application but also for larger properties with a 3 phase supply. This inverter driven technology reduces the need cascading smaller heat pumps, which reduces the overall footprint of the installation.

- Refrigerant R410A
- Scroll Compressor with Inverter Technology
- Carel Electronic Expansion Valve
- Alfa Laval Asymmetric plate heat exchangers
- Carel PCOS+ Control

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Size
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Quantity

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Figure: GSHP Specifications - El=-Alamein

Cost Assessment Results

Floor	No.	Space	Floor area (m ²)	TR	Hp (electric)	Split needed	Cost (EGP)	KWE installed
Ground	1	Reception	93.309	5	9.5	2*4hp + 1*1.5hp	105,670	6.98
	2	Dining room	27.946	1.5	3	1*3hp	30,830	2.2
	3	Kitchen	12.139	0.65	1.5	1*1.5hp	20,450	1.1
	4	Main entrance	6.02	0.322	1.5	1*1.5hp	20,450	1.1
	5	Nany room	5.841	0.31	1.5	1*1.5hp	20,450	1.1
	6	Bedroom 1	16.272	0.87	1.5	1*1.5hp	20,450	1.1
First	7	Bedroom 2	32.2792	1.73	3	1*3hp	30,830	2.2
	8	Master bedroom & dressing	46.2397	2.5	3	2*1.5hp	40,900	2.2
	9	living and kitchen	40	2.15	4	1*4hp	42,610	2.94
	10	bedroom1	18.1	0.97	1.5	1*1.5hp	20,450	1.1
				Σ	30	SUM	353,090	22.02

Air-Conditioning Cost Evaluation

No. of Ac units 10

Initial Cost = 353,090 LE

Operation & Maintenance Cost = 252,743.334 LE

SHARP Ac units

Cost

1.5 hp 20,450 EGP

3 hp 30,830 EGP

4 hp 42,610 EGP

Cost Assessment Results

AC VS Geothermal VS Geothermal + Solar

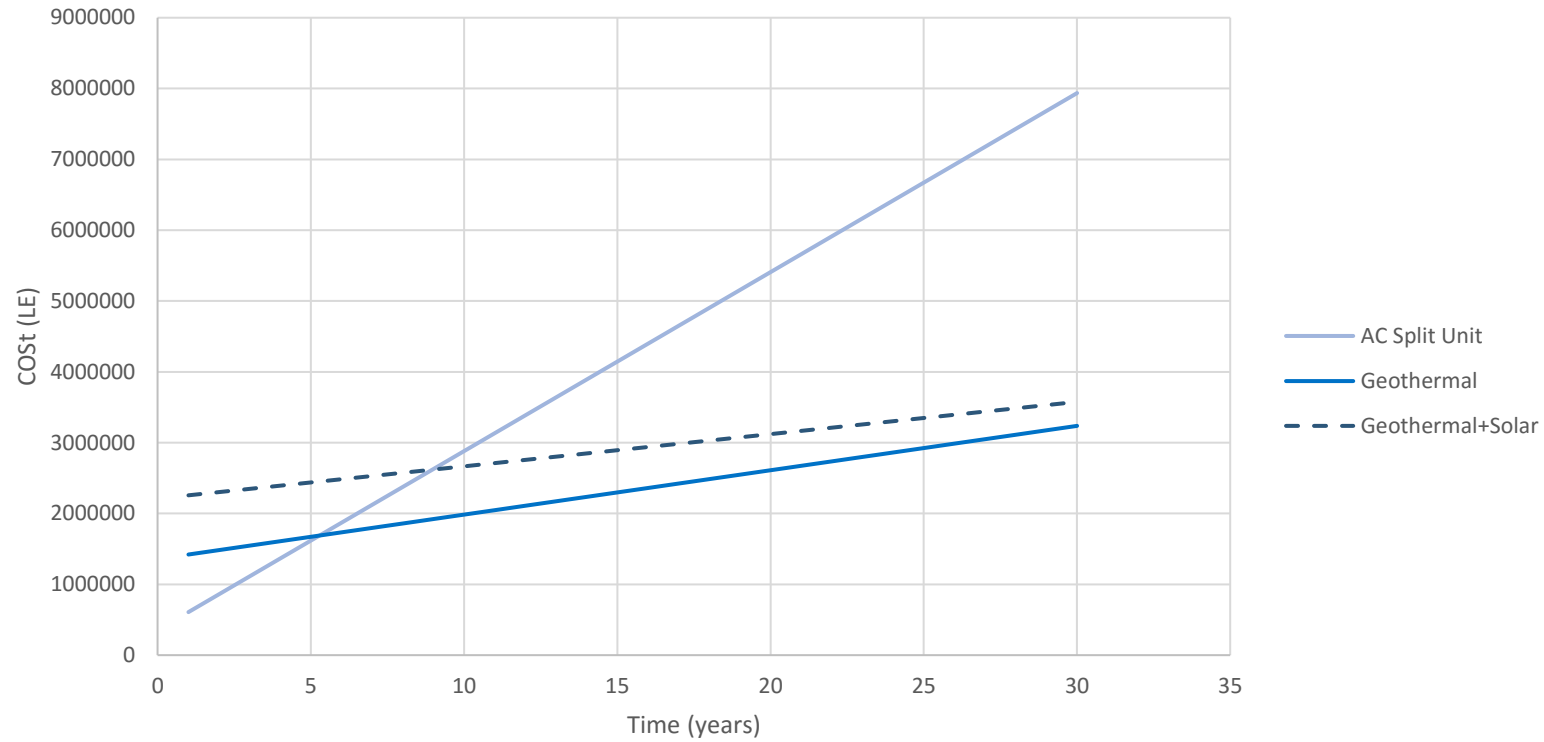


Figure: Payback period (Ac vs GSHP vs GSHP+PV) – El-Alamein Villa

Geothermal heat pumps Vs Ac Split unit	GSHP + PV vs Ac Split unit
Payback period is 5.6 years	Payback period is 9.17 years

CO₂ Emission Savings: (GSHP vs AC)

<i>AC</i>	<i>GEO</i>	<i>CO₂ emission factor (gCO₂/kWh)</i>
<i>Elec. Cons. (KWH/Yr)</i>	<i>Elec. Cons. (KWH/Yr)</i>	400
163960.92	29398.917	
<i>CO₂ emission (gCO₂/yr)</i>	<i>CO₂ emission (gCO₂/yr)</i>	
65,584,368	11,759,566.8	

Then, CO₂ Emission Savings per year (g CO₂/yr):

☐ **CO₂ Emission Savings** = 65,584,368 – 11,759,566.8 = **53,824,801.2 gCO₂eq.**


$$\% \text{ Savings} = \frac{53,824,801.2}{65,584,368} \times 100 = 82\%$$



Acoustics

Site Parameters

P.O.C	Data
Location:	The Acoustics building is located at Faculty of engineering Ain Shams University
Floor Area	542 m ²
Goals	Our goal is to calculate the cost of replacing one chiller (38.5 TR) with a Geothermal heat pump to cover the acoustics building's cooling/heating loads to reduce electric consumption & carbon footprint.
Building use	Educational Purpose



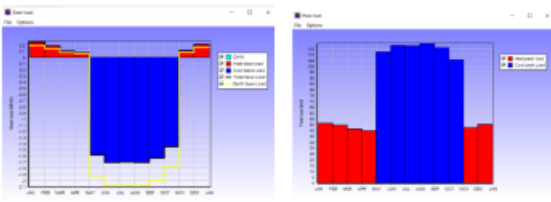
Geo-cooling 18

Site Parameters



Geo-cooling 18

Cooling and Heating Load Results



Geo-cooling 18

Closed Loop GSHP Design Parameters

Ground Properties	
Thermal conductivity	2.1 W/m.k
Volumetric heat capacity	2.5 MJ/m ³ .K
Ground surface temperature	24°C
Geothermal heat flux	0.08 W/m ²

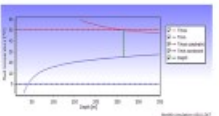

Borehole Specifications	
Type	Single U tube
Depth of one borehole	180 m
Spacing between boreholes	7 m
Borehole Diameter	152 mm
Thermal resistance for pipe/grout	0.074 m.k/W
Geost thermal conductivity	0.6 W/m.k
Flow rate for one borehole	16.2 L/min

Pipe Specifications	
Outer diameter	32 mm
Thickness	3 mm
Thermal conductivity	0.42 W/m.k
Spacw spacing	120 mm

Geo-cooling 18

Closed Loop GSHP Design Results


Best Case Results	
No. of boreholes	38 boreholes
Boreholes configuration	3*8 configuration
Spacing between boreholes	7 m
Depth of one borehole	180 m
Total length	1755 m
Land area	686 m ²
Surface area dimensions (L x W)	49 m x 14 m

Geo-cooling 18

Cost Assessment Results

Cost	
Excavation & instruments	1500 LE for 1 m
Total cost per 1750 m = 2,205,700 LE	
Two heat pump units used	Cost/cool (100 kw-40 kw)
Total cost of two heat pump respectively (957.372 + 17940) = 975,318 LE	
Total system cost = 3,282,018 LE = 108,733 USD \$	

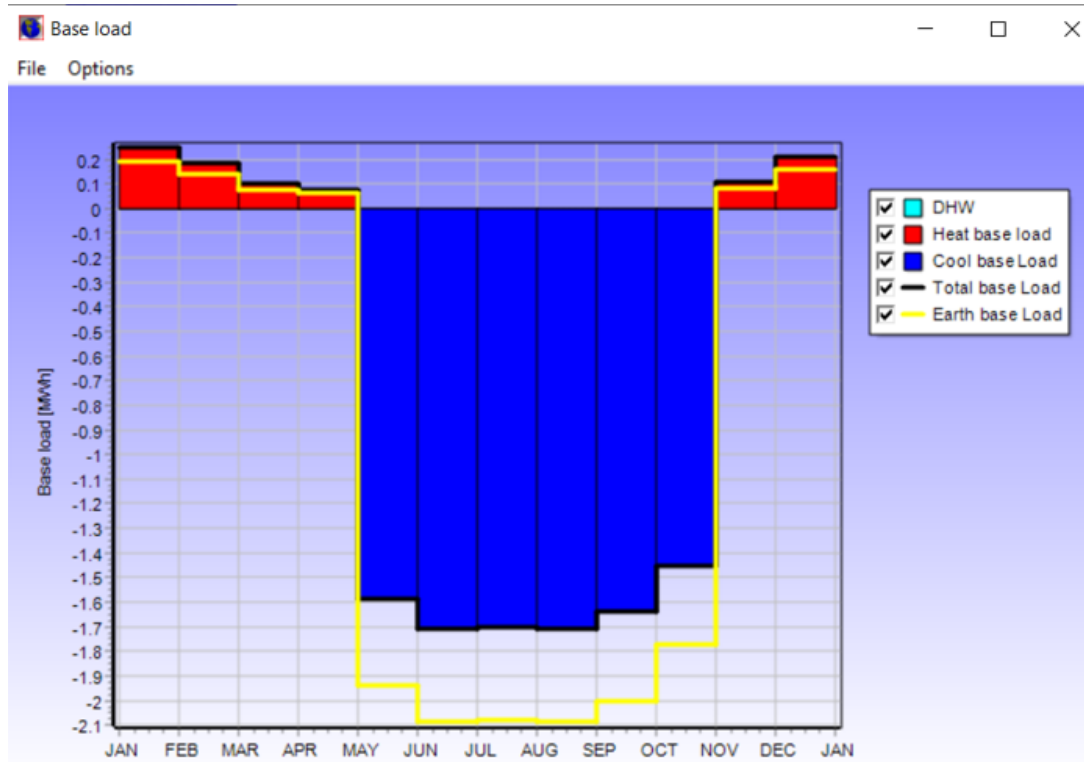


Geo-cooling 18

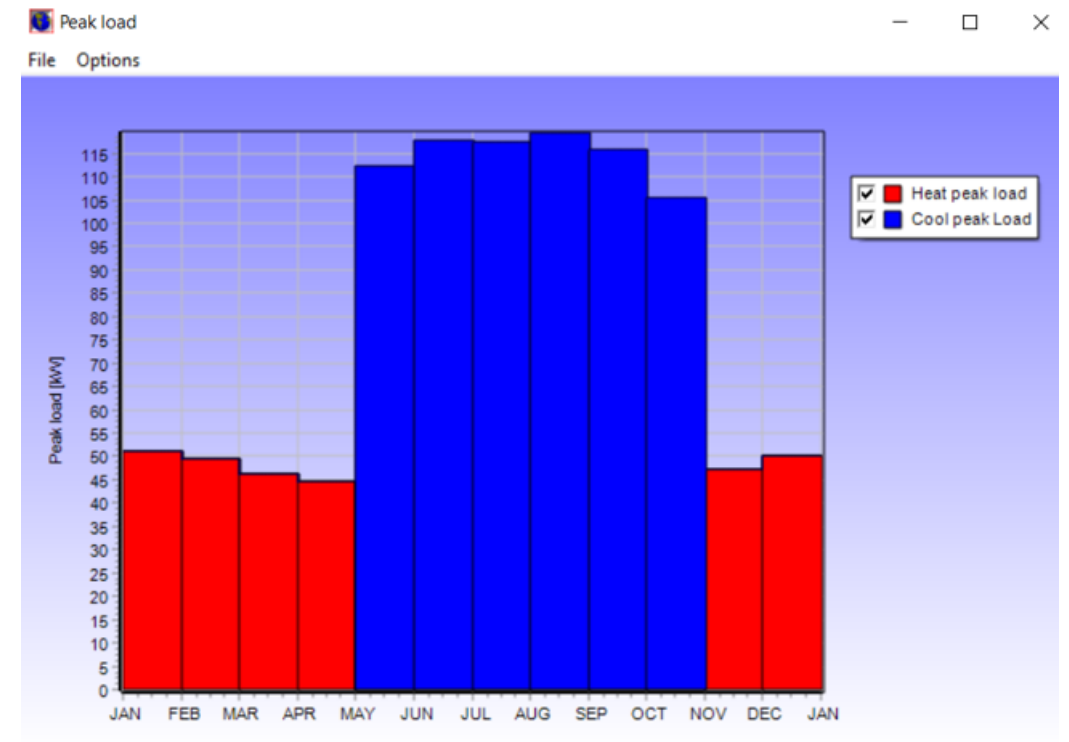
<i>P.O.C</i>	<i>Data</i>
<i>Location:</i>	The Acoustics building is located at Faculty of engineering Ain Shams University
<i>Floor Area</i>	542 m ²
<i>Goals</i>	Our goal is to calculate the cost of replacing one chiller (38.5 TR) with a Geothermal heat pump to cover the acoustics building's cooling/heating loads to reduce electric consumption & carbon footprint.
<i>Building use</i>	Educational Purpose



Cooling and Heating Load Results



Acoustics Building Base load annually.



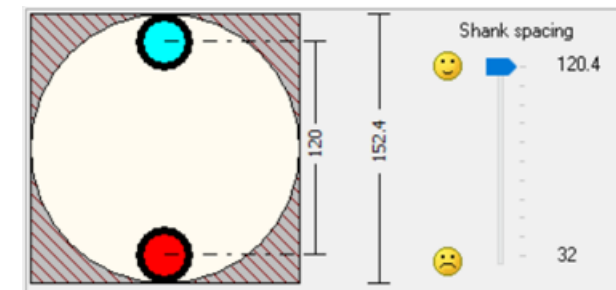
Acoustics Building Peak loads annually.

Closed Loop GSHP Design Parameters

Ground Properties	
Thermal conductivity	2.1 W/m.k
Volumetric heat capacity	2.5 MJ/m ³ .k
Ground surface temperature	24°C
Geothermal heat flux	0.08 W/m ²
Borehole Specifications	
Type	Single U-tube
Depth of one borehole	100 m
Spacing between boreholes	7 m
Borehole Diameter	152 mm
Thermal resistance for pipe/grout	0.074 m.k/W
Grout thermal conductivity	0.6 W/m.k
Flow rate for one borehole	16.2 L/min
Pipe Specifications	
Outer diameter	32 mm
Thickness	3 mm
Thermal conductivity	0.42 W/m.k
Shank spacing	120 mm

Acoustics Building Input Data

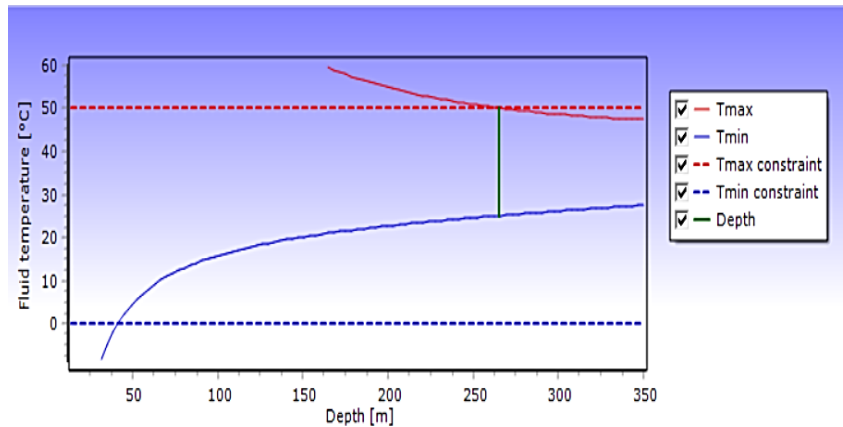
Heat carrier Fluid (Water)	
Thermal conductivity	0.608 W/m.k
Specific heat capacity	4180 J/kg.k
Density	997.2 kg/m ³
Viscosity	0.000891 Kg/m.s
Freezing point	0°C
Earth Energy Designer 4.2	
Simulation period	25 Years
First month of operation	September



Borehole Shank spacing.

Closed Loop GSHP Design Results

Best Case Results	
No. of boreholes	18 boreholes
Boreholes configuration	3 * 8 configuration
Spacing between boreholes	7 m
Depth of one borehole	98 m
Total length	1759 m
Land area	686 m ²
Surface area dimensions: L × W	49 m × 14 m



Monthly simulation: ASU1.DAT
 Year: 25
 Configuration: 7 ("8 : 1 x 8 line")
 Spacing B: 7 m
 Calculated depth D: 265 m
 Tf min: 25.1°C max: 50°C

Fluid Temperature vs depth [For Acoustics Building]



Borehole field configuration [For Acoustics Building]

Cost Assessment Results

Cost	
Excavation & instruments	1300 LE for 1 m
Total cost per 1759 m = 2,286,700 LE	
Two heat pump units used	Ecoforest (100 kw- 40 kw)
Total cost of two heat pump respectively (957,372 + 17946) = 975,318 LE	
Total system cost = 3,262,018 LE = 108,733 USD \$	

ECOFREST ECOGEO HP 25-100 KW

Description

Specification

Nuenta are please to offer the EcoGEO High Power range from Ecoforest. This state of the art Ground Source Heat Pump is Inverter driven, providing between 25-100 kW output. The EcoGeo 25 - 100 kw is not only suitable for a commercial application but also for larger properties with a 3 phase supply.

This high power inverter driven technology replaces the need for cascading smaller heat pumps, which reduces the overall footprint of the installation.

- Refrigerant R410A
- Scroll Compressor with Inverter Technology
- Carel Electronic Expansion Valve
- Alfa Laval Asymmetric plate heat exchangers
- Carel PCO5+ Control

£28,158.27
(£33,789.92 inc. VAT)

For Specific Delivery Times please contact us on: **01543 466642**

Size:

Quantity:

ADD TO CART +




Figure: Acoustic Building Heat pump specifications



Prototype

This prototype was built to discuss the ability of designing a horizontal ground source heat pump that aims to operate a 1/8 hp dispenser giving a high performance to the system instead of using conventional electric grid.

Prototype CFD Setup

Initial and Boundary Conditions	Value
ambient ground temperature	$T_{ground} = 35\text{ }^{\circ}\text{C}$
inlet temperature	$32.5\text{ }^{\circ}\text{C}$
Outlet Temperature	$T_{Outlet} = T_{in} - \frac{\dot{Q}_{cool}}{\rho_w \dot{V} C_{p,w}}$
fluid flow rate at the inlet pipe	1 L/min, or 0.03 m ³ /s
reference atmospheric pressure in outlet pipe	$p_0 = 101,325\text{ Pa}$

Components

- Water Dispenser
- Plate Heat Exchanger
- Soil trench
- Water circulating pump
- UPVC U-shaped loops
- Thermocouples
- Glass wool insulation

Prototype Performance Baseline

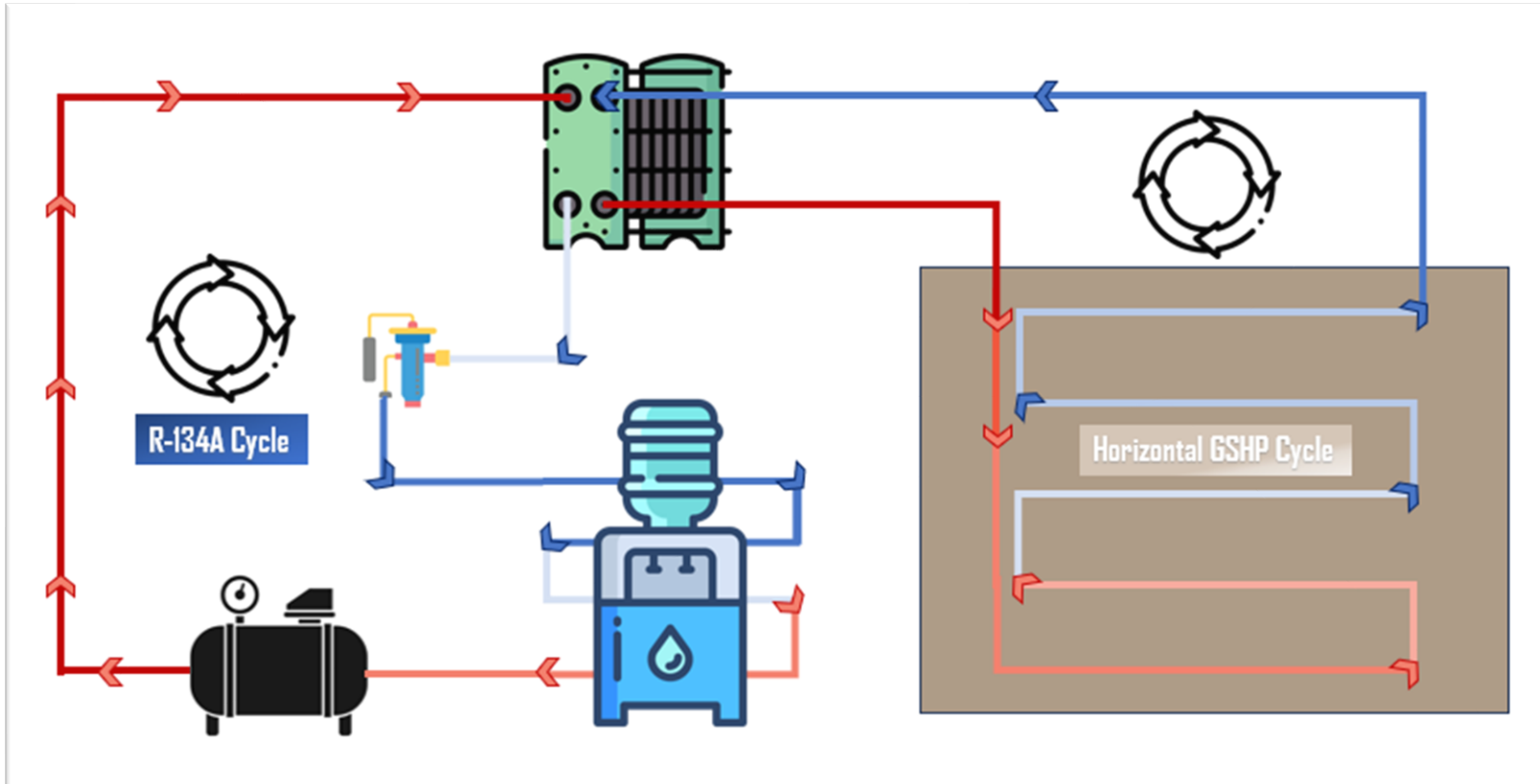
To study the prototype performance, observing the refrigerant ability of cooling water by setting a requirement of calculating the power consumption of cooling 5.5 L of water and to understand the losses of the prototype's (refrigerant – water) cooled system, a comparison is made for (refrigerant – air) cooled systems.

Water Cooled System			Air Cooled System		
Parameters			Parameters		
Cooling refrigerant (DC Drive)	3.2 L/min	0.34 Ampere	Cooling Water Ability	2 Liter/hr	
Plate Heat Exchanger	10 plates		Rated Cooling Current	0.6 Ampere	
Refrigerant	0.5 Hz		Cooling Power (Q _c)	30 Watt	
			Refrigerant	0.3 Hz	

Power Factor of the dispenser = 0.8

Prototype Performance Baseline

Water Cooled System		Air Cooled System	
Results		Results	
Time	48.2 sec	Time	66 sec
Work of the compressor (W _c)	100.32 watt	Work of the compressor (W _c)	186.32 watt
Cooling power (Q _c)	27.16 watt	Cooling power (Q _c)	23.22
Rejected power to the ground (Q _g)	127.55 watt	Rejected power to the air (Q _{air})	123.54 watt
Cooling Energy (Q_c) = 13,207.92 J		Cooling Energy (Q_c) = 8,400.74 J	
Total Energy consumption = 97,461.6 J		Total Energy consumption = 97,461.6 J	
Cap = 0.27		Cap = 0.23	



Horizontal Design Project #1

Results | Fluid | Soil | Piping | Configuration | Extra kW | Information

Calculate

	COOLING	HEATING
Total Area (m ²):	2.0	2.0
Trench Number:	1	1
Single Trench Length (m):	2.0	2.0
Total Pipe Length (m):	16.0	16.0
Single Trench Pipe Length (m):	16.0	16.0
Unit Inlet (°C):	36.0	2.4
Unit Outlet (°C):	43.5	2.4
Total Unit Capacity (kW):	0.1	0.0
Peak Load (kW):	0.1	0.0
Peak Demand (kW):	0.2	0.1
Heat Pump COP:	1.4	0.0
System COP:	0.6	0.0
System Flow Rate (L/min):	0.3	0.3

Optional Hybrid System: Off

Update *Peaks *Cooling 0 % *Heating 0 %

Reset

Summary *Totals 0 % 0 %

This prototype was built to discuss the ability of designing a horizontal ground source heat pump that aims to operate a 1/8 hp dispenser giving a high performance to the system instead of using conventional electric grid.

Prototype CFD Setup

Initial and Boundary Conditions	Value
undisturbed ground temperature	$T_{ground} = 25 \text{ }^{\circ}\text{C}$
Inlet Temperature	$33.5 \text{ }^{\circ}\text{C}$
Outlet Temperature	$T_{out(t)} = T_{in} - \frac{Q_{GHE}}{\rho_W v A C_{p,w}}$
Fluid flow rate at the inlet pipe	1 L/min. or 0.03 m/s
Reference atmospheric pressure in outlet pipe	$p_o = 101,325 \text{ Pa}$

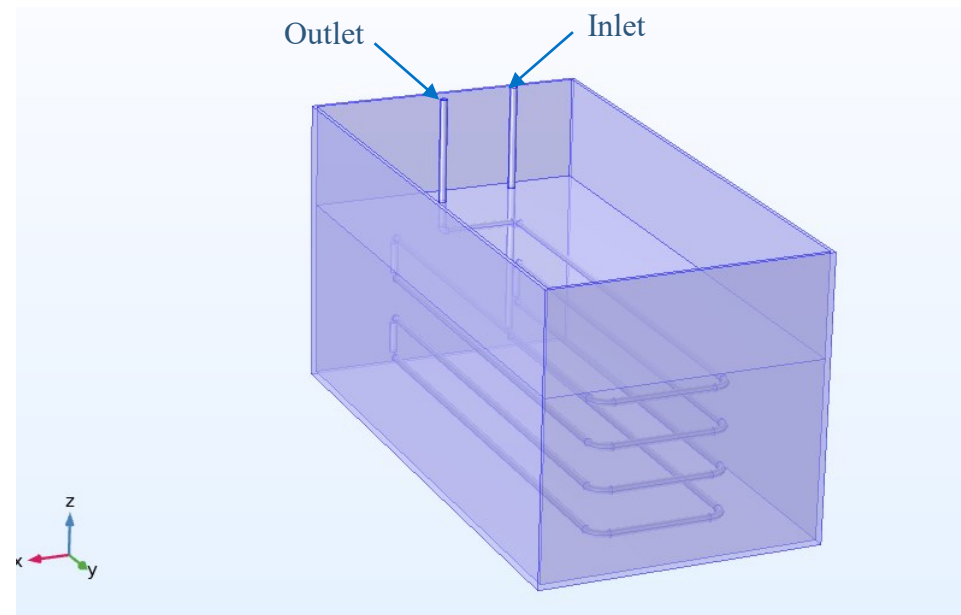


Figure: Prototype CAD on COMSOL software

Prototype Meshing

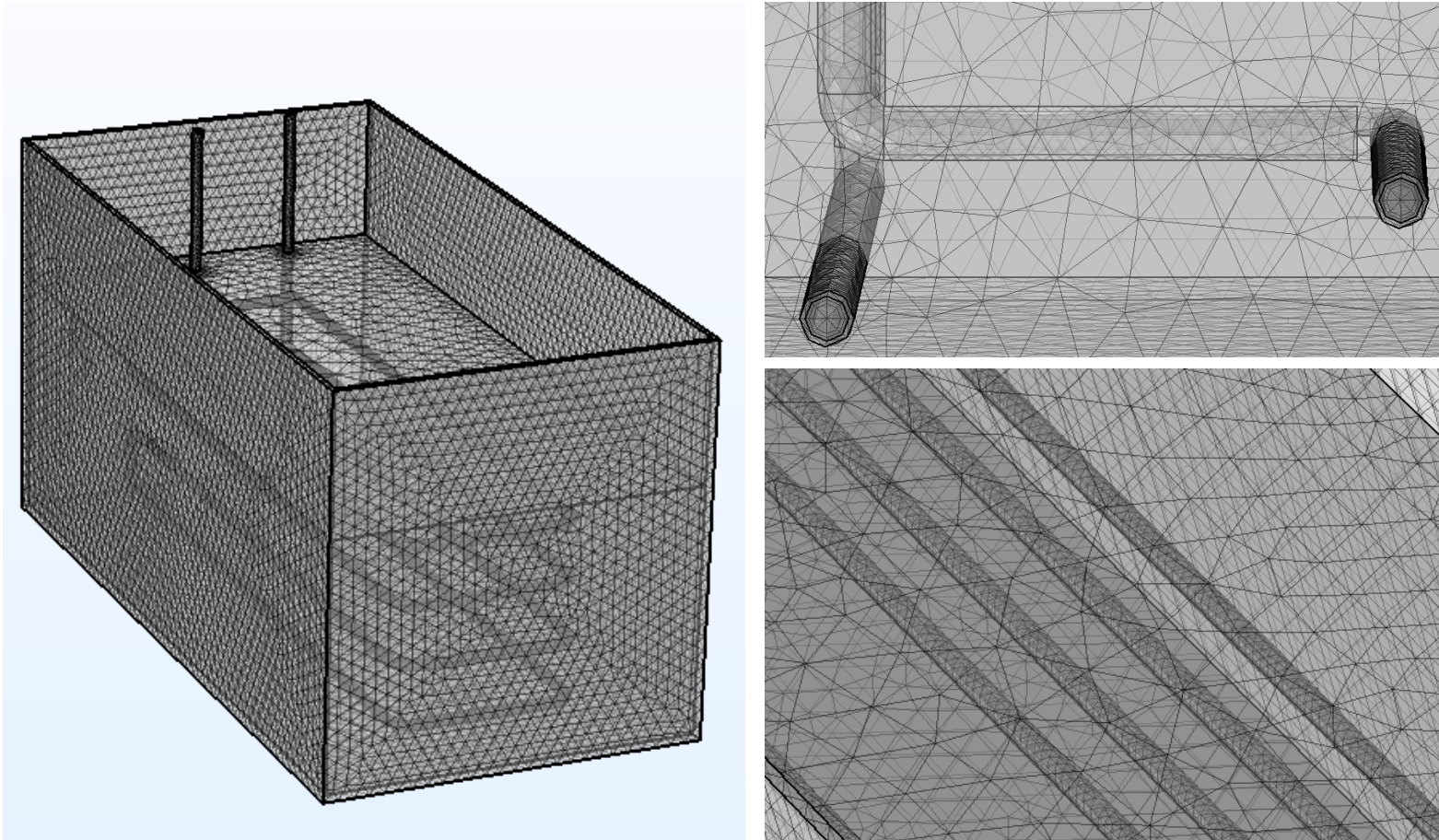


Figure: ASU Prototype Meshing

Prototype Steady state solution

To be able to make a study of stationary solution, adding another boundary condition should be considered as in this case, the soil domain will be given a constant soil temperature along the simulation. So, a Steady state is created between the inlet water temperature to the soil and the soil temperature

Thus, considering the soil in the box as an infinite heat sink similar to the ground behaviour as the soil temperature theoretically shouldn't change.

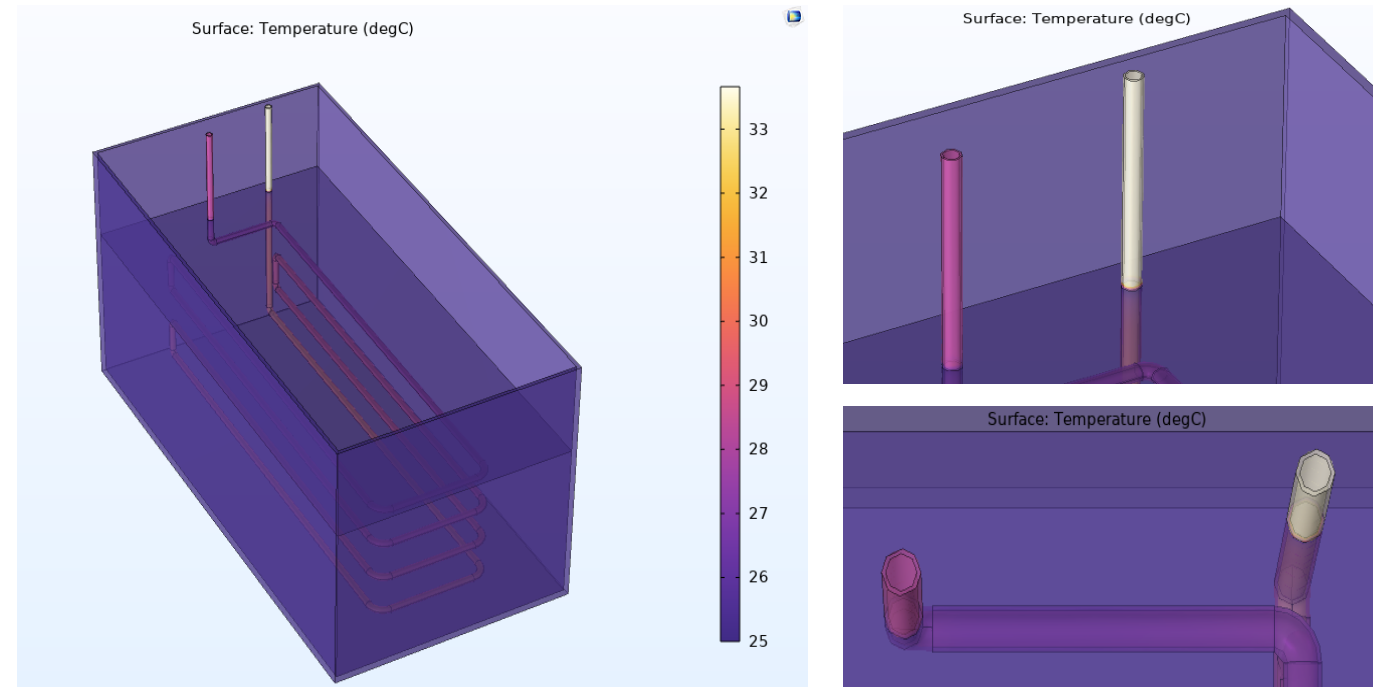


Figure: Steady state solution - Temperature distribution ($^{\circ}\text{C}$)

Prototype Steady state solution

Results have shown that the outlet water temperature from the soil:

$$T_{out} = 28.896 \text{ }^{\circ}\text{C}$$

And since the inlet fluid temperature is $33.5 \text{ }^{\circ}\text{C}$ and the undistributed ground temperature is $25 \text{ }^{\circ}\text{C}$, then the simulated effectiveness will be:

$$\theta (\%) = \frac{33.5 - 28.896}{33.5 - 25} \times 100 = 54.16\%$$

And the temperature difference is:

$$\Delta T = 33.5 - 28.896 = 4.604 \text{ }^{\circ}\text{C}$$

Prototype Transient solution

On the contrast of the previous study, the study of the soil thermal behaviour is being simulated by assuming certain operation conditions which are:

- Supplying constant inlet fluid temperature which is equal to $33.5\text{ }^{\circ}\text{C}$
- Soil as a heat sink will have its wall insulated which means the soil will store heat with respect to time.

The study will be done twice but with different time intervals

24-hour Time Interval Results

30 Days' Time Interval Results

24-hour time interval Results

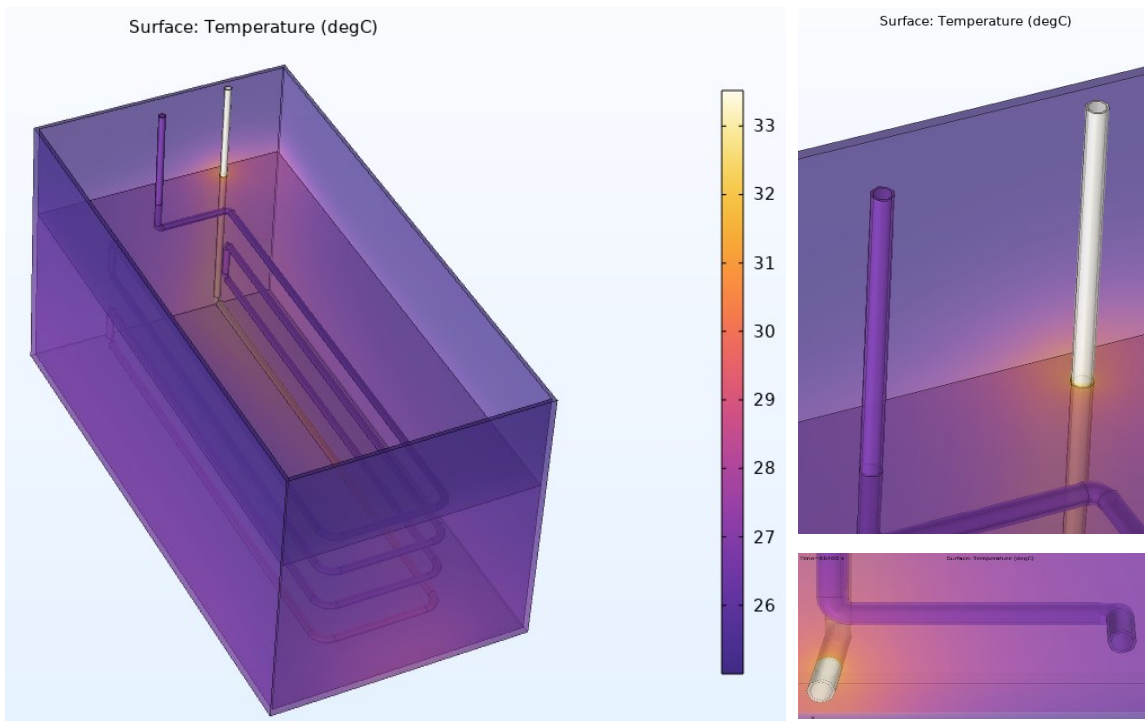


Figure: Transient solution after passing 24 hours- Temperature distribution (°C)

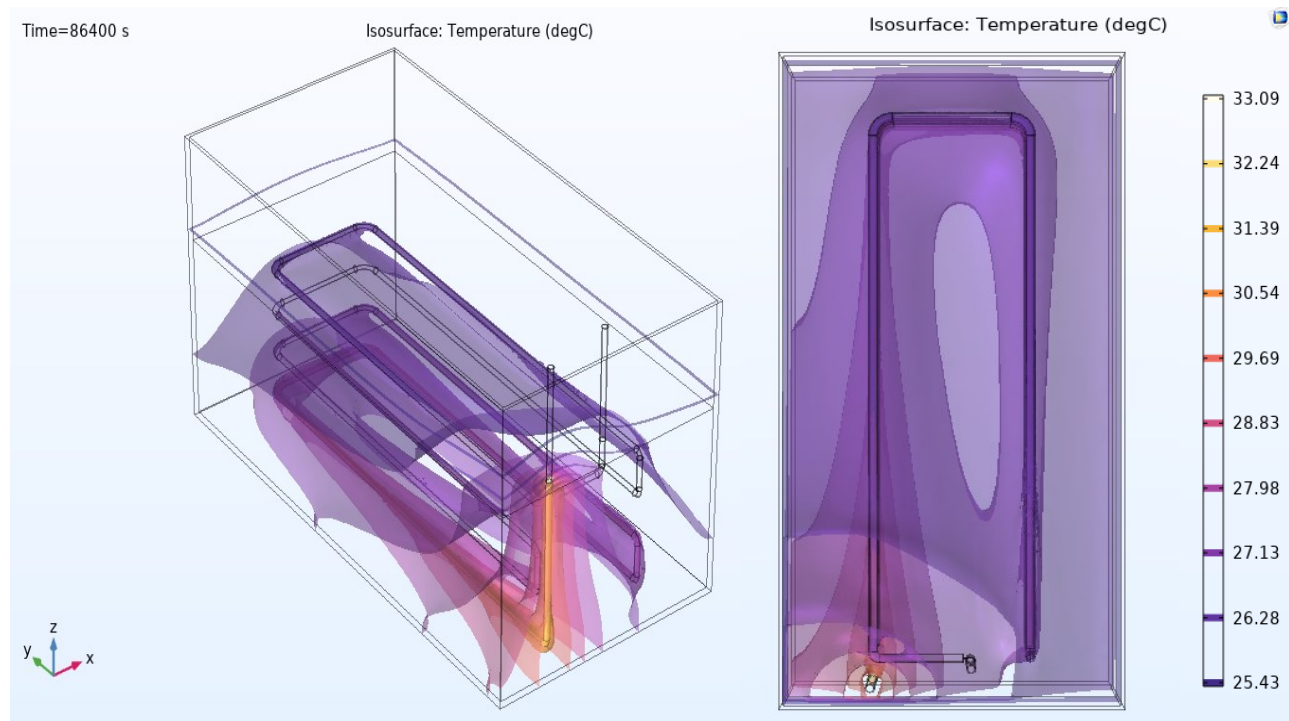


Figure: Isothermal Contours of prototype after 24 hours

24-hour time interval Results

Results have shown that the rate of heat energy (power) that has been stored in the ground – which can be used if considering the soil as thermal storage - can be described from the following curve:

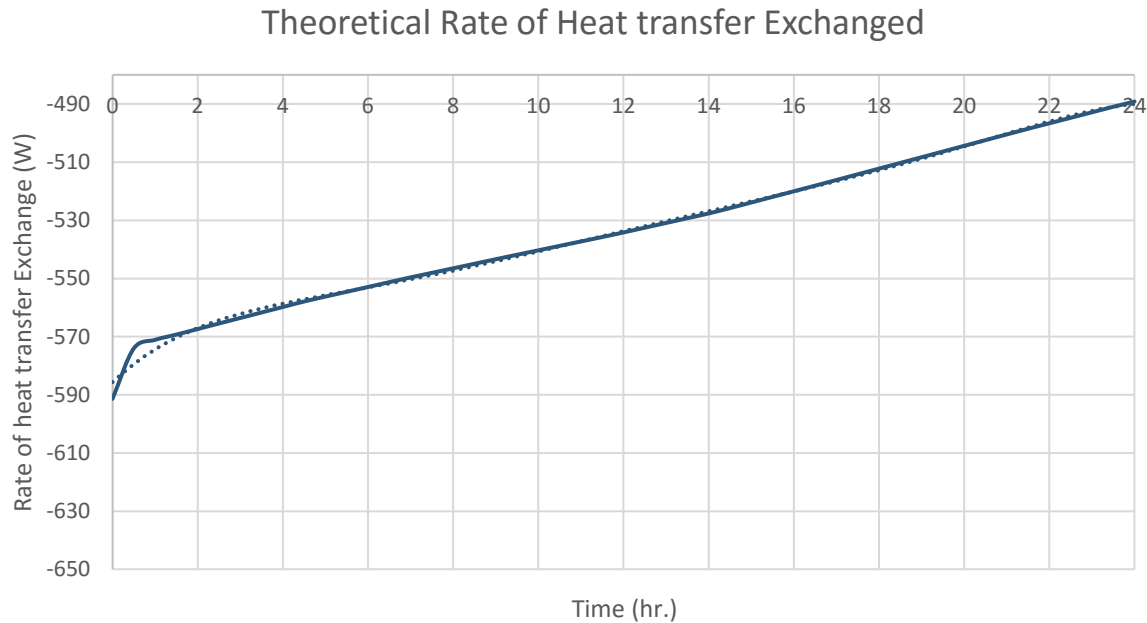


Figure: Rate of heat transfer Exchange Vs Time - 24 hr. simulation

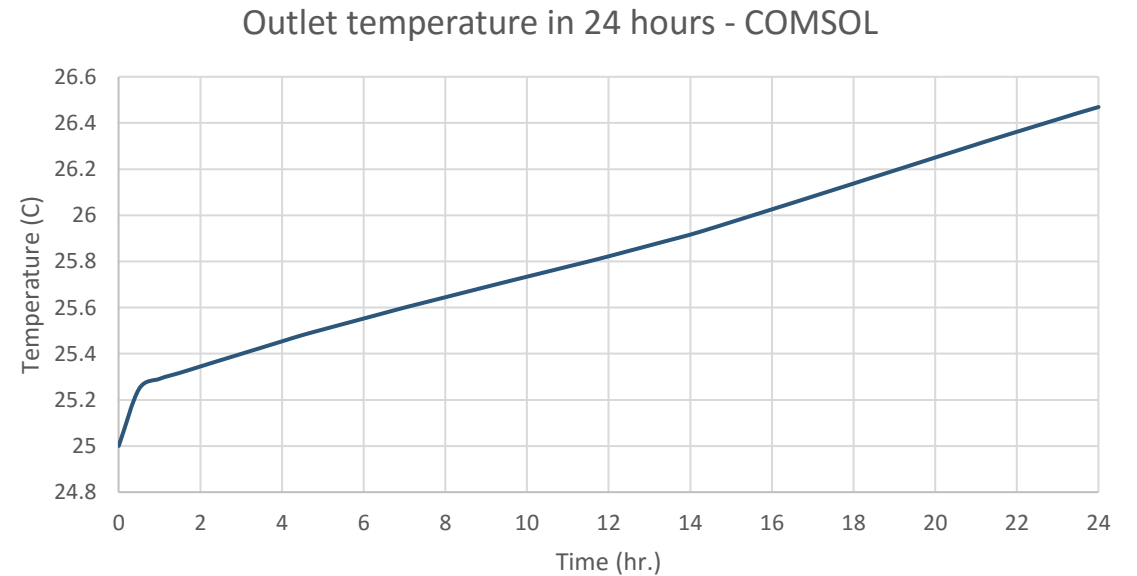


Figure: Temperature vs Time - 24 hr. simulation

By using surface integration for power per unit area has a function of:
 $(T-306.65)*spf.U*spf.rho*comp1.mat1.def.Cp(T)$ as unit is in Watts (W)

30-day time interval Results

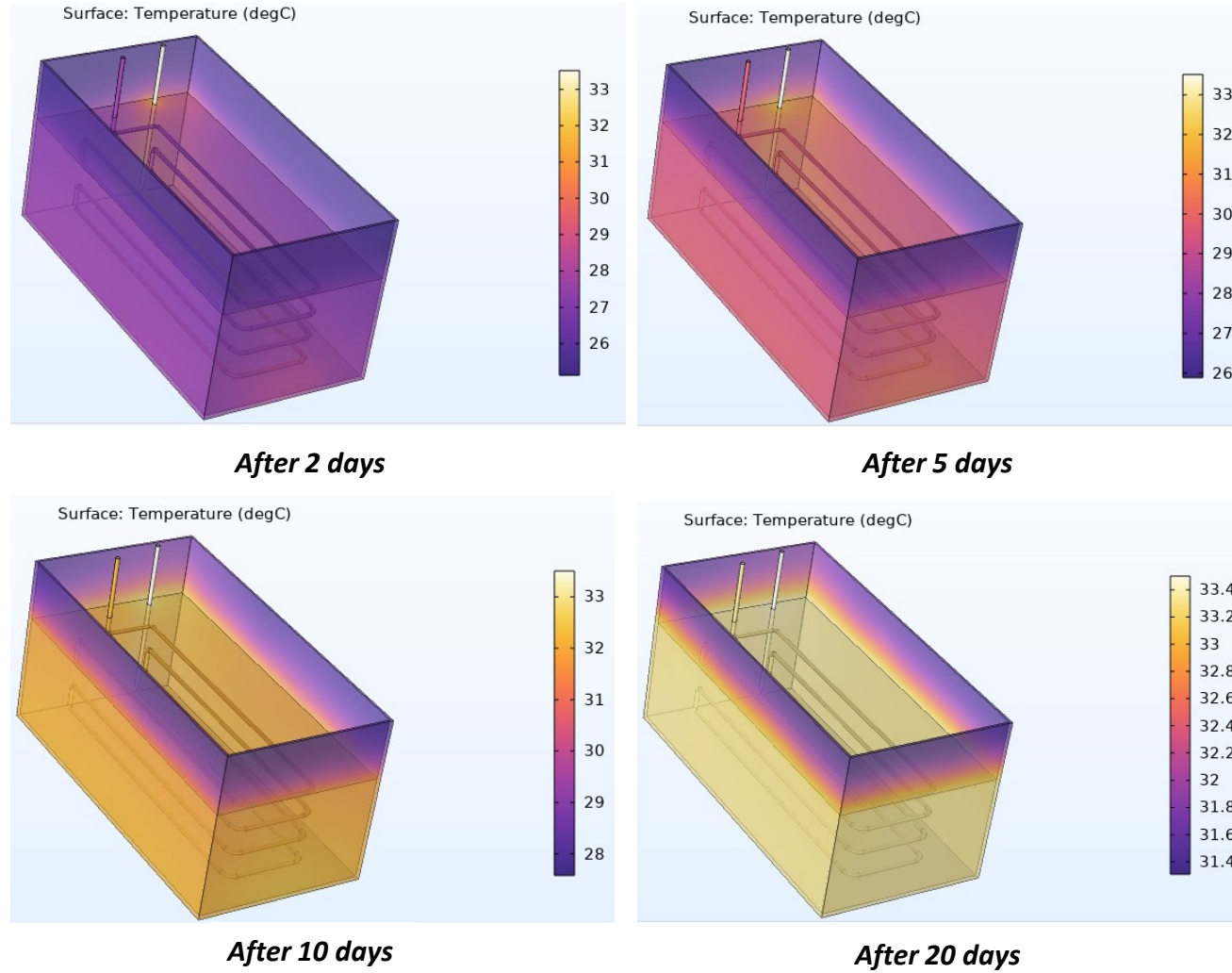


Figure: Transient solution at different times - Temperature distribution (°C)

30-day time interval Results

Results have shown that the rate of heat energy (power) that has been stored in the ground – which can be used if considering the soil as thermal storage - can be described from the following curve:

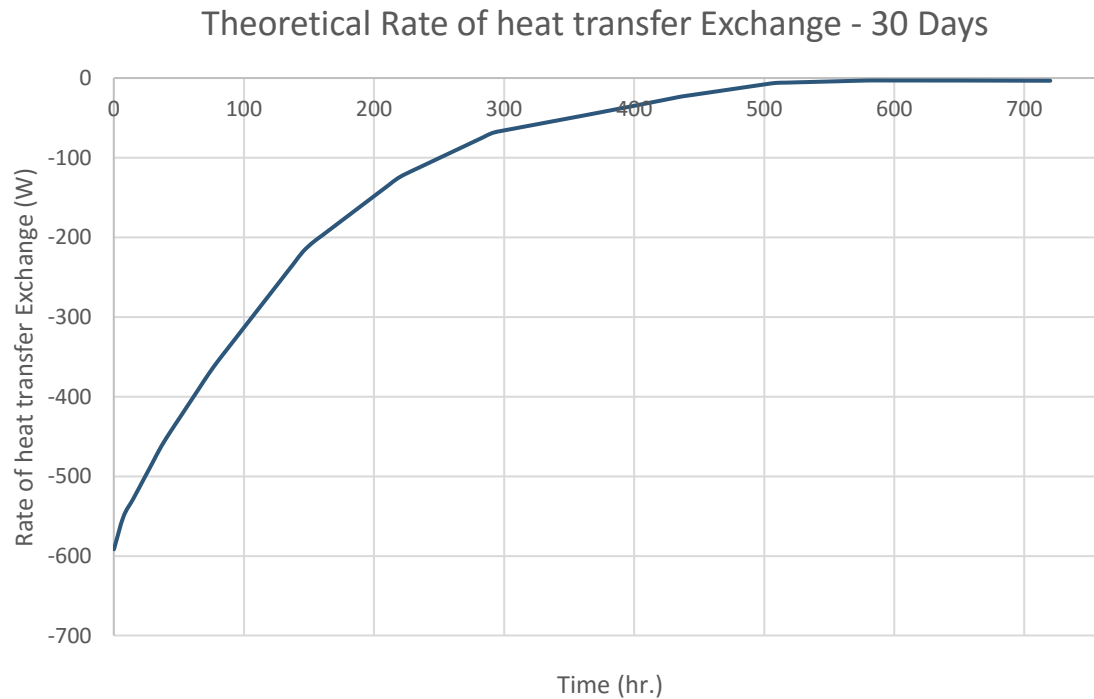


Figure: Rate of heat transfer Exchange Vs Time - 30 days' simulation

By using surface integration for power per unit area has a function of:
 $(T-306.65)*spf.U*spf.rho*comp1.mat1.def.Cp(T)$ as unit is in Watts (W)

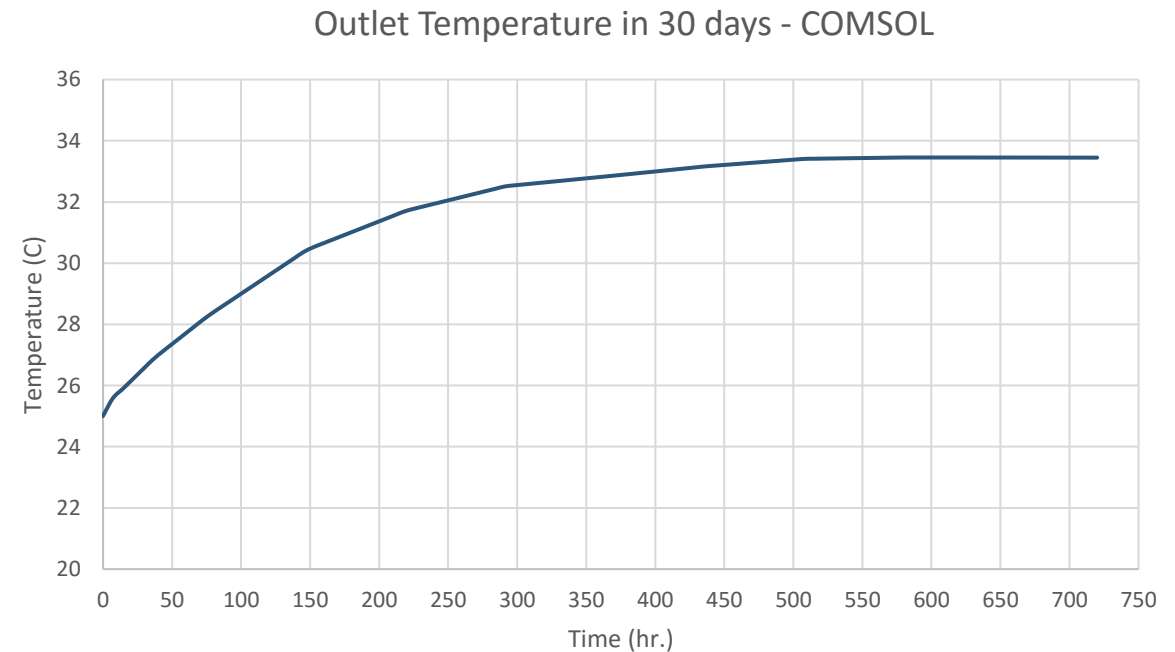


Figure: Temperature vs time - 30 days' simulation



Prototype

This prototype was built to discuss the ability of designing a horizontal ground source heat pump that aims to operate a 1/8 hp dispenser giving a high performance to the system instead of using conventional electric grid.

Prototype CFD Setup

Initial and Secondary Conditions	Value
undisturbed ground temperature	$T_{ground} = 25\text{ }^\circ\text{C}$
Inlet Temperature	$33.5\text{ }^\circ\text{C}$
Outlet Temperature	$T_{outlet} = T_{inlet} - \frac{Q_{cool}}{\rho C_p Q_{flow}}$
Fluid flow rate of the inlet pipe	1 l/min, or 0.0167 m ³ /s
Reference atmospheric pressure in outlet pipe	$P_0 = 101.325\text{ Pa}$

Components

- Water Dispenser
- Plate Heat Exchanger
- Soil trench
- Water circulating pump
- UPVC U-shaped loops
- Thermocouples
- Glass wool insulation

Prototype Performance Results

To study the prototype performance, observing the refrigerant ability of cooling water by setting a requirement of calculating the power consumption of cooling 5.5 l of water and to understand the losses of the prototype's (refrigerant – water) cooled system, a comparison is made for (refrigerant – air) cooled systems.

Water Cooled System			Air Cooled System		
Parameters			Parameters		
Cooling refrigerant (DC Drive)	3.2 l/min	0.34 Ampere	Cooling Water Ability	2 l/min/hr	
Plate Heat Exchanger	10 plates		Rated Cooling Current	0.6 Ampere	
Refrigerant	0.5 l/s		Cooling Power (Q _c)	30 Watt	
			Refrigerant	0.314s	

Power Factor of the dispenser = 0.8

Prototype Performance Results

Water Cooled System		Air Cooled System	
Results	Value	Results	Value
Time	48.2 sec	Time	66 min
Work of the compressor (W _c)	100.32 watt	Work of the compressor (W _c)	186.32 watt
Cooling power (Q _c)	27.16 watt	Cooling power (Q _c)	23.22
Rejected power to the ground (Q _g)	127.55 watt	Rejected power to the air (Q _a)	123.54 watt
Cooling Energy (Q _c)	13,277.76 J	Cooling Energy (Q _c)	8,387.14 J
Total Energy consumption = 100,320 J		Total Energy consumption = 186,320 J	
Cap = 0.27		Cap = 0.23	

Components

Water Dispenser

Plate Heat Exchanger

Soil trench

Water circulating pump

UPVC U-shaped loops

Thermocouples

Glass wool insulation



Components

Water Dispenser

Plate Heat Exchanger

Soil trench

Water circulating pump

UPVC U-shaped loops

Thermocouples

Glass wool insulation



Components

Water Dispenser

Plate Heat Exchanger

Soil trench

Water circulating pump

UPVC U-shaped loops

Thermocouples

Glass wool insulation



Components

Water Dispenser

Plate Heat Exchanger

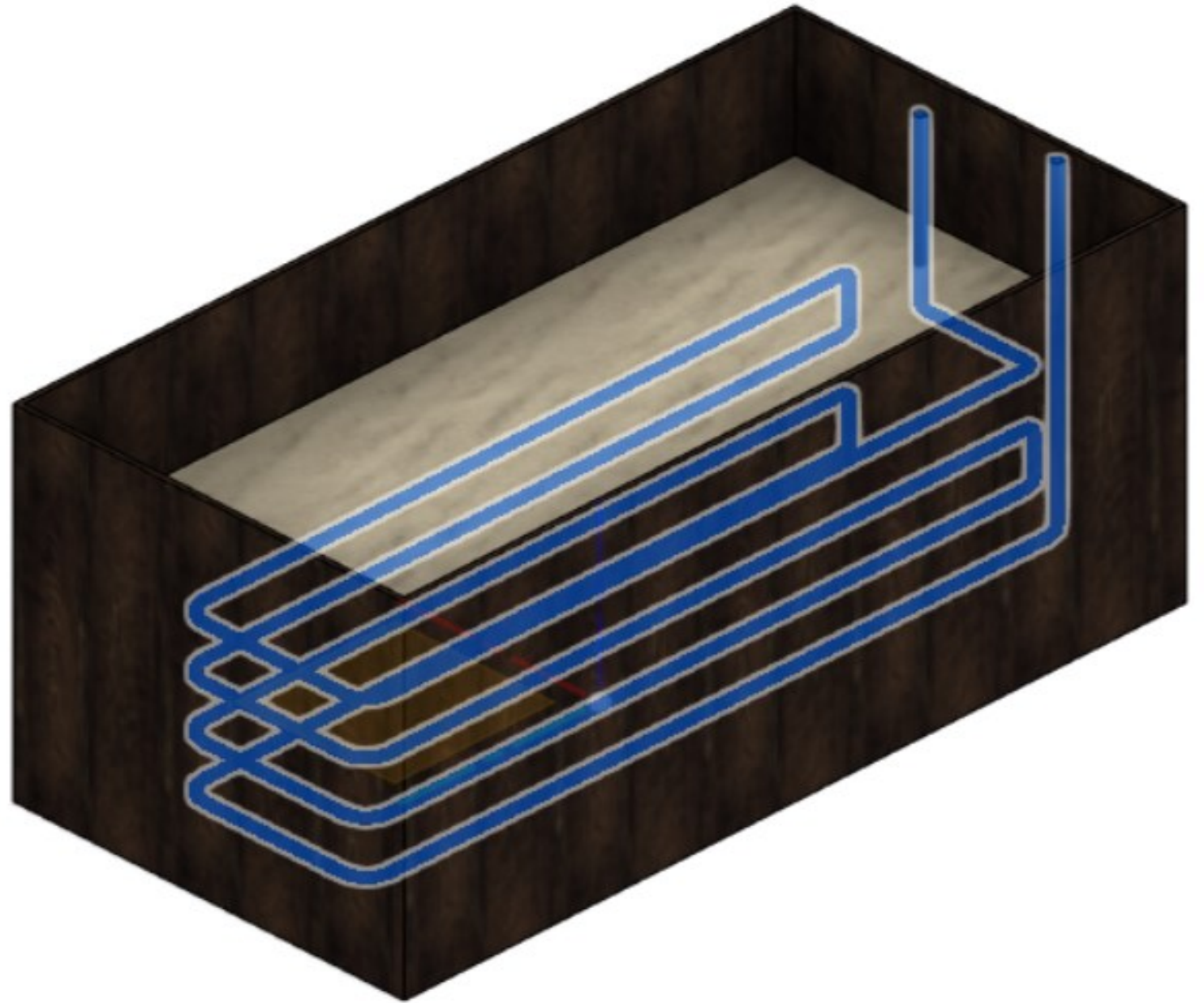
Soil trench

Water circulating pump

UPVC U-shaped loops

Thermocouples

Glass wool insulation



Components

Water Dispenser

Plate Heat Exchanger

Soil trench

Water circulating pump

UPVC U-shaped loops

Thermocouples

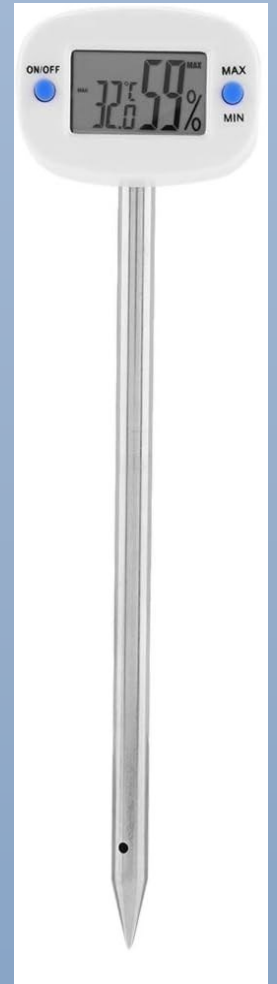
Glass wool insulation



Multi-meter (Avometer)



Thermocouple type K



Soil Hygrometer

Prototype Performance Results

To study the prototype performance, observing the refrigerant ability of cooling water by setting a requirement of calculating the **power consumption** of cooling **1.5 L** of water and to understand the success of the prototype's (refrigerant – water) cooled system, a comparison is made for (refrigerant – air) cooled system.

Water Cooled System

Parameters

Circulating diaphragm DC pump	1.2 L/min.	0.24 Ampere
Plate Heat Exchanger	10 plates	
Refrigerant	R-134a	

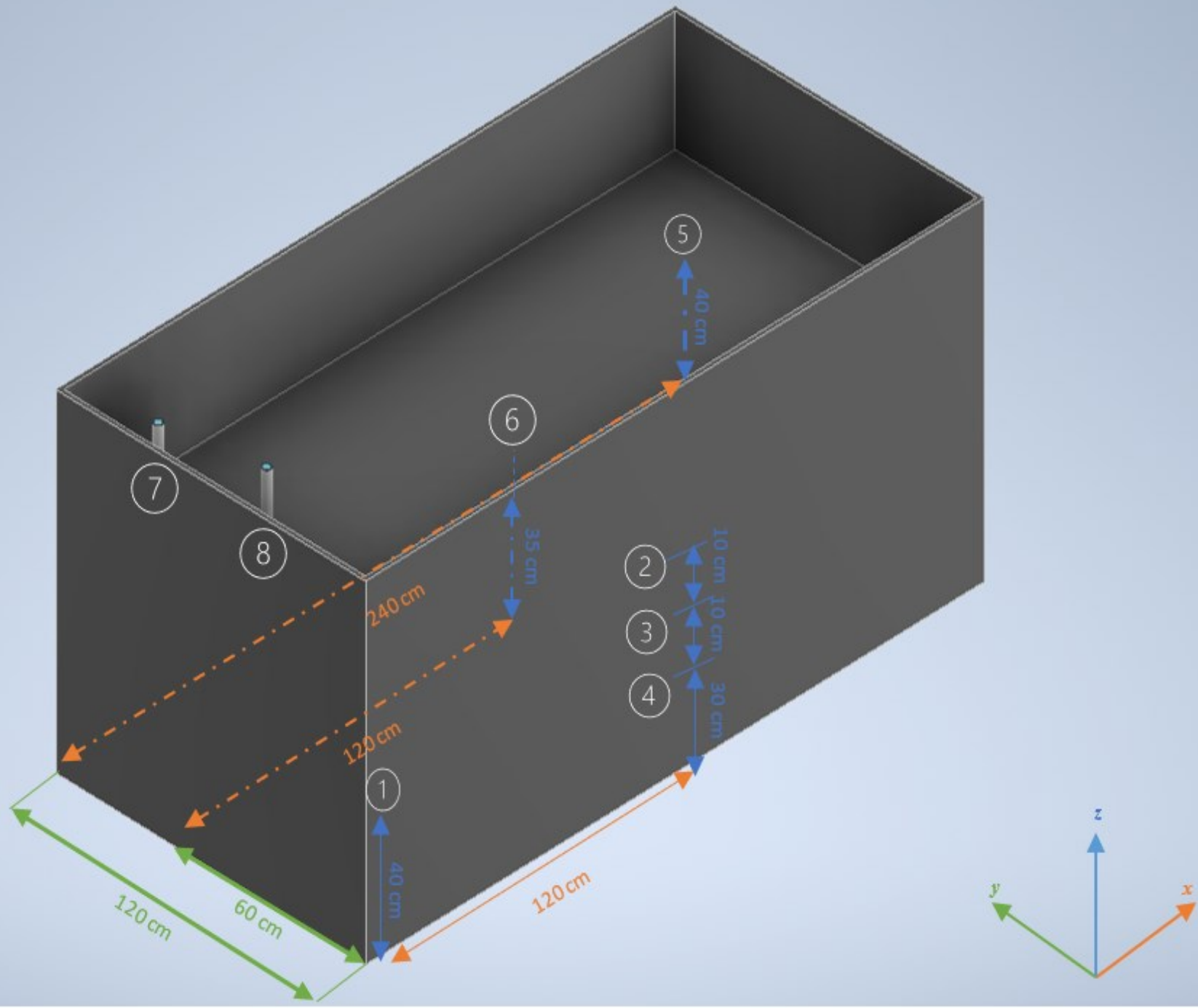
Air Cooled System

Parameters

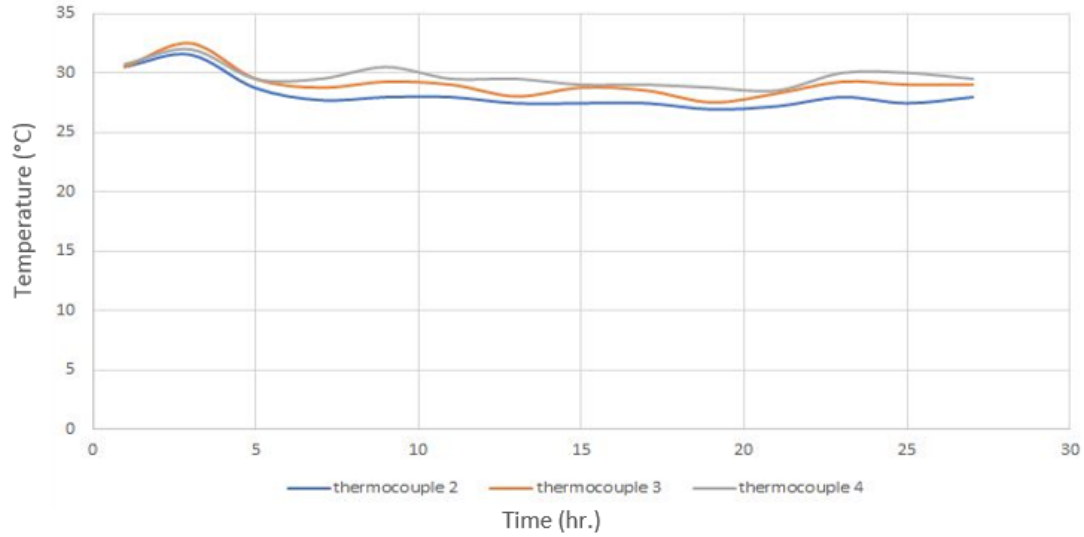
Cooling Water Ability	2 Liter/hr.
Rated Cooling Current	0.6 Ampere
Cooling Power (Q_L)	90 Watt
Refrigerant	R-134a

Power Factor of the dispenser = 0.8

Pin No.	Sensor Type
1	Thermocouple Type-K for soil
2	
3	
4	
5	
6	Digital Soil hygrometer
7	Thermocouple Type-K for inlet and outlet of pipes
8	



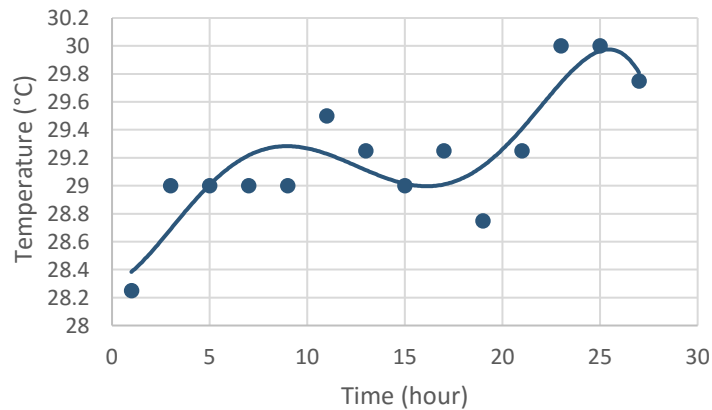
2 VS 3 VS 4



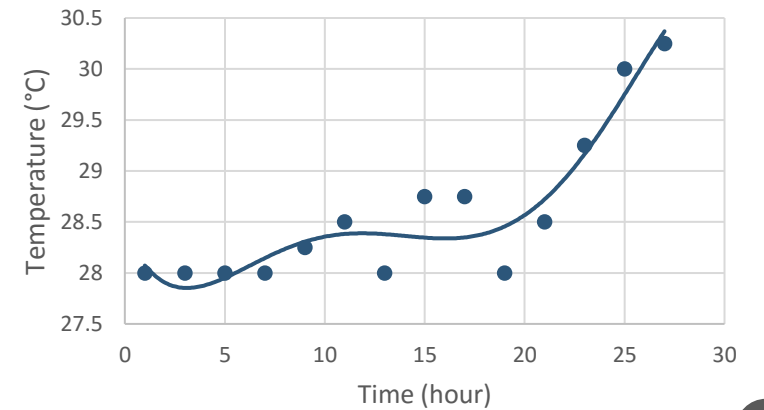
For every *10 cm* in the vertical direction, there is a temperature difference of about $[0.5 - 1.5] \text{ } ^\circ\text{C}$

Pin (1) and (5) was put at depth 35 cm from soil's surface & are located at the box corners.

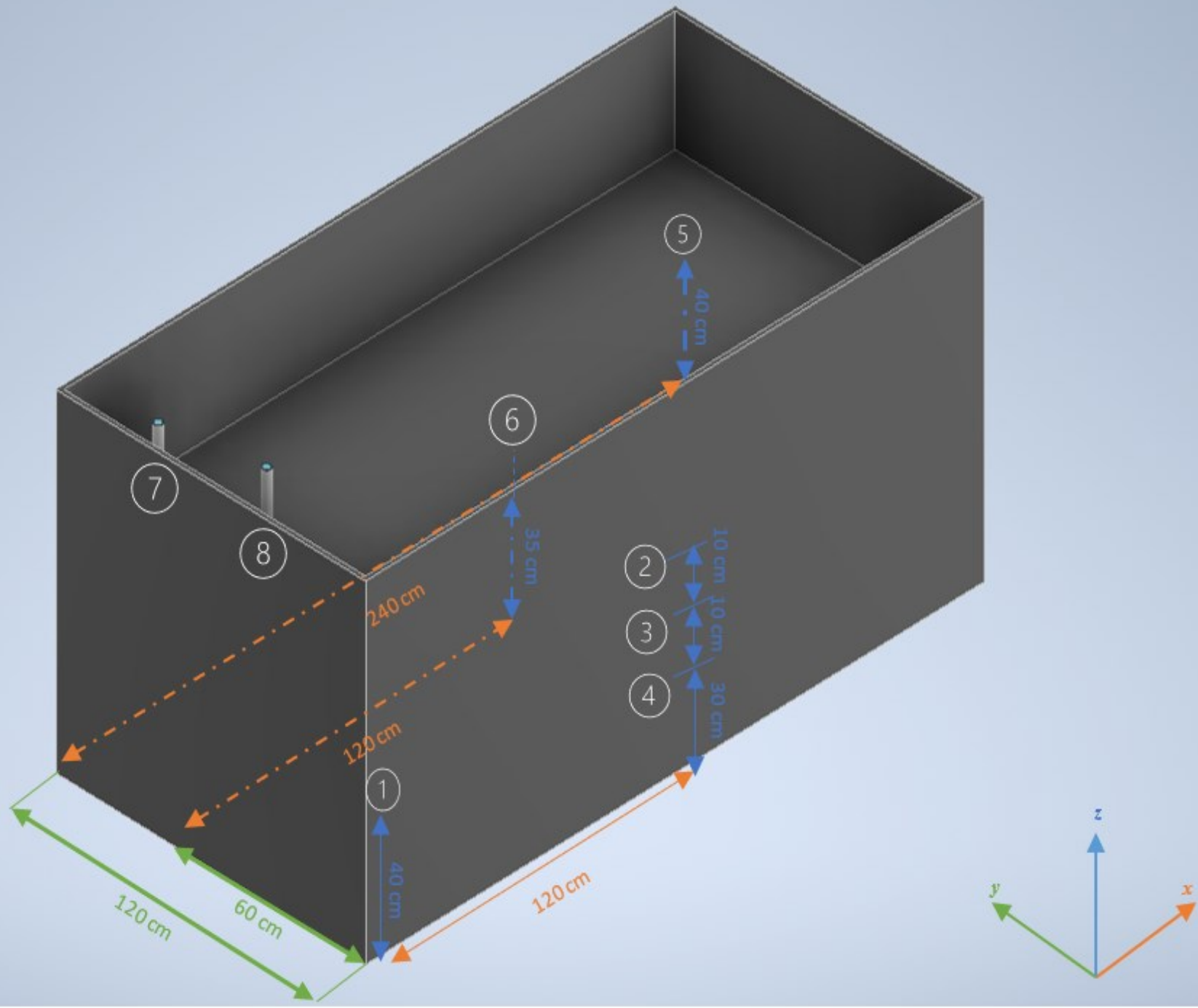
Thermocouple 1



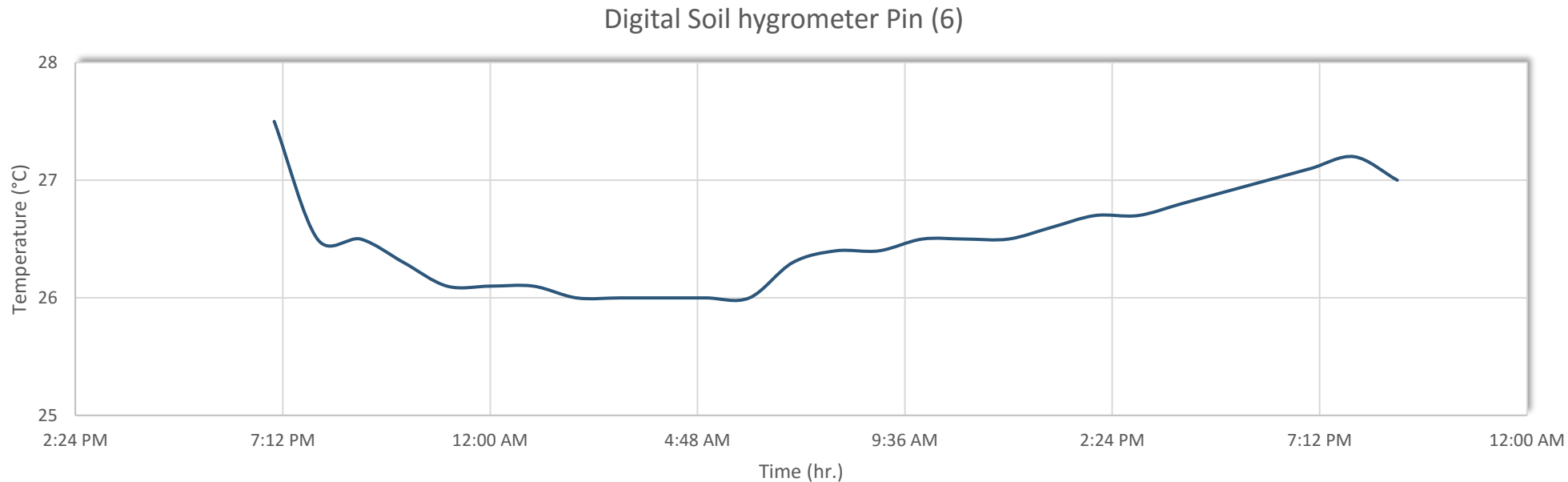
Thermocouple 5



Pin No.	Sensor Type
1	Thermocouple Type-K for soil
2	
3	
4	
5	
6	Digital Soil hygrometer
7	Thermocouple Type-K for inlet and outlet of pipes
8	



From Pin (6), the soil temperature range between [26 – 27] °C at the soil's surface throughout the experiment.



To understand the diffusion time made by experiment,

Diffusion time started at **6:00 am** and changed temperature from **26°C to 27°C** after **12 hours**, which shows that:

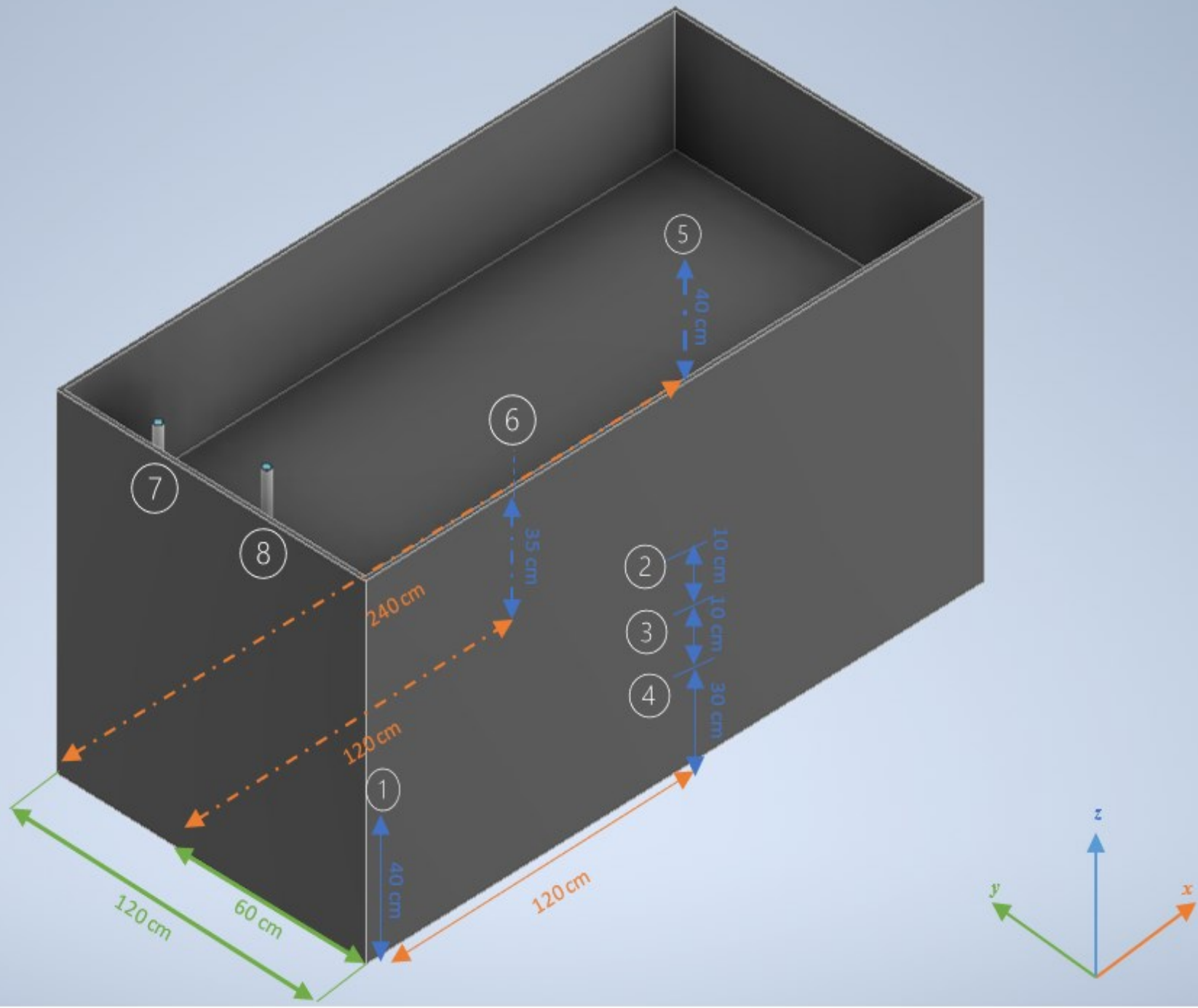
Experimental diffusion time=0.5 day

For knowing thermal diffusivity = 0.058 m²/day

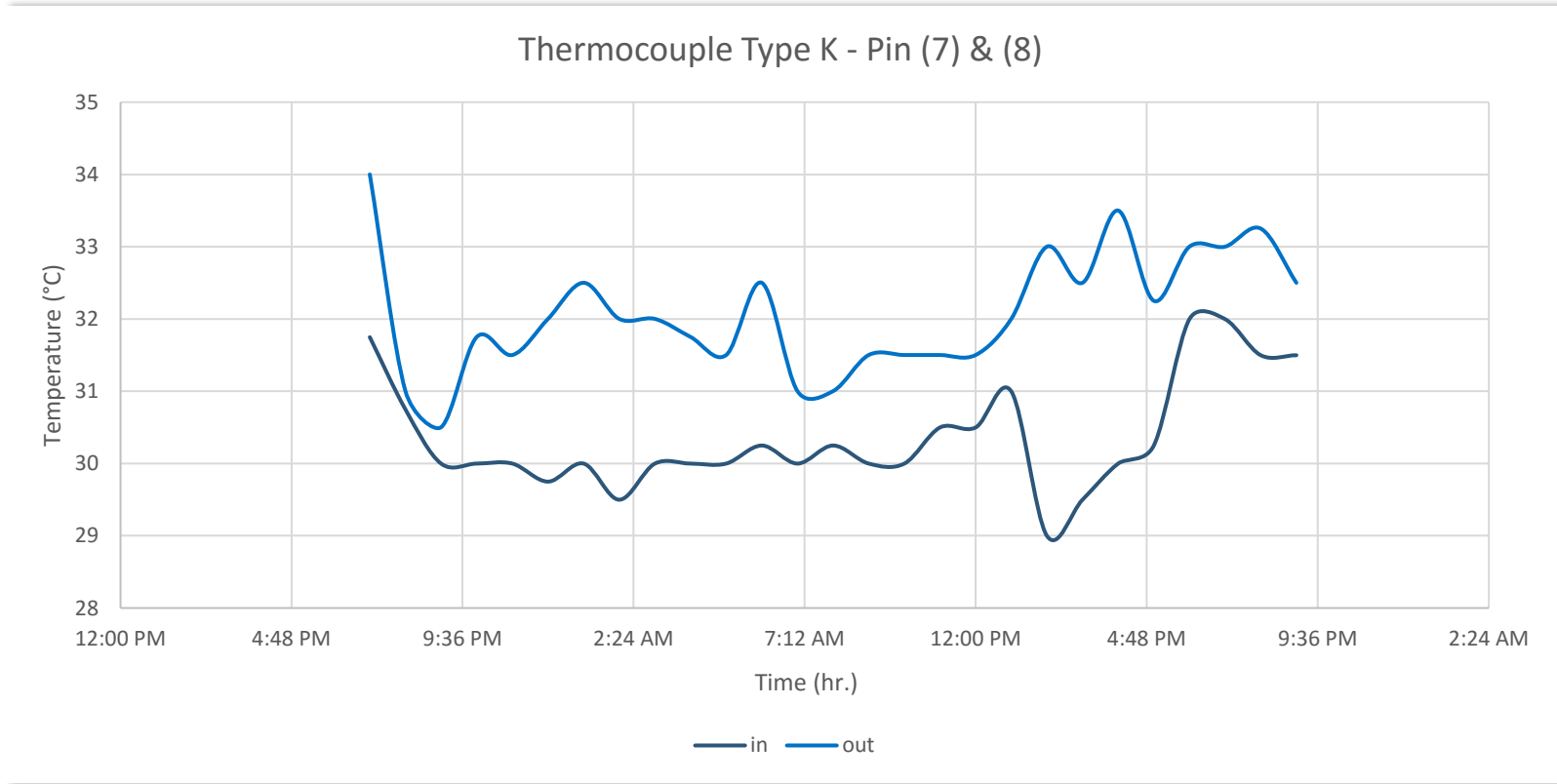
Theoretical Diffusion time=(Characteristic Length)²/(Thermal Diffusivity)=(0.18)²/0.058=0.558 day

% Error=(0.5 -0.558)/0.5×100= -11.6%

Pin No.	Sensor Type
1	Thermocouple Type-K for soil
2	
3	
4	
5	
6	Digital Soil hygrometer
7	Thermocouple Type-K for inlet and outlet of pipes
8	

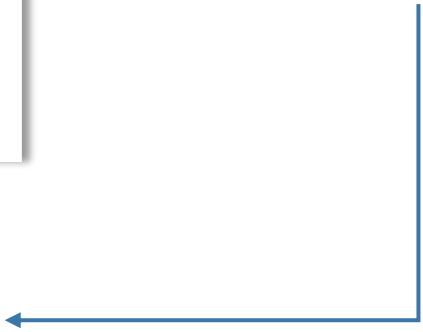


Pin (7) and Pin (8) represents the **inlet** and **outlet** water temperature entering and exiting from the heat pump, where results have shown that:



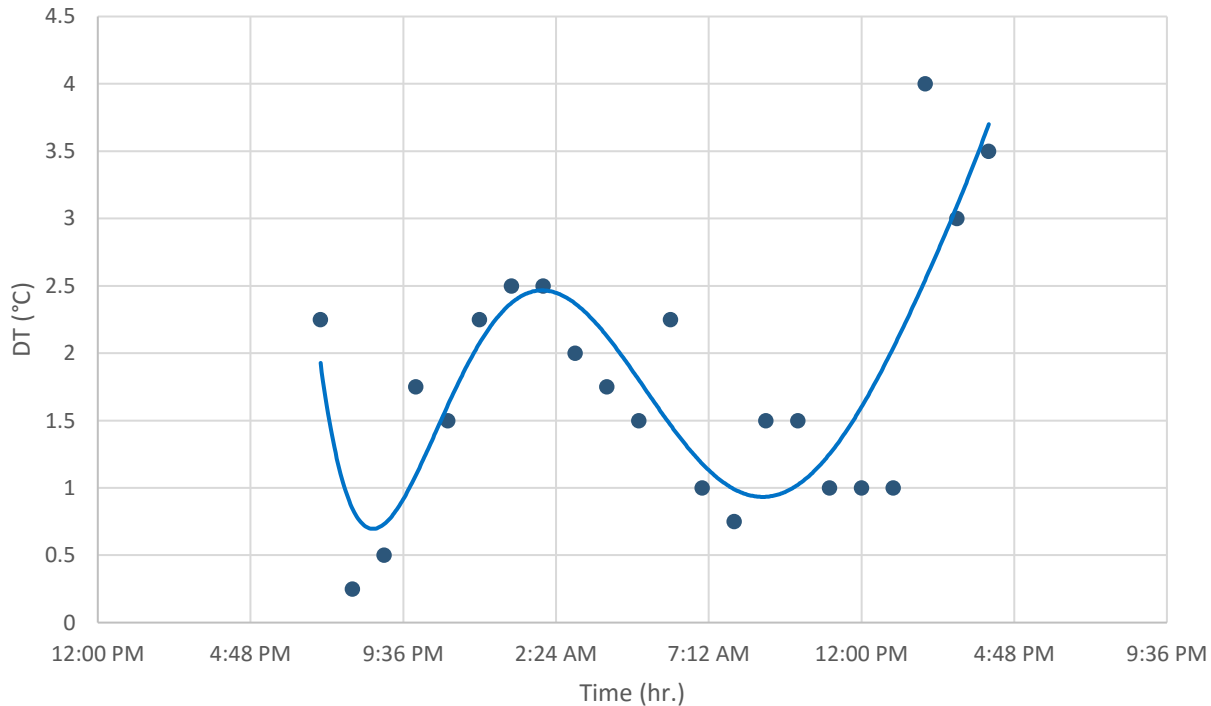
To explain the value of the temperature readings, the effectiveness of the ground heat exchanger should be measured

$$\theta (\%) = \frac{T_{in} - T_{out}}{T_{in} - T_{ground}} \times 100$$

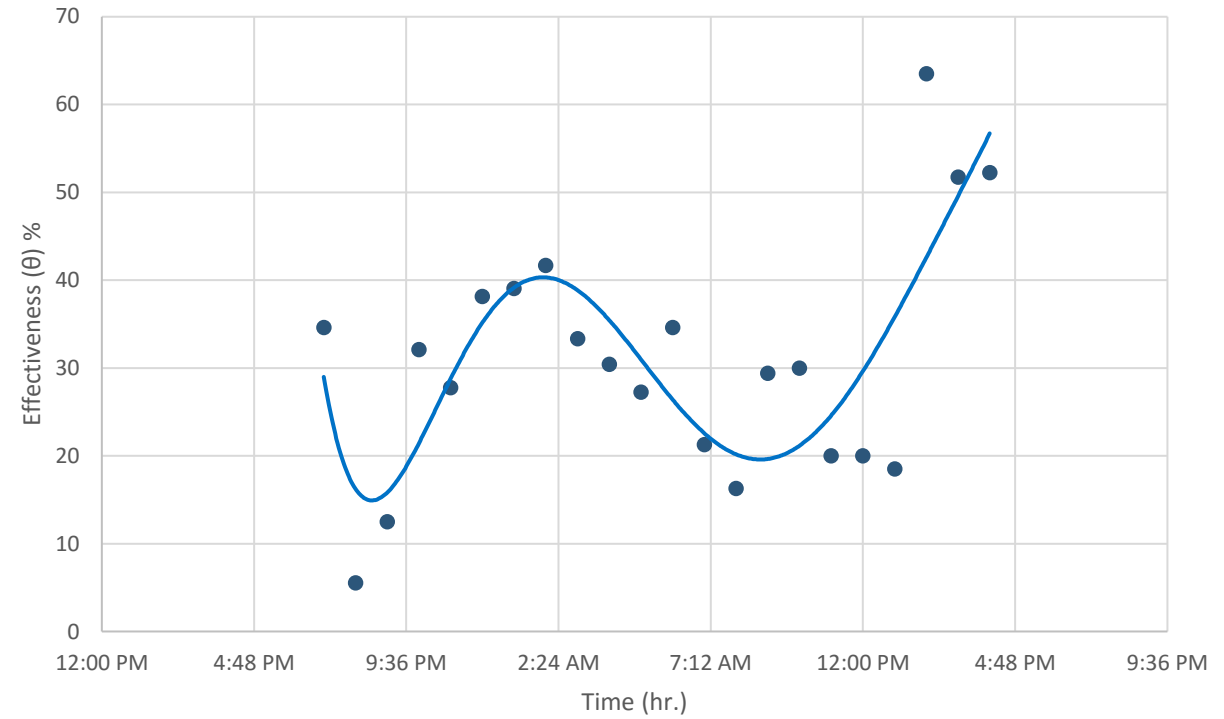


By considering T_{ground} is a function of pin (6), then from the following graph, valuable data can be analysed to understand the performance of the prototype system:

Temperature difference vs time



Effectiveness vs time





Prototype

This prototype was built to discuss the ability of designing a horizontal ground source heat pump that aims to operate a 1/8 hp dispenser giving a high performance to the system instead of using conventional electric grid.

Prototype CFD Setup

Initial and Secondary Conditions	Value
undisturbed ground temperature	$T_{ground} = 25\text{ }^\circ\text{C}$
Inlet Temperature	$33.5\text{ }^\circ\text{C}$
Outlet Temperature	$T_{outlet} = T_{inlet} - \frac{Q_{cool}}{\rho C_p Q_{flow}}$
Fluid flow rate of the inlet pipe	1 l/min, or 0.05 m ³ /s
Reference atmospheric pressure in outlet pipe	$P_0 = 101.325\text{ Pa}$

Components

- Water Dispenser
- Plate Heat Exchanger
- Soil trench
- Water circulating pump
- UPVC U-shaped loops
- Thermocouples
- Glass wool insulation

Prototype Performance Results

To study the prototype performance, observing the refrigerant ability of cooling water by setting a requirement of calculating the power consumption of cooling 5.5 l of water and to understand the losses of the prototype's (refrigerant – water) cooled system, a comparison is made for (refrigerant – air) cooled systems.

Water Cooled System			Air Cooled System		
Parameters			Parameters		
Cooling refrigerant (DC Drive)	3.2 l/min	0.34 Ampere	Cooling Water Ability	2 l/min/hr	
Plate Heat Exchanger	10 plates		Rated Cooling Current	0.6 Ampere	
Refrigerant	R-134a		Cooling Power (Q _L)	30 Watt	
			Refrigerant	R-134a	

Power Factor of the dispenser = 0.8

Prototype Performance Results

Water Cooled System		Air Cooled System	
Results		Results	
Time	48.2 sec	Time	66 sec
Work of the compressor (W _c)	100.32 watt	Work of the compressor (W _c)	106.32 watt
Cooling power (Q _L)	27.16 watt	Cooling power (Q _L)	23.22
Rejected power to the ground (Q _W)	127.55 watt	Rejected power to the air (Q _W)	123.54 watt
Cooling Energy (Q_L) = 13.097 kJ		Cooling Energy (Q_L) = 13.097 kJ	
Total Energy consumption = 90.4614 kWh		Total Energy consumption = 90.4614 kWh	
Cap = 0.27		Cap = 0.23	

Prototype Performance Results

Water Cooled System

Results	
Time	46.2 min
Work of the compressor (W_C)	100.32 watt
Cooling power (Q_L)	27.14 watt
Rejected power to the ground (Q_H)	127.56 watt
Cooling Energy (Q_L) = 20.897 Wh	
Total Energy consumption = 81.6816 Wh	
COP = 0.27	

Air Cooled System

Results	
Time	56 min
Work of the compressor (W_C)	100.32 watt
Cooling power (Q_L)	23.22
Rejected power to the air (Q_H)	123.54 watt
Cooling Energy (Q_L) = 20.897 Wh	
Total Energy consumption = 90.288 Wh	
COP = 0.23	

Conclusion



GEOTHERMAL ENERGY
USAGE IN HVAC
APPLICATIONS IS:



REDUCE CARBON
EMISSIONS (COULD BE
MORE REDUCED BY
INTEGRATING HYBRID
SYSTEMS)



ECONOMICALLY FEASIBLE
(DEPENDS ON LOCATION,
GROUND PROPERTIES &
THERMAL LOADS).

Recommendations

- ✓ choosing suitable sites with suitable ground properties
- ✓ Further research on borehole separation distances and hybridization
- ✓ Explore varying borehole lengths in system configurations
- ✓ Conduct thermal response test prior to implementation
- ✓ Expand studies to explore other applications of geothermal technology
- ✓ Integration of photovoltaic systems with ground source heat pump cooling systems
- ✓ implementing of feasibility studies

Any Questions

The background consists of numerous overlapping, light blue rectangular sticky notes scattered across the frame. Each sticky note features a dark blue question mark. A single, thin, vertical white line runs down the center of the image, starting from the top and extending past the bottom of the text.



Thank You