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

Acknowledgment

Supervisors

Prof. Amr Yehia Hussein Elbanhawy

Associate Professor at Mechanical Power Engineering,

Prof. Walid Aboelsoud Abdelhaady Aboelsoud

Associate Professor at Mechanical Power Engineering,

Special Thanks To

Prof. Mohamed Nabil Sabry

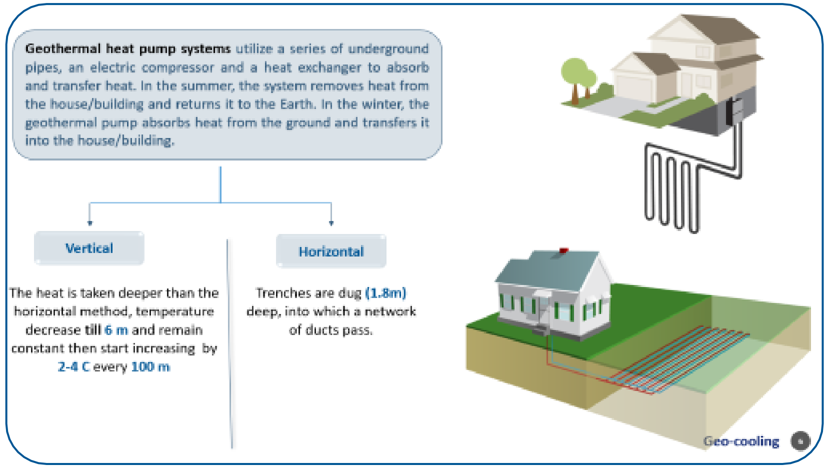
Emeritus Professor at Mechatronics

Team Members (Alphabetically)

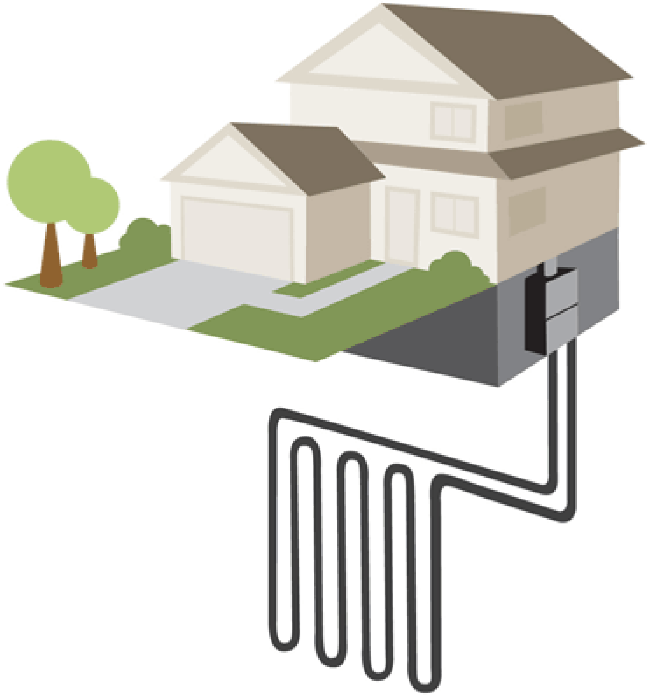
Student Name	Code
Ahmed El-Sayed Hashem	1808308
Khaled Ali Ahmed	1808332
Rogeih Emad Shoukry	1804753
Youssef Mohamed Abdelhamid	1808622
Youssef Tamer Magdy	1806334
Ziad Tarek Mohamed	1803906


INTRODUCTION
Project Aspects
AIM OF WORK
Cooling & Heating Load calculations
Closed GSHP Design
Finite Element Simulation
Life Cycle Assessment
METHODOLOGY
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
Geo-cooling
Cairo University
Geo-cooling
El-Alamein
Geo-cooling
Acoustics
Prototype
Geo-cooling
Thank You

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.

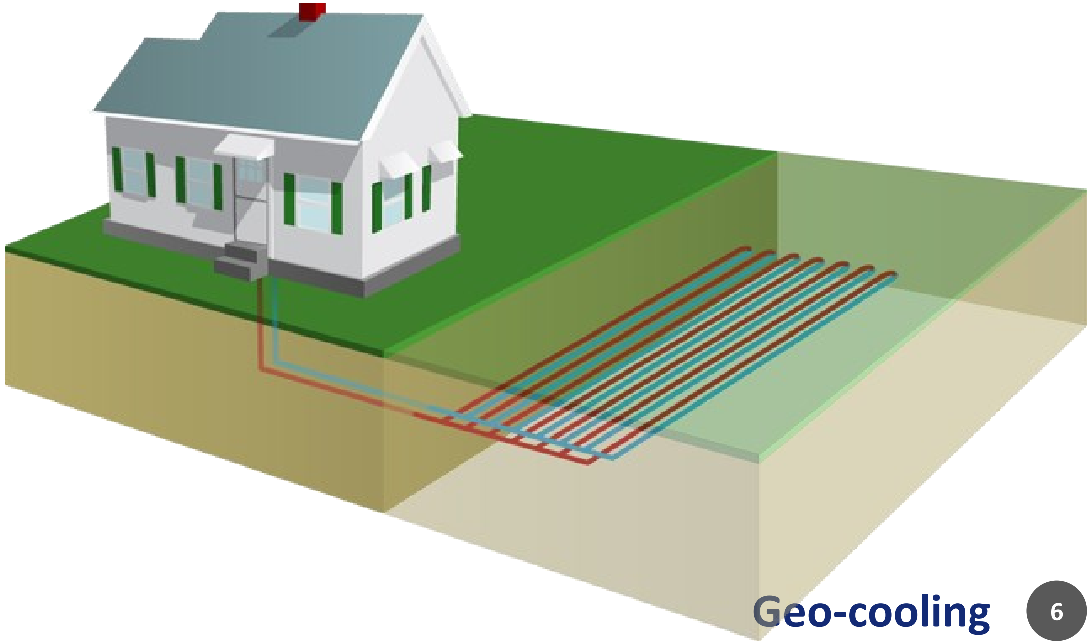


Vertical

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
8

AIM OF WORK

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


INTRODUCTION
AIM OF WORK
Project Aspects
Cooling & Heating Load calculations
Closed GSHP Design
Finite Element Simulation
Life Cycle Assessment
METHODOLOGY
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
Geo-cooling
Cairo University
Geo-cooling
El-Alamein
Geo-cooling
Acoustics
Prototype
Geo-cooling
Thank You

METHODOLOGY

Cooling & Heating Load calculations

Closed GSHP Design

Finite Element Simulation

Life Cycle Assessment

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.

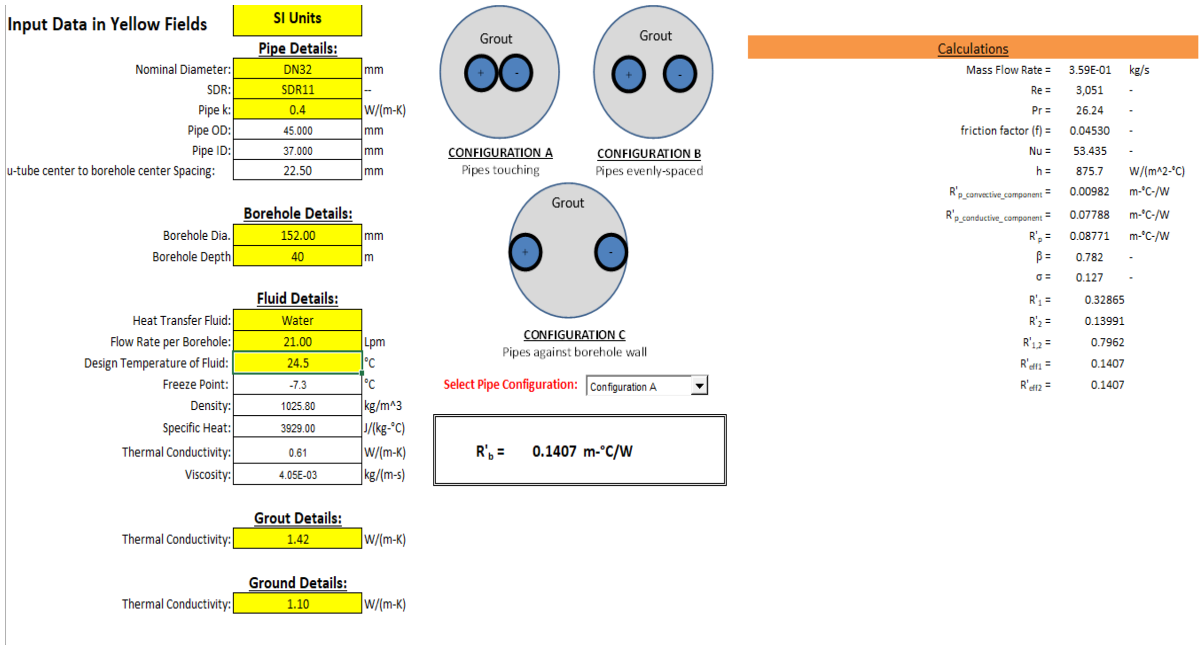
Second, according to the selection of closed loop GSHP, soil parameters as well as other parameters are being defined.

I. For Vertical GSHP

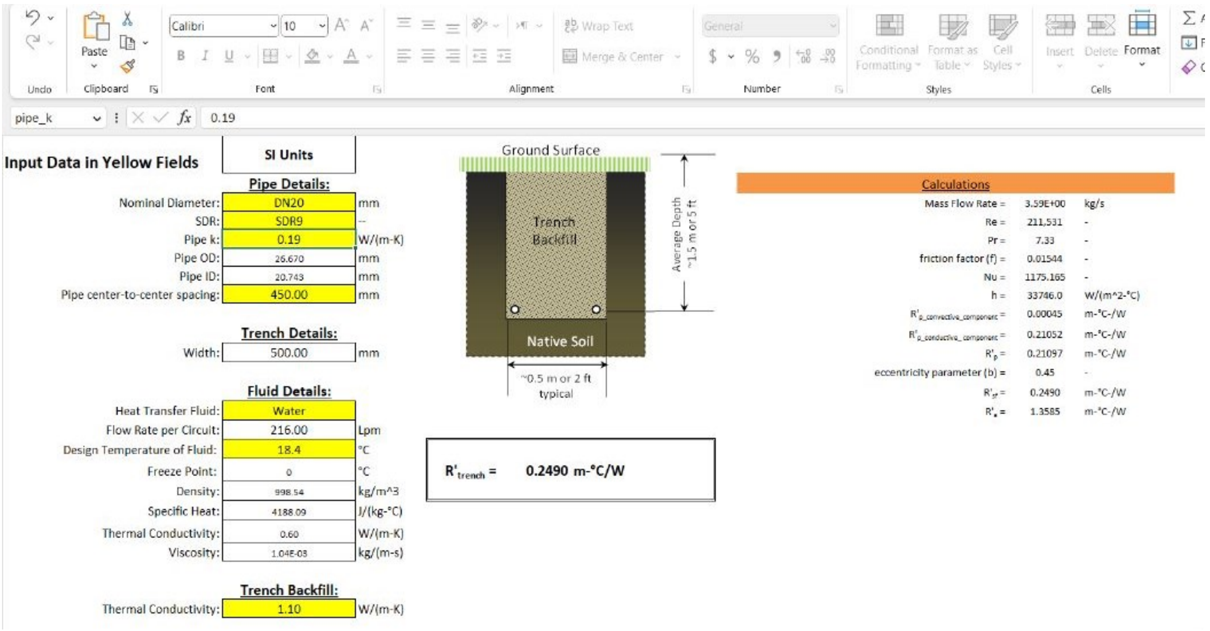
II. For Horizontal GSHP

Closed GSHP Design

I. For Vertical GSHP



II. For Horizontal GSHP



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
soil domain dimensions considering model as a cylinder of 5 m radius and 45 m depth	***soil domain dimensions*** 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 ***heat and mass transfer in the soil*** and ***fluid flow***	

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.

Life Cycle Assessment

LCA Report Scope Objective

Goal / Scoping:	Evaluate LCA comparing potential environmental impacts of geothermal heat pumps relative to conventional HVAC system
Application:	Basis for decisions on geothermal heat pumps installation
Functional Unit:	One unit of a heat pump (e.g., 1 ***KWhth*** of the process)
System Boundaries:	- Geothermal Heat pumps operational energy - All manufacturing processes contributing significantly to the life cycle impacts are considered. - Scope is based on ***Cradle-to-gate***

Life Cycle Assessment

Life Cycle Inventory Analysis

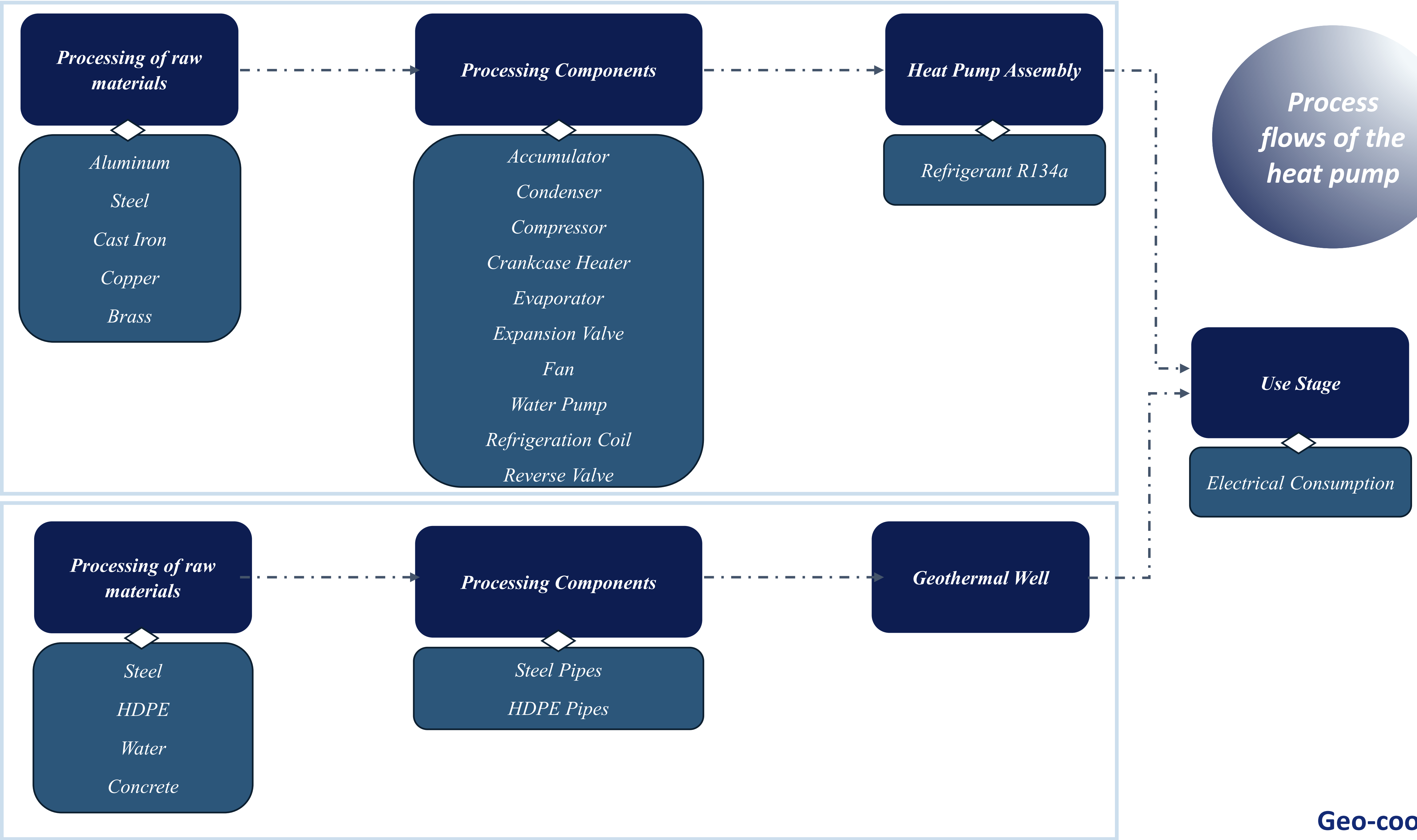
Inputs:
- Raw Material Extraction
- Energy Performance
- Manufacturing Process
- Energy consumption

Processes

Outputs:
- Emissions to air
- Emissions to water
- Emissions to soil

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

Process flows of the heat pump



Life Cycle Assessment

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.

Results

Cairo University

Designing a cooling geothermal plant for computer laboratory

El-Alamein

Designing geothermal cooling plants for El-Alamein Real estates

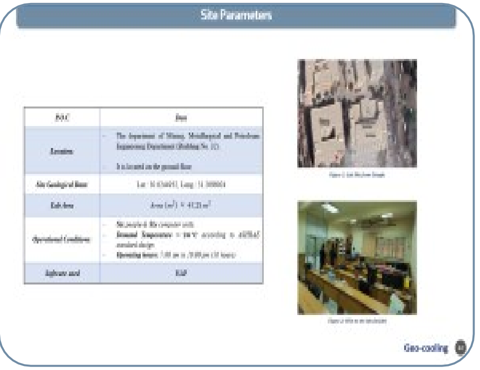
Acoustics

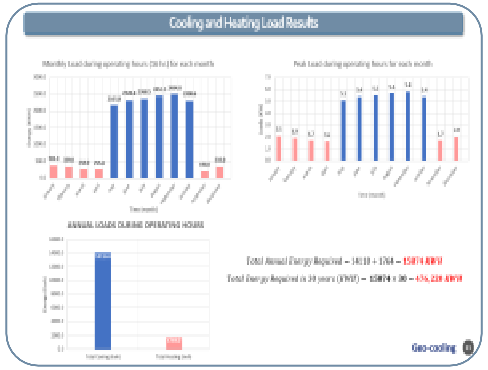
Substitution of One Chiller capacity using geothermal heat pump

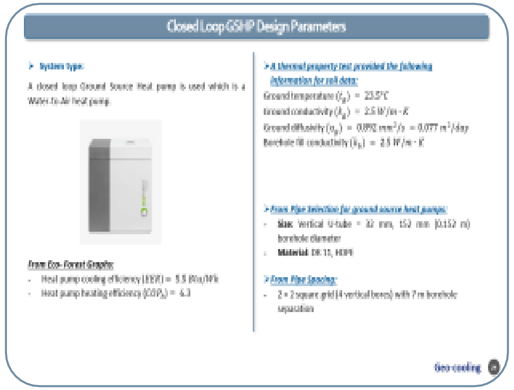
Prototype

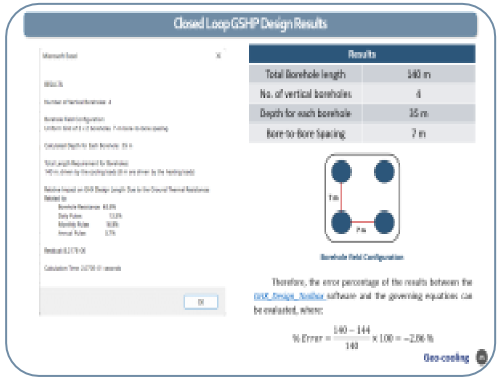
Enhancing the performance of a cooling water dispenser

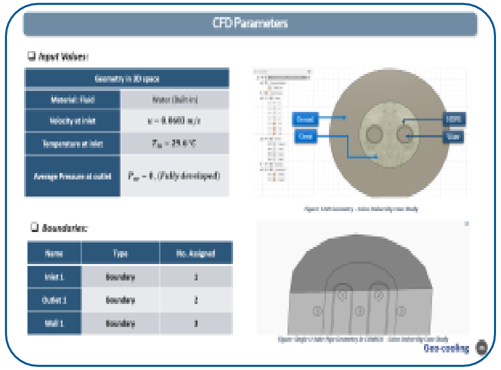
Cairo University











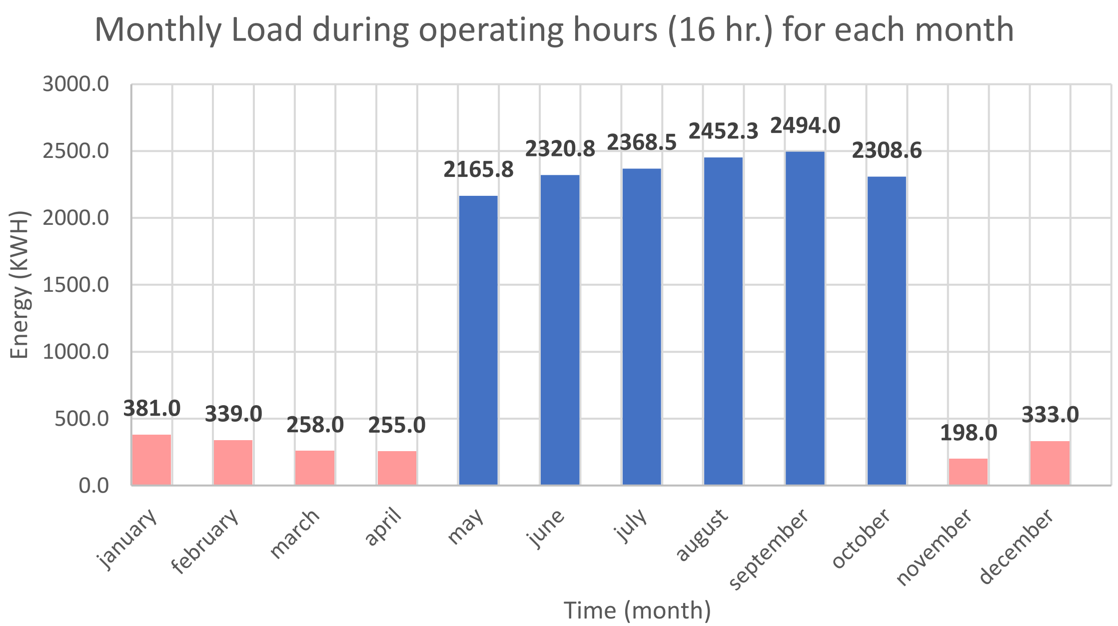
Site Parameters

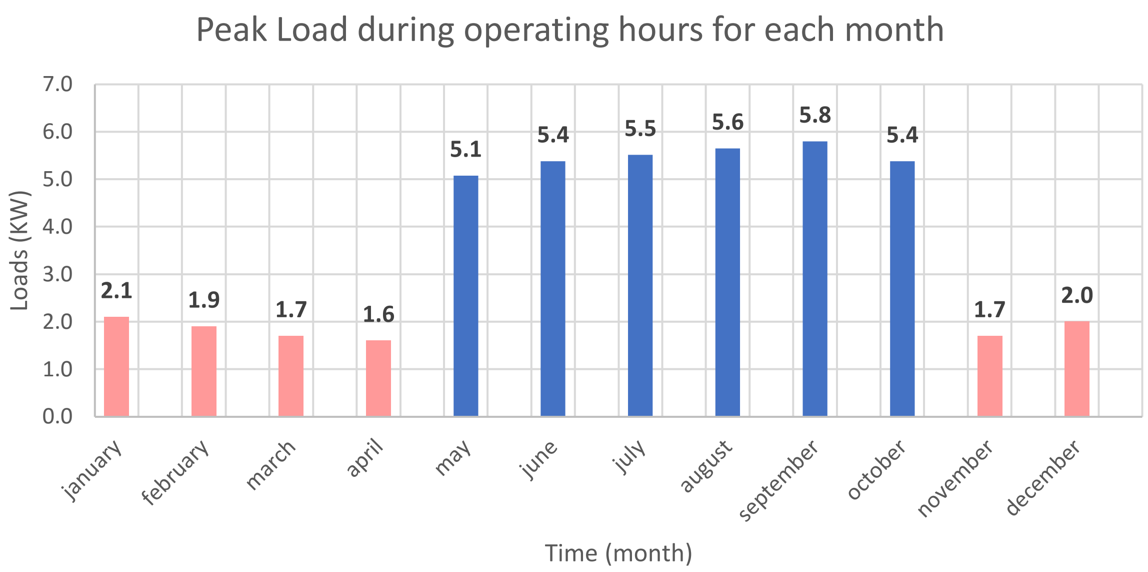
P.O.C	*Data*
Location:	- The department of Mining, Metallurgical and Petroleum Engineering Department (Building No. 32). - It is located on the ground floor.
Site Geological Data:	Lat.: 30.0244932, Long.: 31.2099024
Lab Area	$Area\ (m^2)\ \approx\ 47.25\ m^2$
Operational Conditions:	- ***Six*** *people &* ***Six*** *computer units.* - ***Demand Temperature*** $= \mathbf{24\ °C}$ *according to ASHRAE standard design.* - ***Operating hours:*** *7:00 am to 10:00 pm (16 hours)*
Software used	HAP

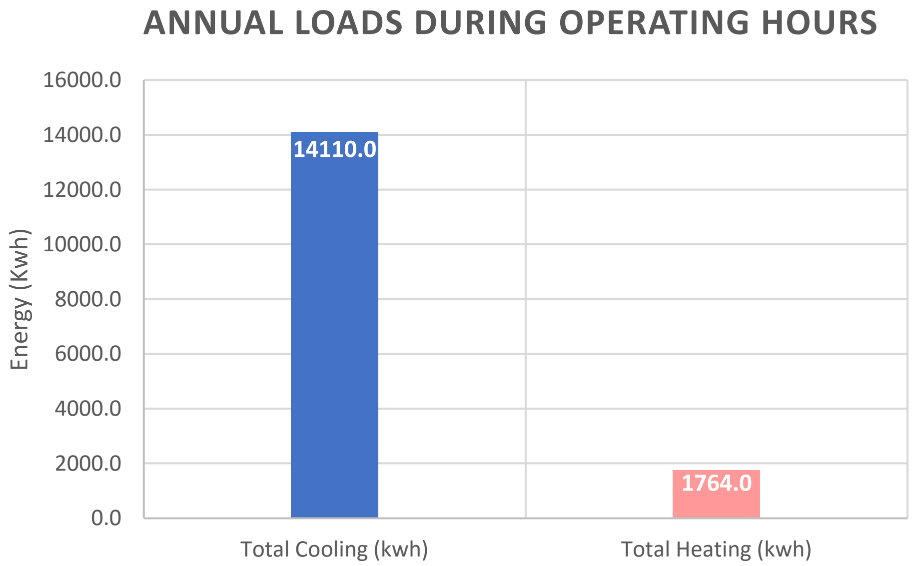
Figure 1: Lab Site from Google

Figure 2: Visit to the lab (Inside)

Cooling and Heating Load Results







$$Total\ Annual\ Energy\ Required = 14110 + 1764 = \mathbf{15874\ KWH}$$

$$Total\ Energy\ Required\ in\ 30\ years\ (KWH) = \mathbf{15874 \times 30} = \mathbf{476,220\ KWH}$$

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 $(k_g) = 2.5\ W/m \cdot K$

Ground diffusivity $(\alpha_g) = 0.892\ mm^2/s = 0.077\ m^2/day$

Borehole fill conductivity $(k_b) = 2.5\ W/m \cdot K$

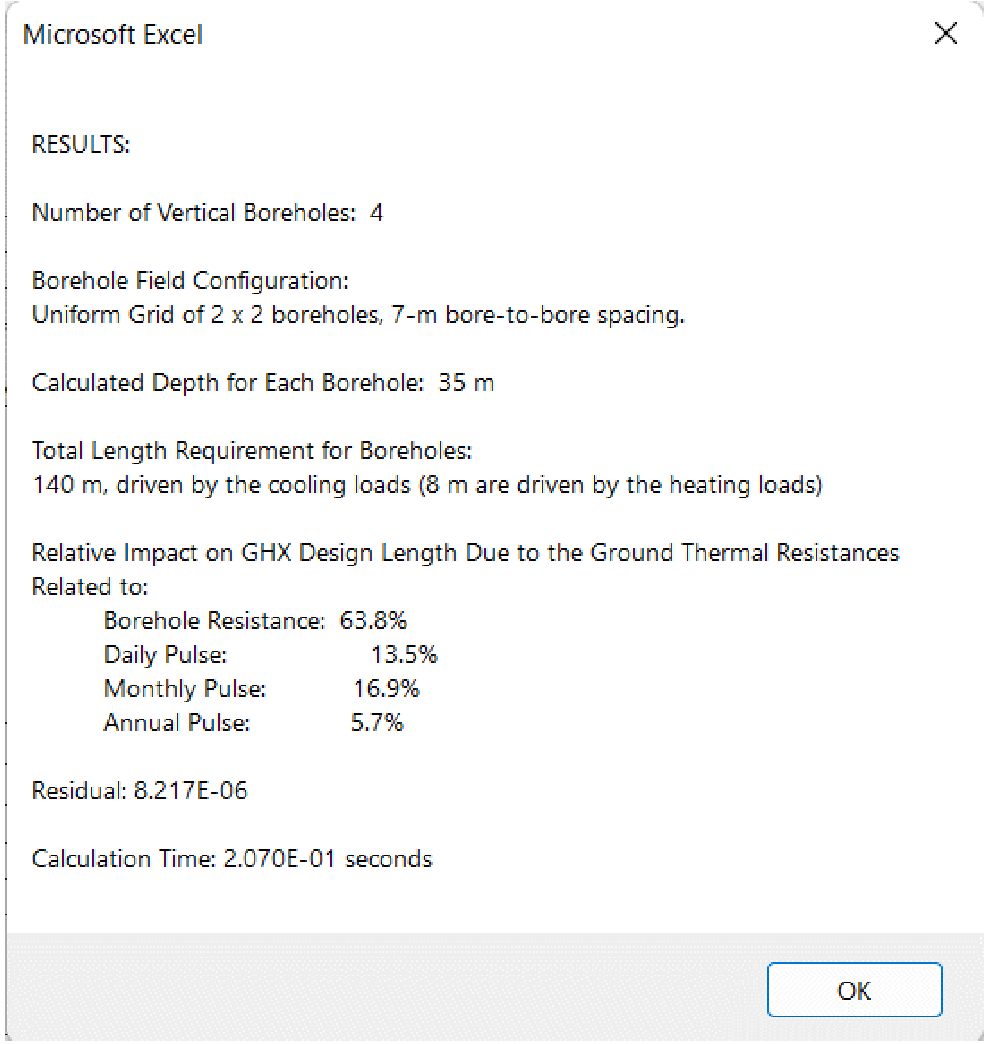
➢ ***From Pipe Selection for ground source heat pumps:***

- **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)

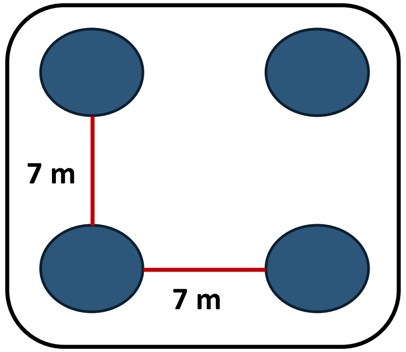
Relative Impact on GHX Design Length Due to the Ground Thermal Resistances
Related to:
Borehole Resistance: 63.8%
Daily Pulse: 13.5%
Monthly Pulse: 16.9%
Annual Pulse: 5.7%

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:

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

CFD Parameters

❑ *Input Values:*

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

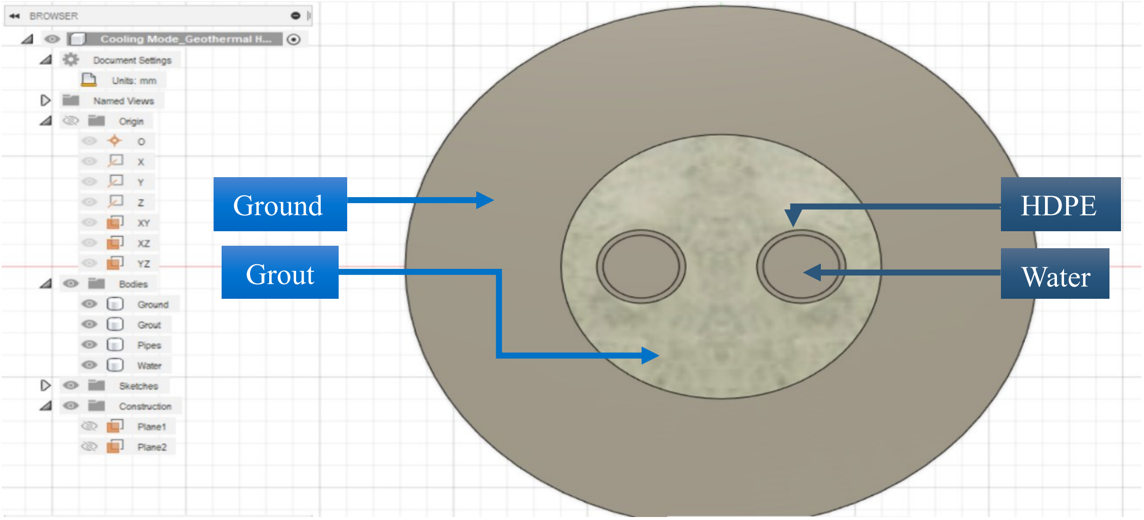


Figure: CAD Geometry - Cairo University Case Study

❑ *Boundaries:*

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

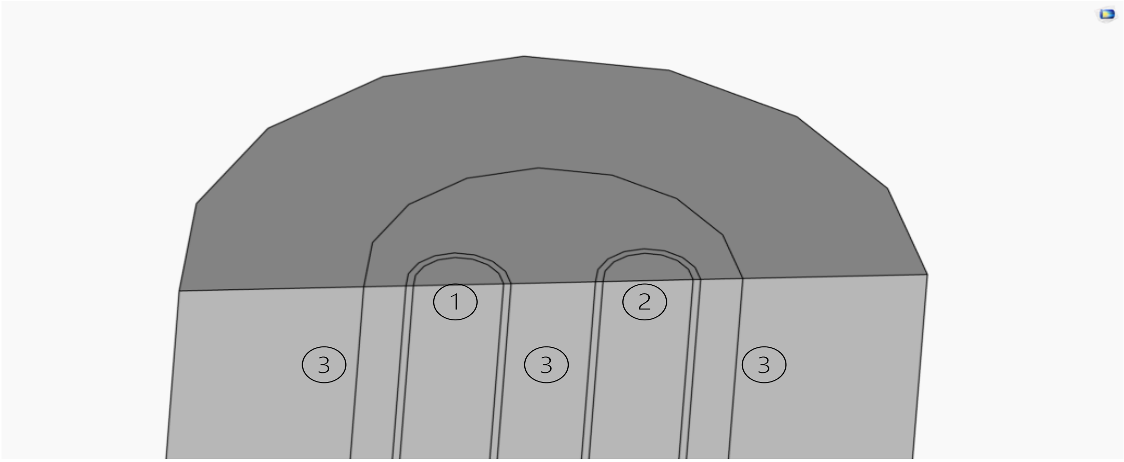


Figure: Single U-tube Pipe Geometry in COMSOL - Cairo University Case Study

CFD Results

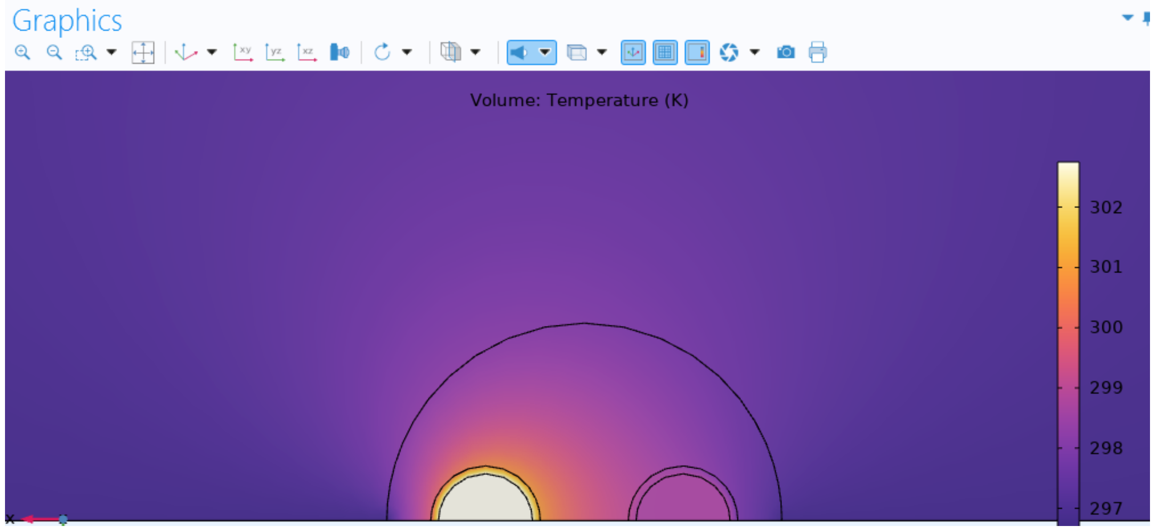
From a steady state analysis:

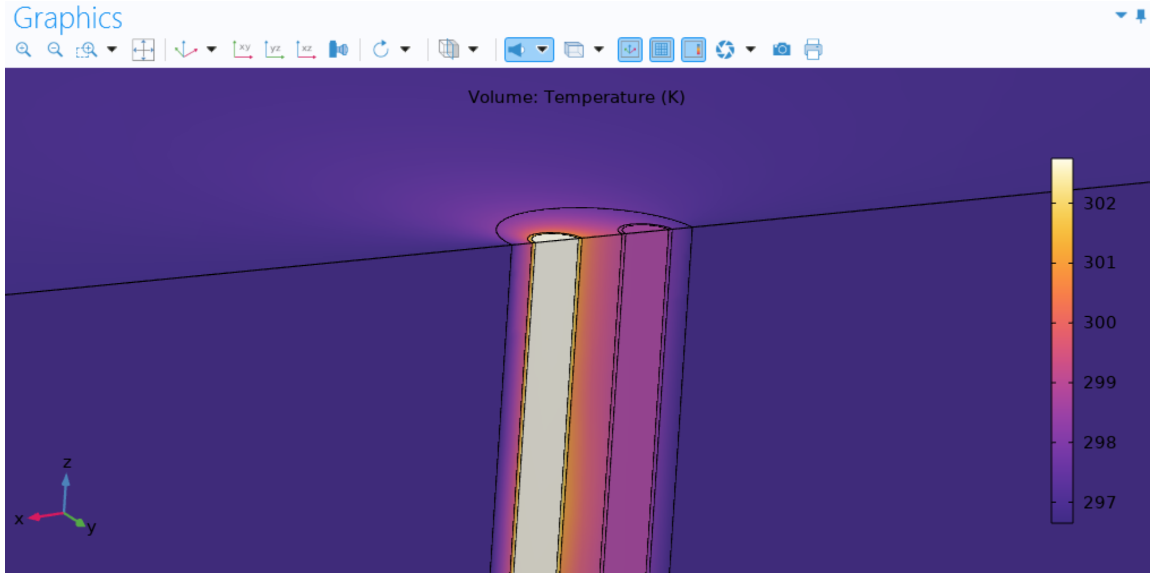
$$\therefore T_{out} = 25.53\ °C \quad \text{(From simulation)}$$

$$\therefore T_{ground} = 23.5°C\ (Input)$$

$$\therefore \boldsymbol{Effectiveness\ (\theta)} = \frac{T_{in} - T_{out}}{T_{in} - T_{ground}}$$

$$= \frac{29.6 - 25.53}{29.6 - 23.5} \times 100 = \mathbf{66.72}\ \%$$





Cost Assessment Results

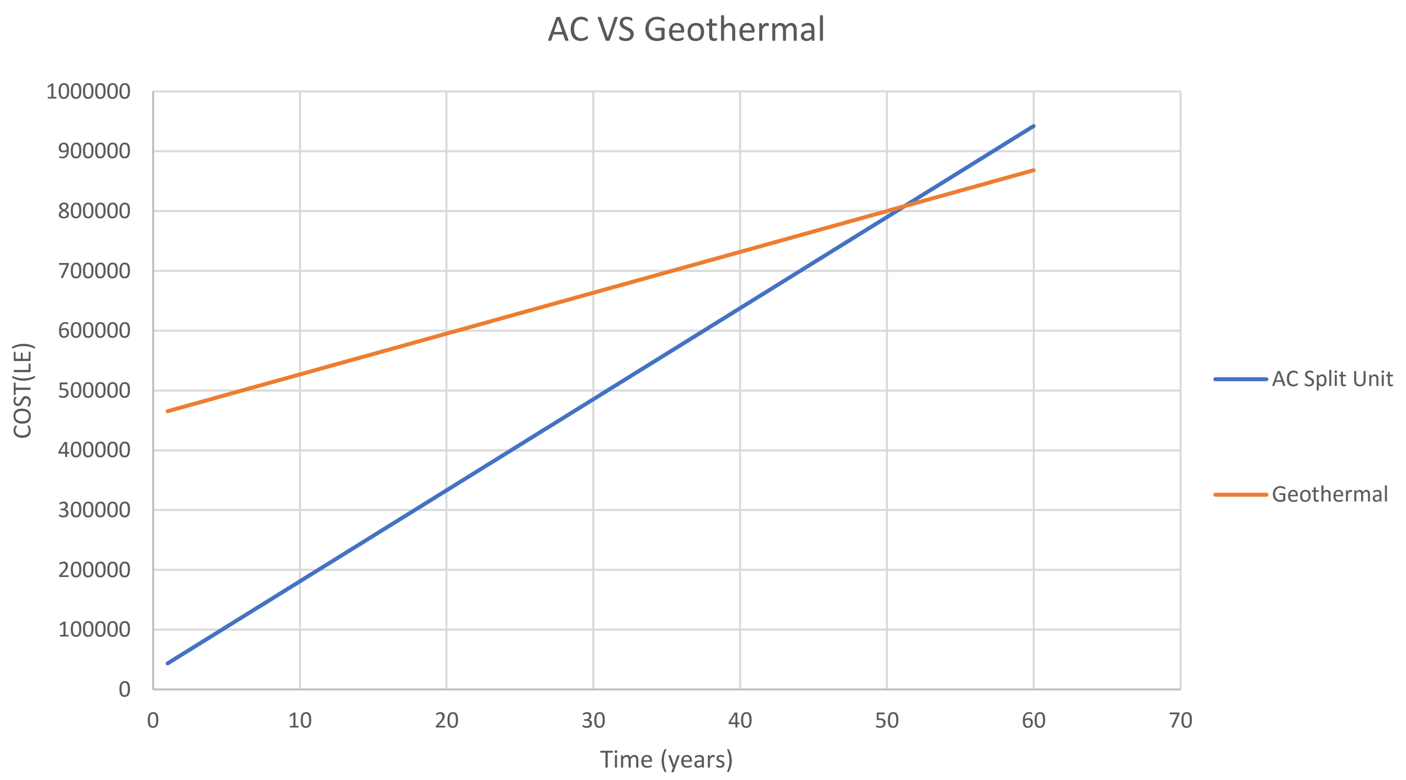
Geothermal heat pump Cost Evaluation	
Drilling Cost (LE)	182,000
Unit Cost (LE)	276,308
Initial Cost = 182,000 + 276,308 = 458,308 LE	
Operation & Maintenance Cost = 6835.3 LE	

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	

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**

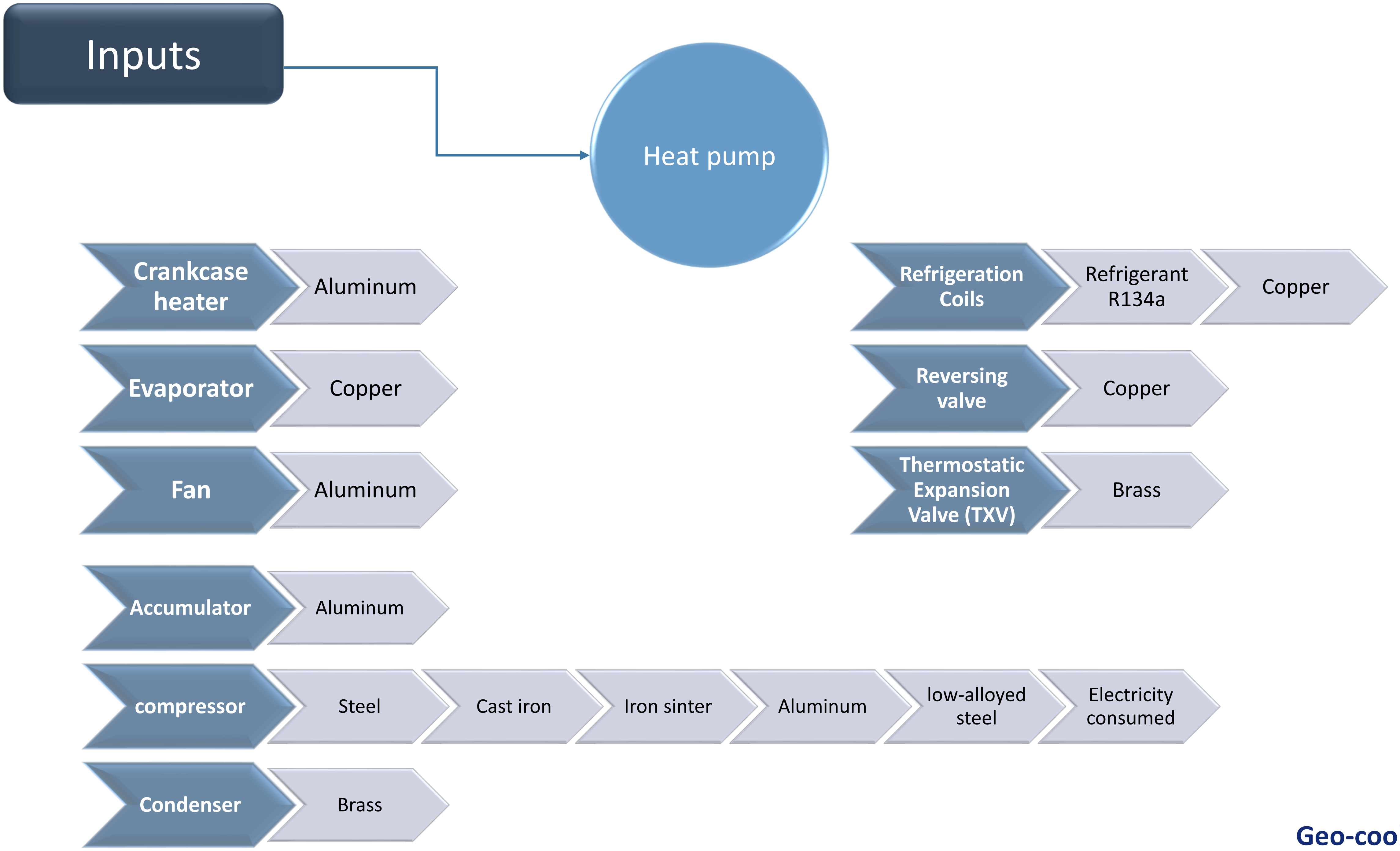
Cost Assessment Results



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

LIFE CYCLE ASSESSMENT

CAIRO UNIVERSITY

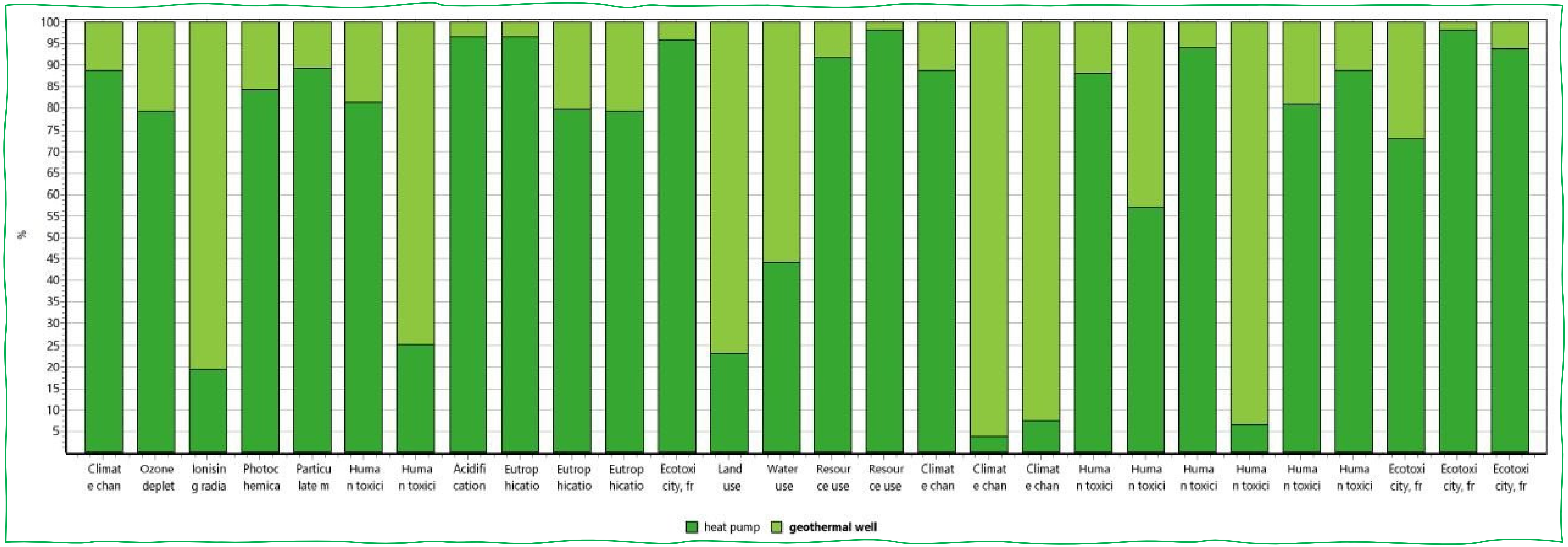

Inputs
Heat pump
Crankcase heater
Aluminum
Evaporator
Copper
Fan
Aluminum
Accumulator
Aluminum
compressor
Steel
Cast iron
Iron sinter
Aluminum
low-alloyed steel
Electricity consumed
Condenser
Brass
Refrigeration Coils
Refrigerant R134a
Copper
Reversing valve
Copper
Thermostatic Expansion Valve (TXV)
Brass

Inputs

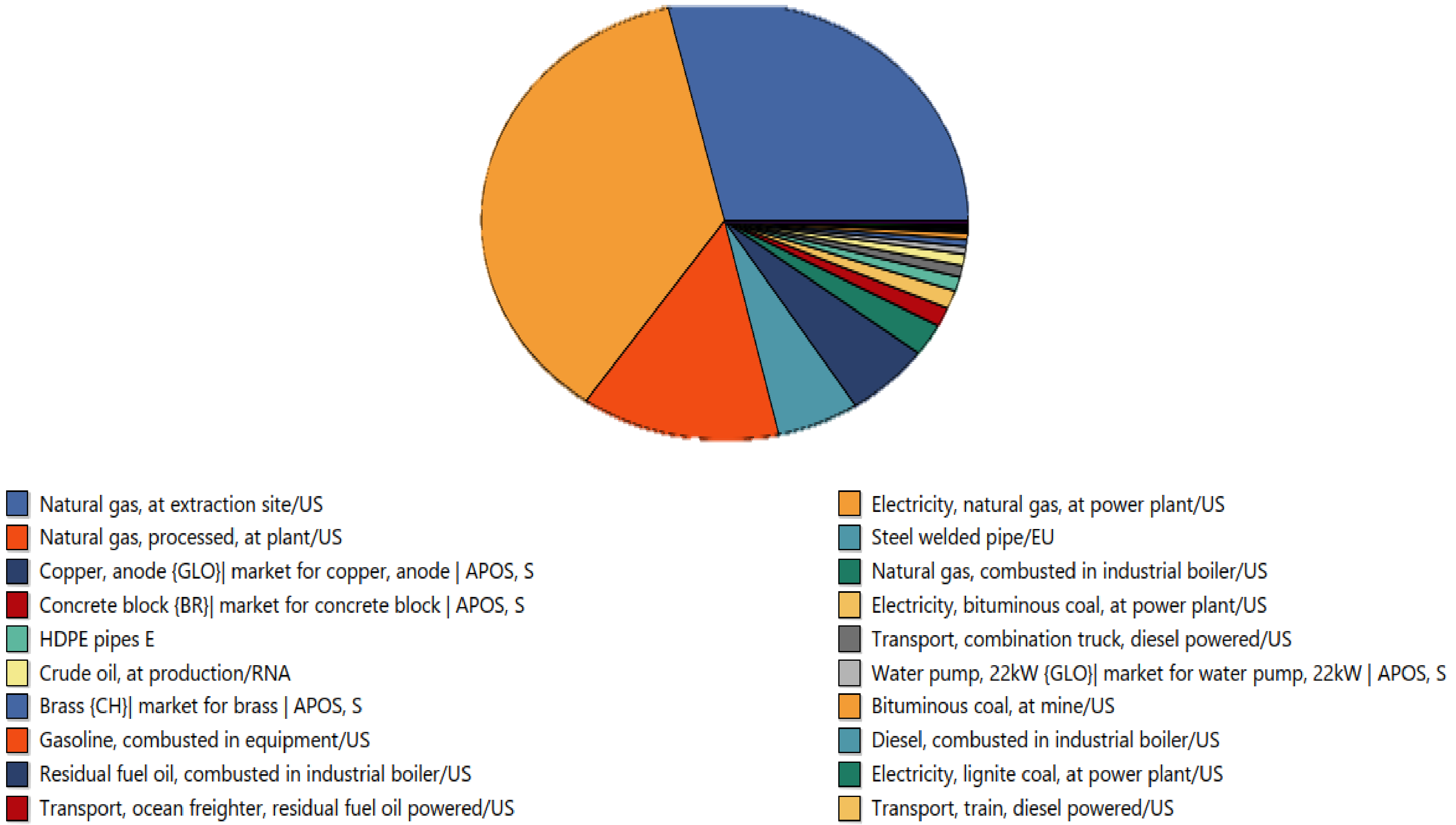
Geothermal Well

Steel pipe	Steel welded pipe
Water	Tap water
HDPE pipe	HDPE pipes E
Grout	Concrete block

LCA Results

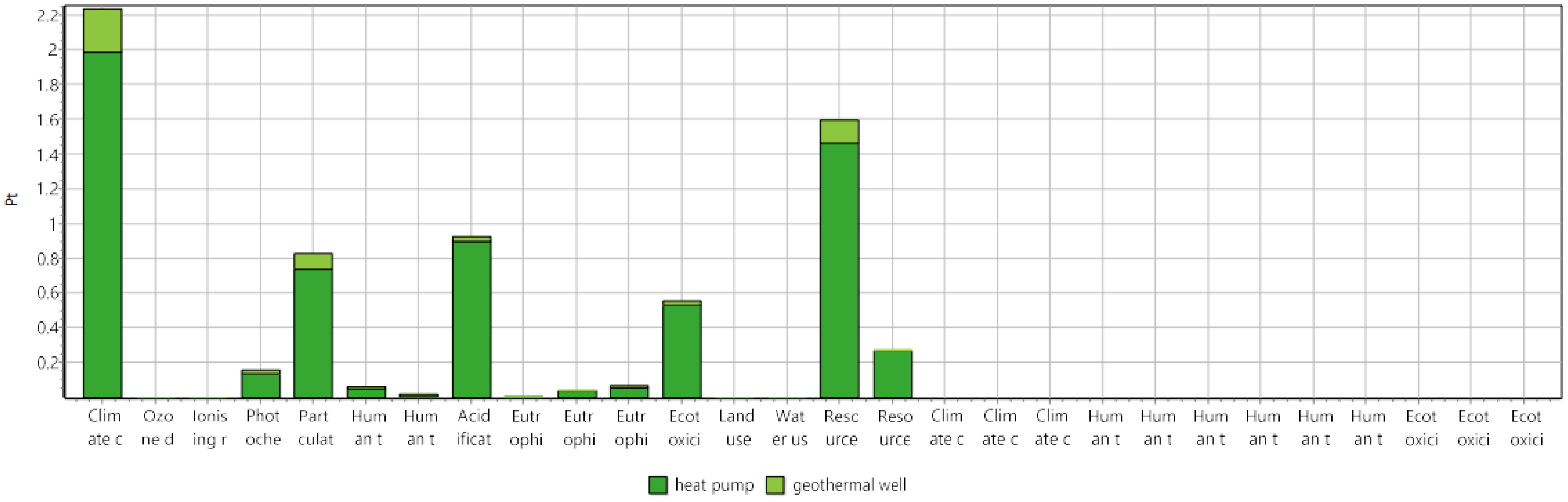


Heat pump vs geothermal well contribution for each category (characterization)

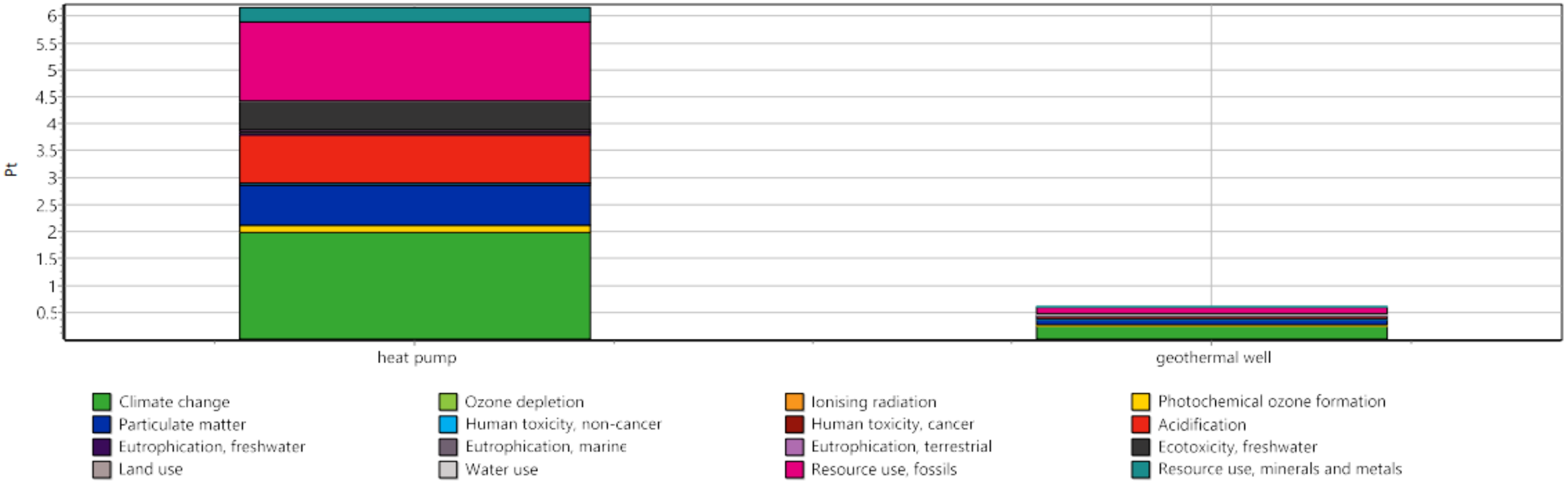


About 75% of the emissions is produced by the electrical consumption of the compressor. This electrical consumption is consumed by the natural gas power plants as most of the power plants in Egypt are Natural gas.

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
g 1 p 'the process';



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

Top 5 processes contributing for each category

Climate change

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

Ozone depletion

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

Ionizing radiation

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

Photochemical ozone formation

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

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

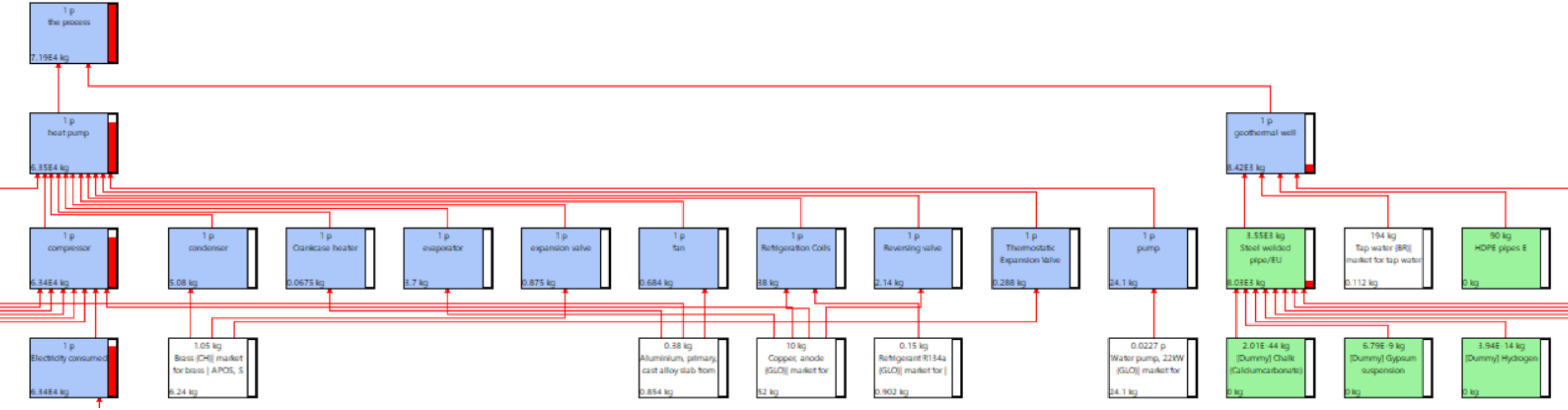
No	Process	Project	Unit	Total	heat pump	geothermal well
	Total of all processes		Pt	1.25E4	2.89E3	9.64E3
1	Concrete block {BR}| market for concrete block | APOS, S	Ecoinvent 3 -	Pt	6.88E3	x	6.88E3
2	Steel welded pipe/EU	Industry data	Pt	2.77E3	x	2.77E3
3	Copper, anode {GLO}| market for copper, anode | 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



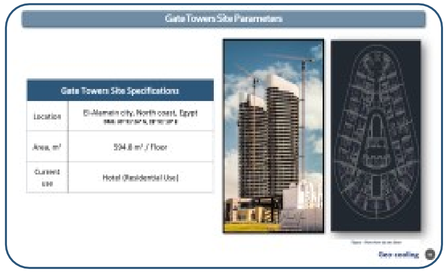
- ***Effect on Climate Change:***

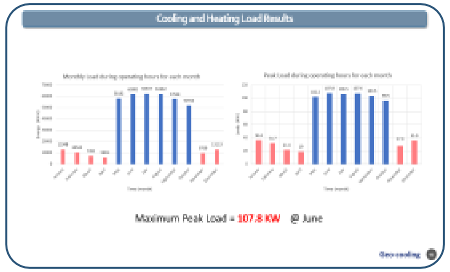
- Total CO_2 produced = 71,900 kg CO_2 ,While the rest of emissions in (kg CO_2 eq.) = 14,000 kg
- Total heating load injected / produced from the ground= 565,920 kWhth

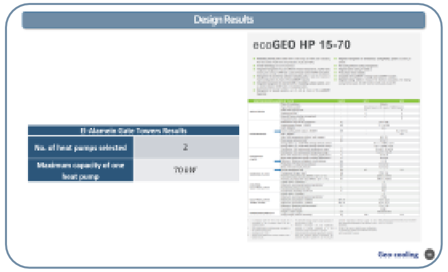
$$\text{GHG produced} = \frac{71{,}900 + 14{,}000}{565920} = \mathbf{0.1517}\ \textbf{\textit{kgCO2eq./kWhth}}$$

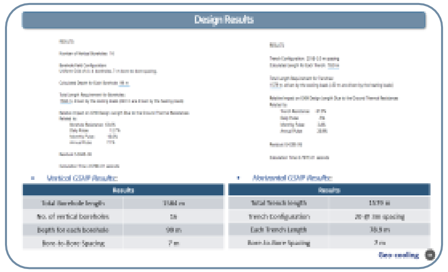
From references, Heat pump system designed and implemented in Cairo university rock laboratory has GHG production = ***0.1517 kgCO2eq./kWhth*** which is below average for India, Singapore and China references and is in range for Europe standards. ***This shows how this heat pump system is environmental-friendly.***

El-Alamein

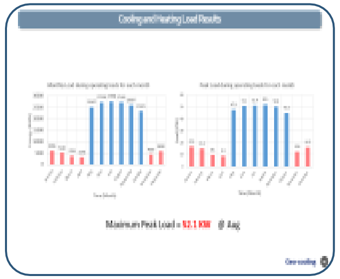

Gate Towers Site Parameters
Gate Towers Site Specifications
Location
El-Alamein city, North coast, Egypt
Area, m²
594.8 m² / Floor
Current use
Hotel (Residential Use)
Geo-cooling

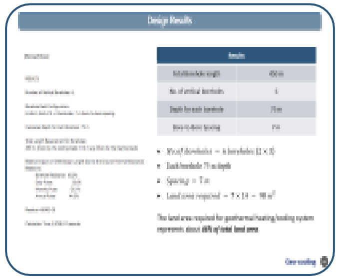

Cooling and Heating Load Results
Maximum Peak Load = 107.8 KW @ June
Geo-cooling

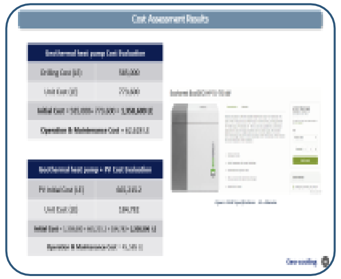

Design Results
ecoGEO HP 15-70
El-Alamein Gate Towers Results
No. of heat pumps selected
2
Maximum capacity of one heat pump
70 kW
Geo-cooling


Design Results
Geo-cooling

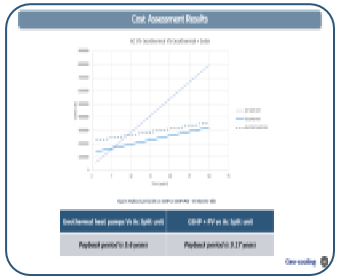

Gate Towers Site Parameters
Geo-cooling

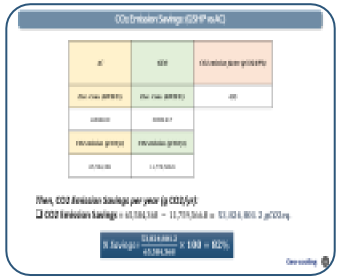

Cooling and Heating Load Results
Geo-cooling


Design Results
Geo-cooling


Cost Assessment Results
Geo-cooling

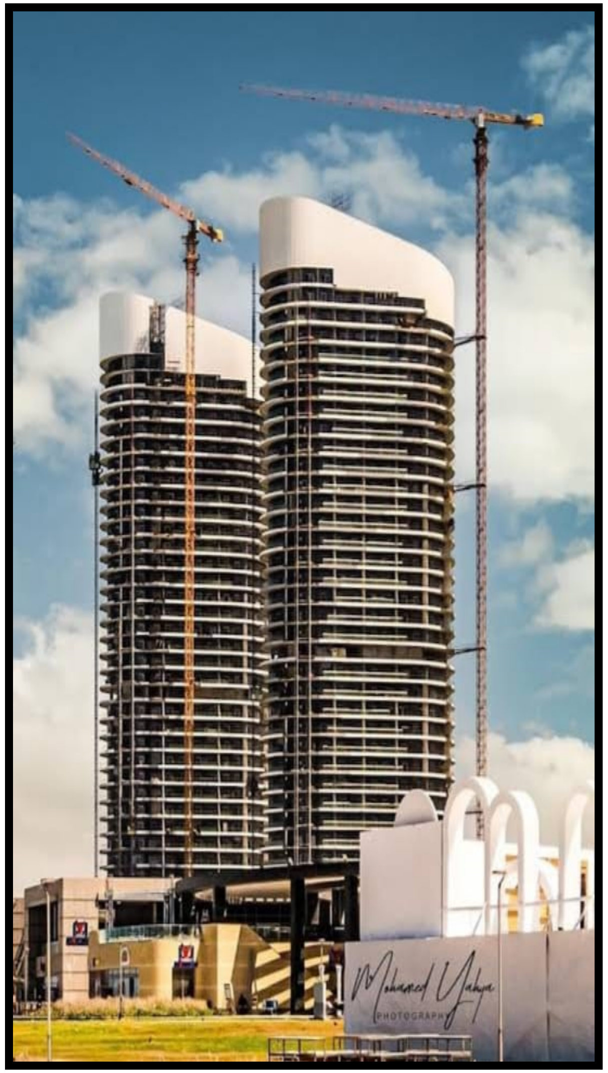

Cost Assessment Results
Geo-cooling


Cost Assessment Results
Geo-cooling


Geo-cooling

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)



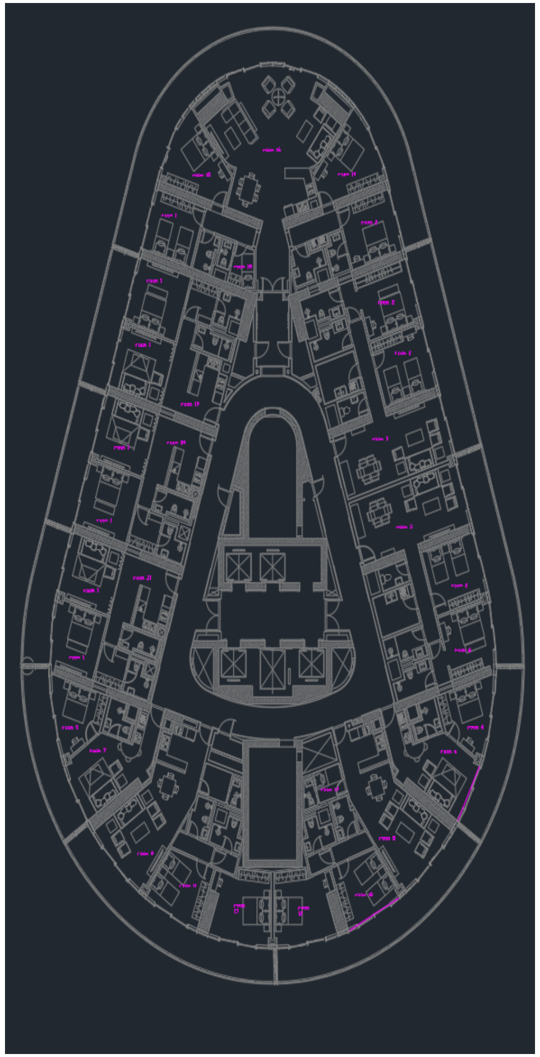
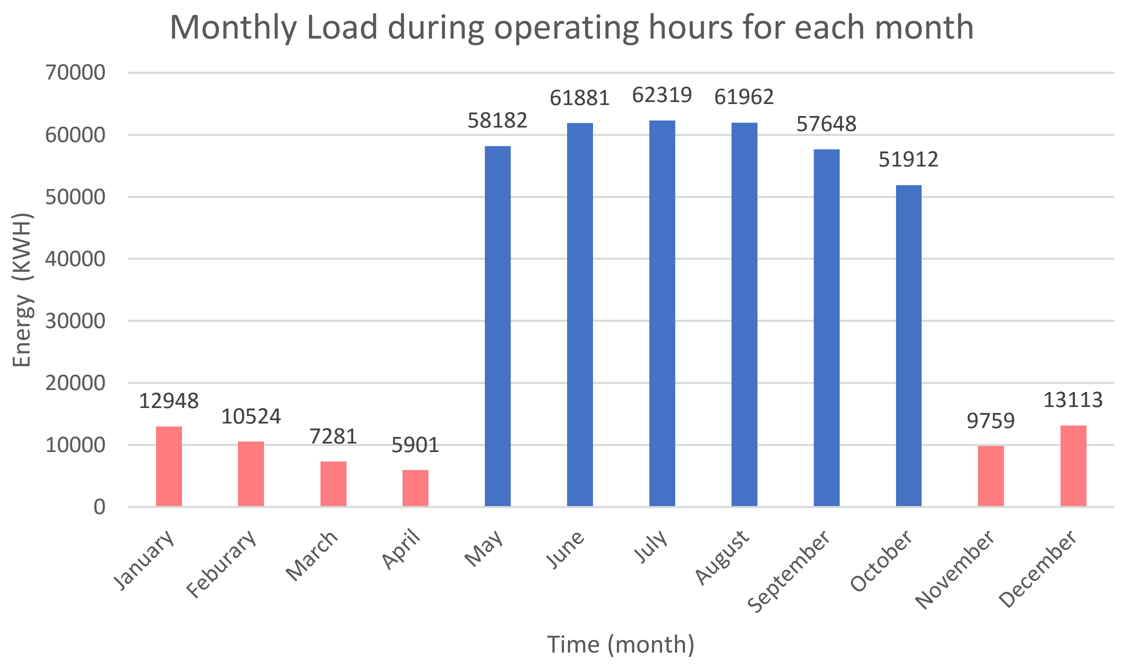
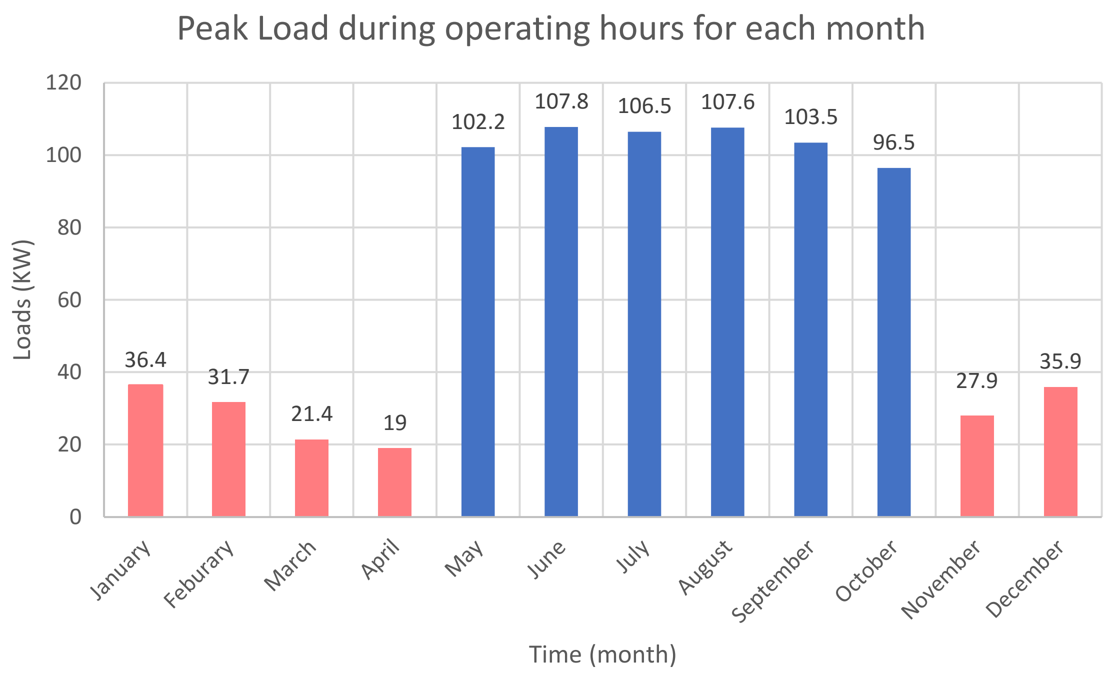


Figure : Plan view of one floor

Cooling and Heating Load Results

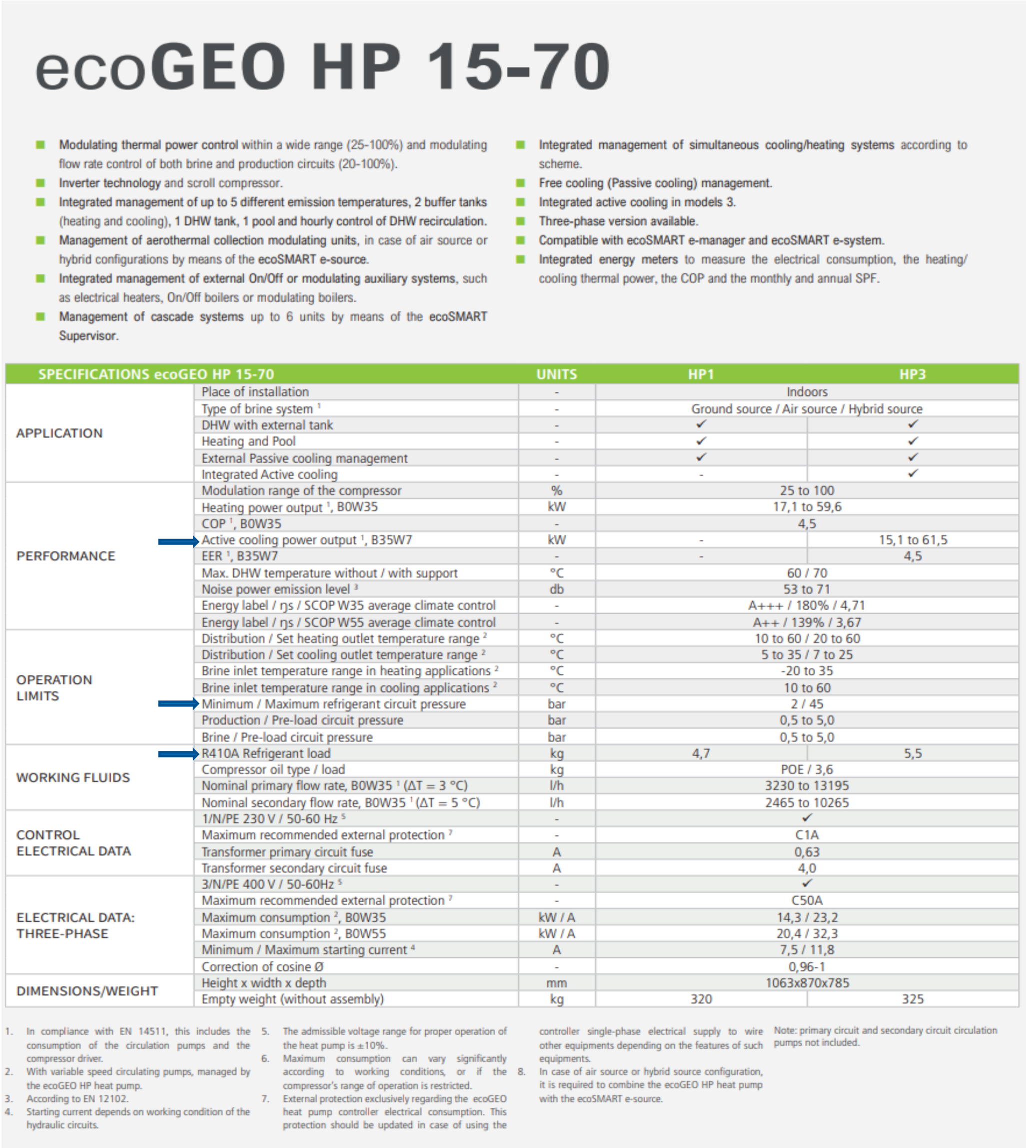




Maximum Peak Load = **107.8 KW** @ June

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 aerothermal 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	
	Noise power emission level [3]	db	53 to 71	
	Energy label / ηs / SCOP W35 average climate control	-	A+++ / 180% / 4,71	
	Energy label / ηs / SCOP W55 average climate control	-	A++ / 139% / 3,67	
OPERATION LIMITS	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	
	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	
WORKING FLUIDS	R410A Refrigerant load	kg	4,7	5,5
	Compressor oil type / load	kg	POE / 3,6	
	Nominal primary flow rate, B0W35 [1] ($\Delta T = 3$ °C)	l/h	3230 to 13195	
	Nominal secondary flow rate, B0W35 [1] ($\Delta T = 5$ °C)	l/h	2465 to 10265	
CONTROL ELECTRICAL DATA	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	
	Minimum / Maximum starting current [4]	A	7,5 / 11,8	
	Correction of cosine Ø	-	0,96-1	
DIMENSIONS/WEIGHT	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

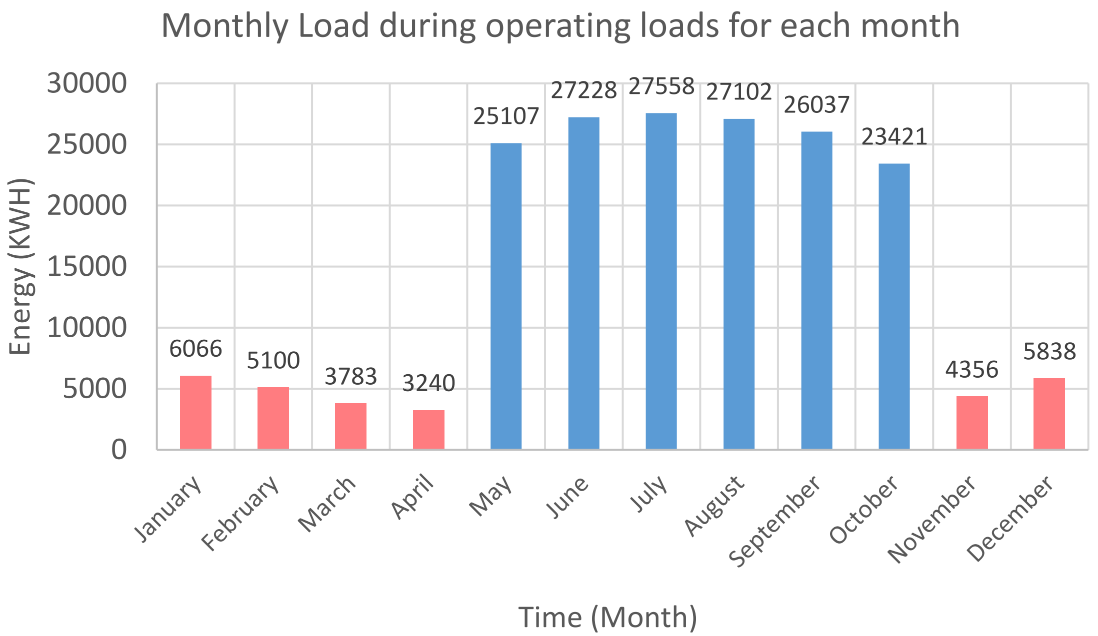
Gate Towers Site Parameters

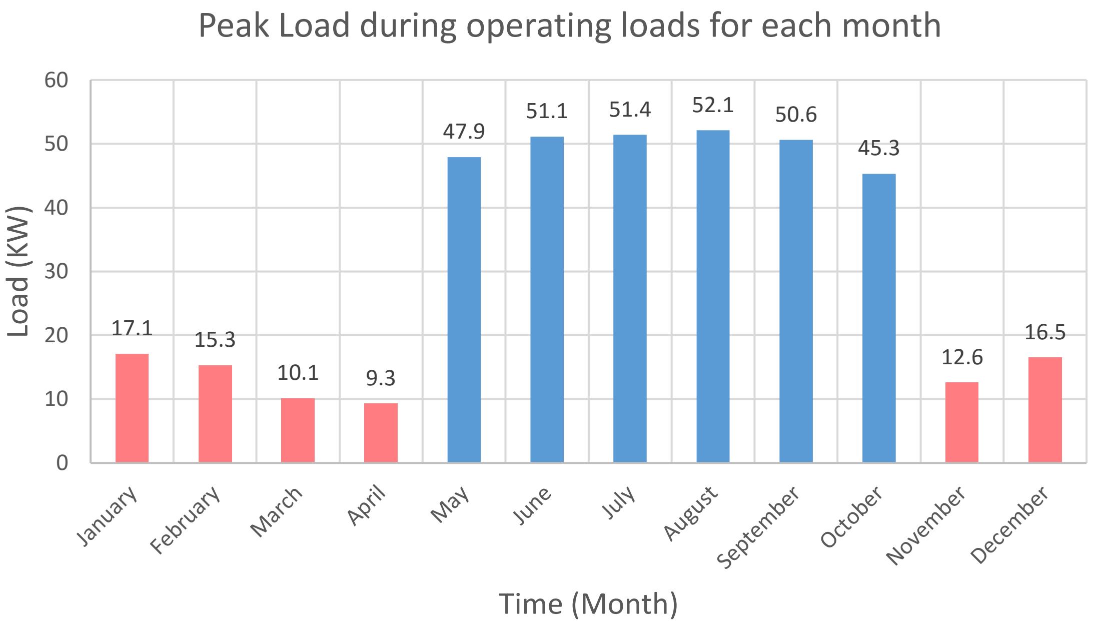
Ground Floor Plan View

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





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

- $No.of\ boreholes\ =\ 6\ boreholes\ (2 \times 3)$
- Each borehole 75 m depth
- $Spacing\ =\ 7\ m$
- $Land\ area\ required\ =\ 7 \times 14\ =\ 98\ m^2$

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	

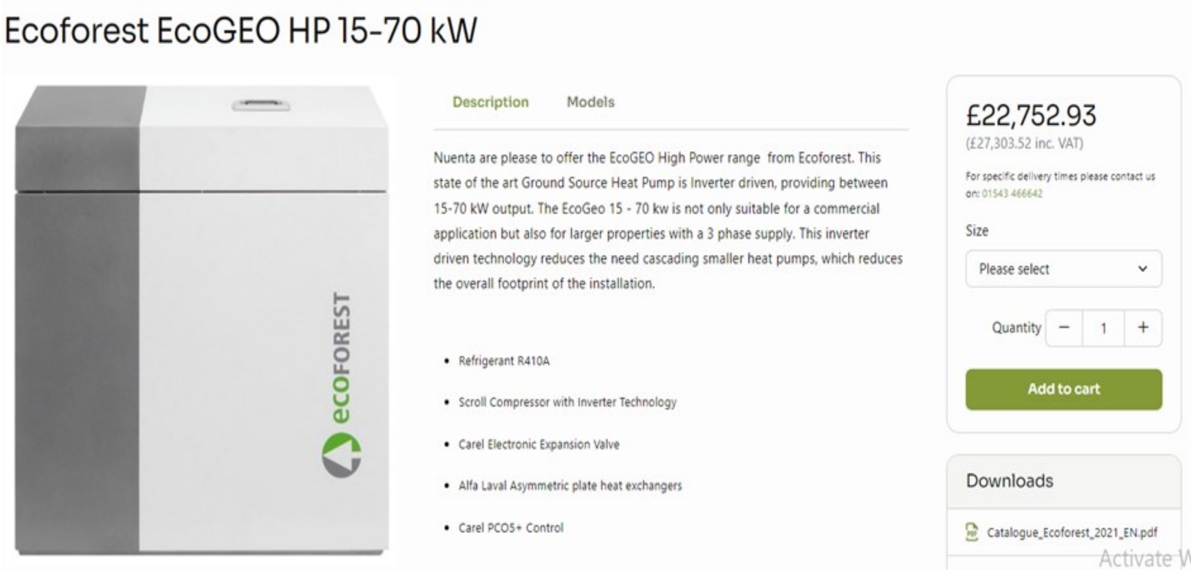


Figure: GSHP Specifications - El=-Alamein

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

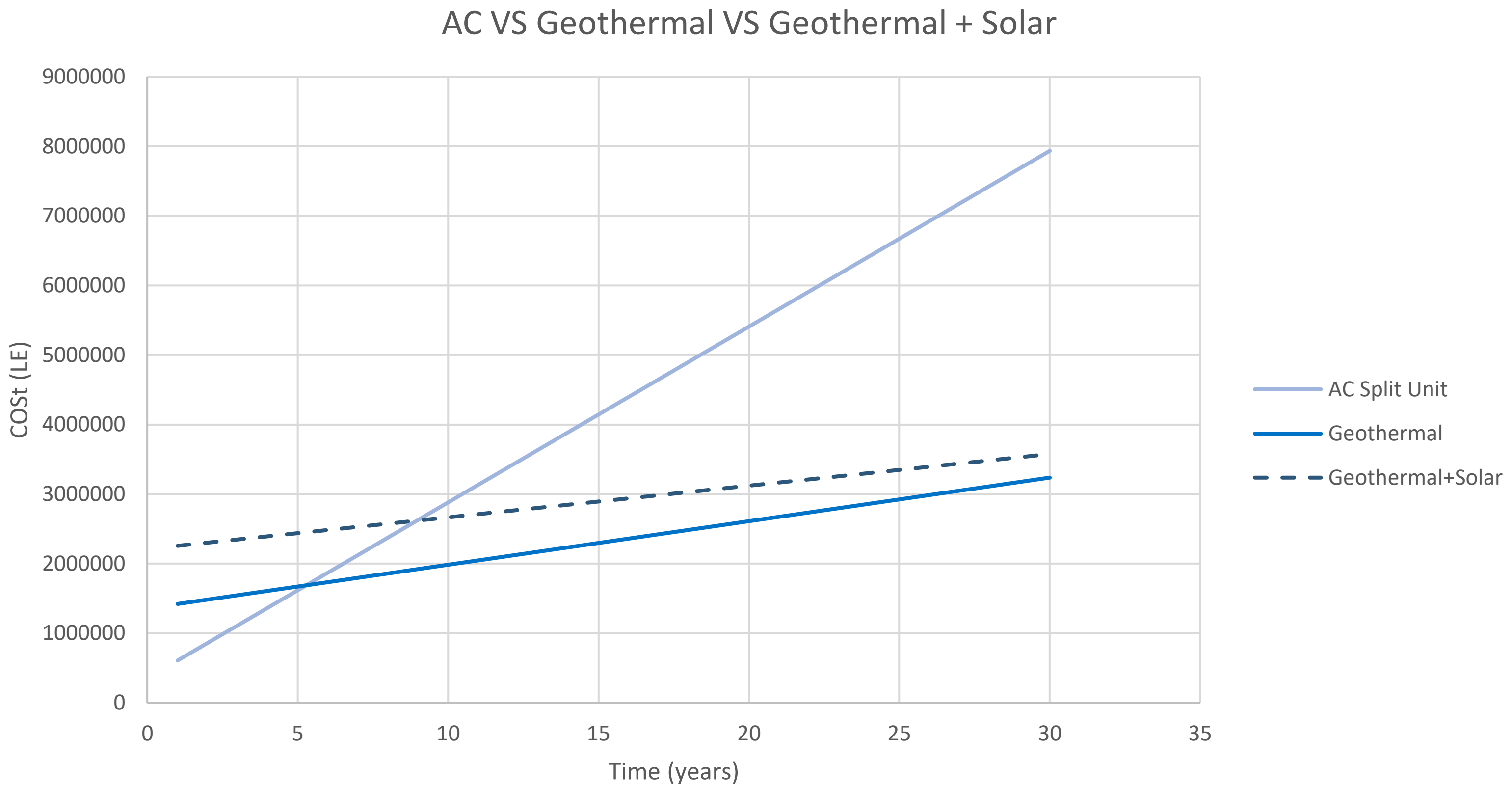


Figure: Payback period (Ac vs GSHP vs GSHP+PV) – El-Alamein Villa

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*

CO_2 Emission Savings: (GSHP vs AC)

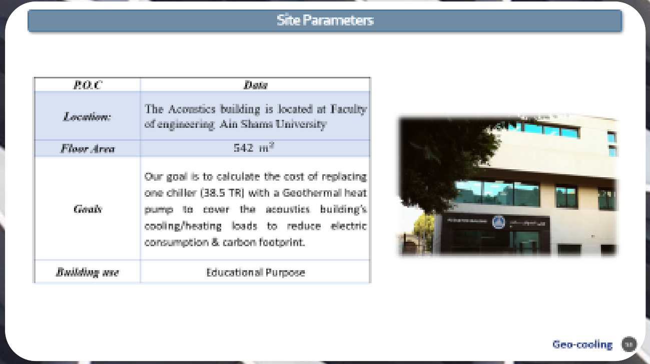
AC	*GEO*	*CO2 emission factor (gCO2/kWh)*
Elec. Cons. (KWH/Yr)	*Elec. Cons. (KWH/Yr)*	400
163960.92	29398.917	
CO2 emission (gCO2/yr)	*CO2 emission (gCO2/yr)*	
65,584,368	11,759,566.8	

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

- ❑ **CO2 Emission Savings** = $65{,}584{,}368 - 11{,}759{,}566.8 = \mathbf{53{,}824{,}801.2\ gCO2eq}.$

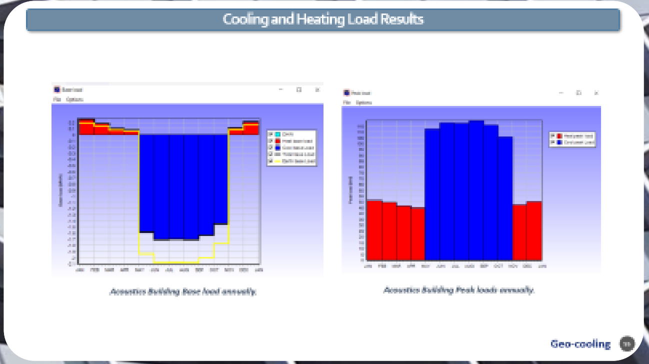
$$\% \text{ Savings} = \frac{53{,}824{,}801.2}{65{,}584{,}368} \times 100 = 82\%$$

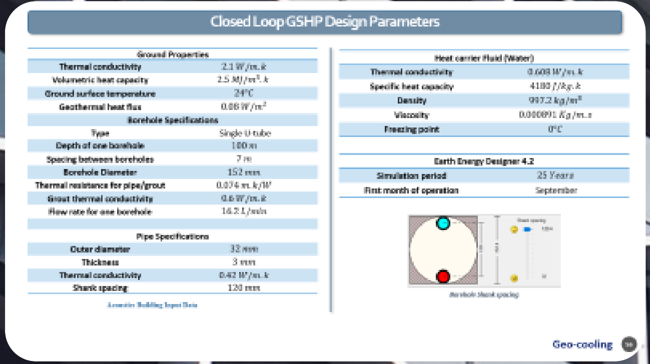
Acoustics



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





Closed Loop GSHP Design Parameters

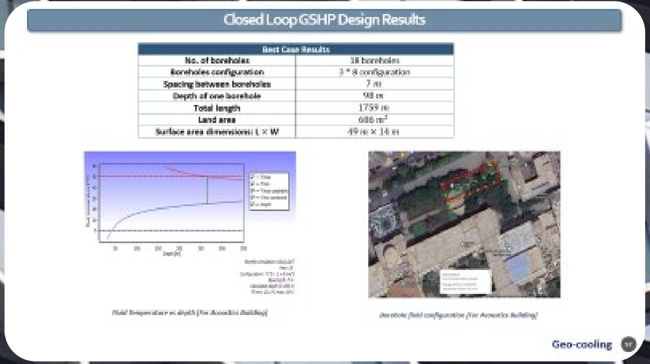
Ground Properties	
Thermal conductivity	2.1 $W/m.k$
Volumetric heat capacity	2.5 $MJ/m^3.k$
Ground surface temperature	24°C
Geothermal heat flux	0.08 W/m^2
Borehole Specifications	
Type	Single U-tube
Depth of one borehole	100 m
Spacing between boreholes	7 m
Borehole Diameter	152 mm
Thermal resistance 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

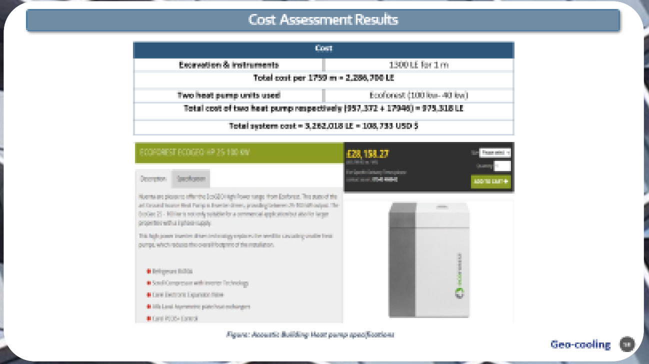


Closed Loop GSHP Design Results

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

Fluid Temperature vs depth (For Acoustics Building)

Borehole field configuration (For Acoustics Building)



Cost Assessment Results

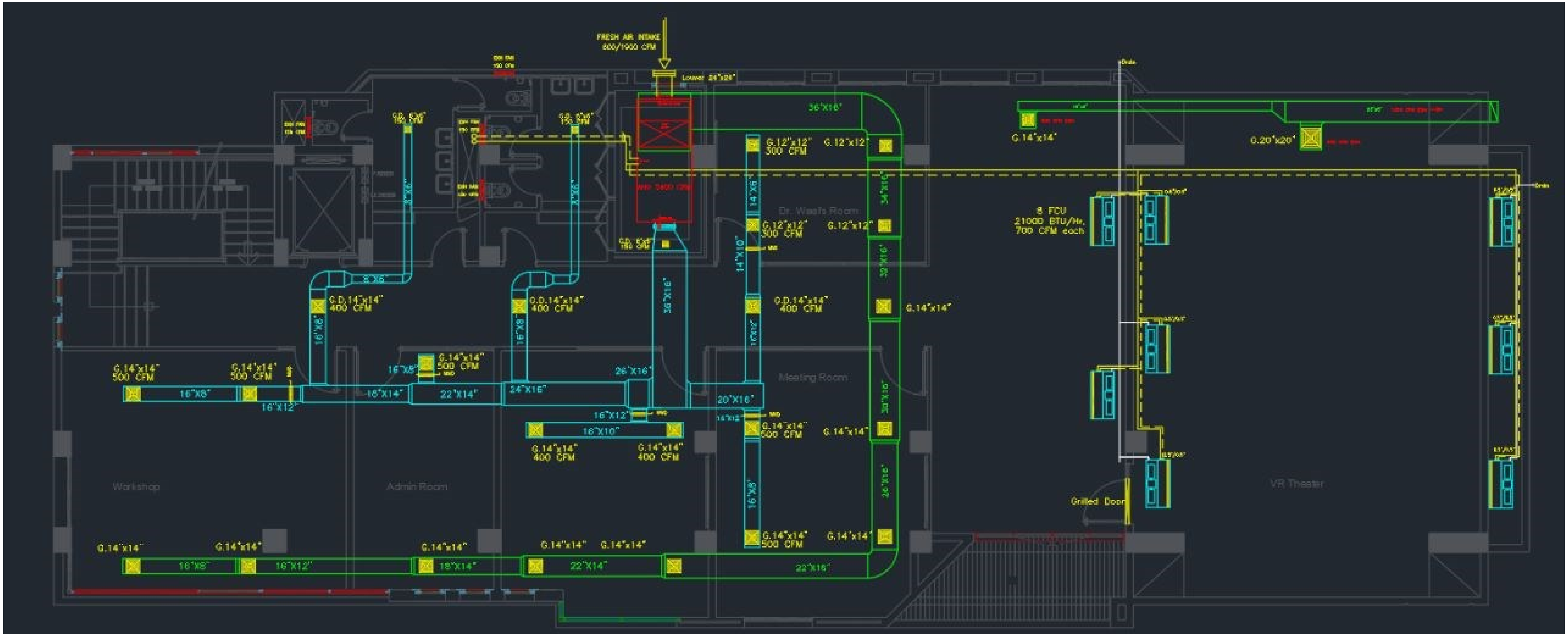
Cost	
Excavation & instruments	1300 LE for 1 m
Total cost per 1759 m = 2,286,700 LE	
Two heat pump units used	Ecoforest (100 kw- 40 kw)
Total cost of two heat pump respectively (957,372 + 17946) = 975,318 LE	
Total system cost = 3,262,018 LE = 108,733 USD $	

Figure: Acoustic Building Heat pump specifications

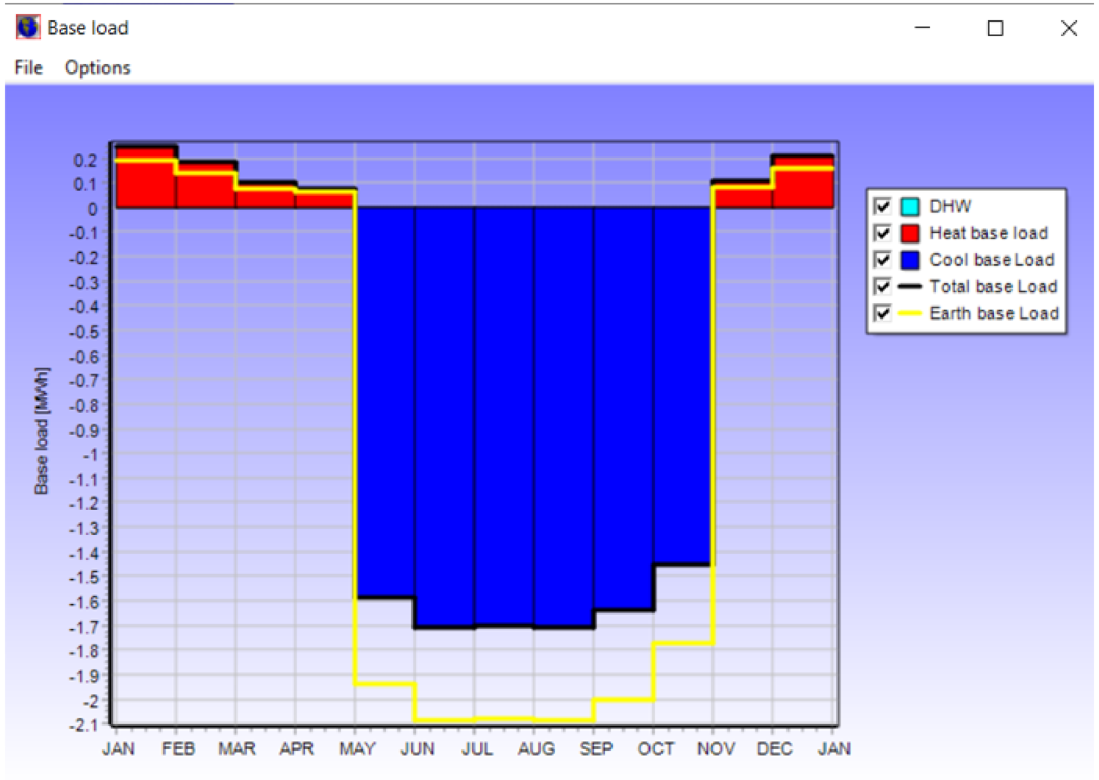
Site Parameters

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

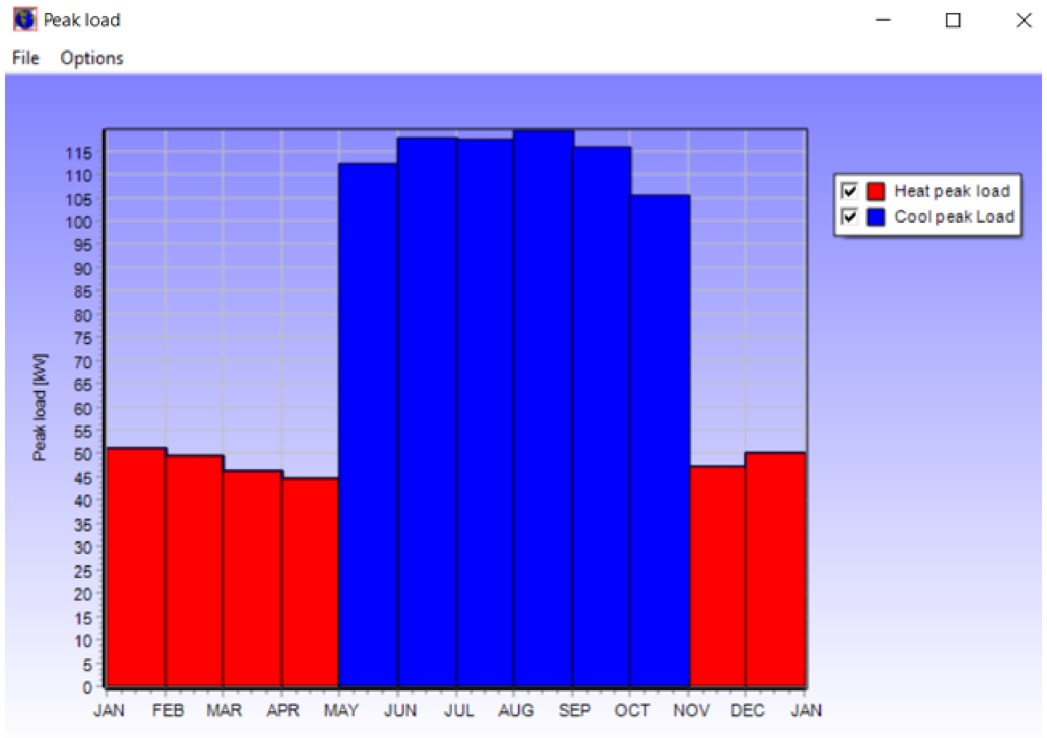
Site Parameters



Cooling and Heating Load Results



Acoustics Building Base load annually.



Acoustics Building Peak loads annually.

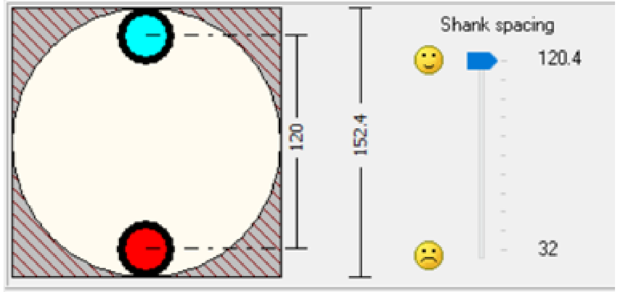
Closed Loop GSHP Design Parameters

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	$0°C$

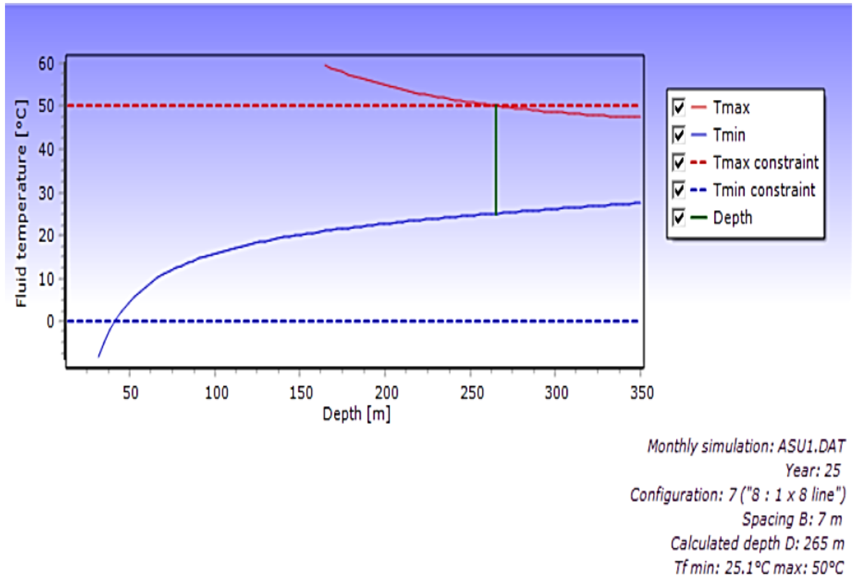
Earth Energy Designer 4.2	
Simulation period	$25\ Years$
First month of operation	September



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	$49\ m \times 14\ m$



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 $	

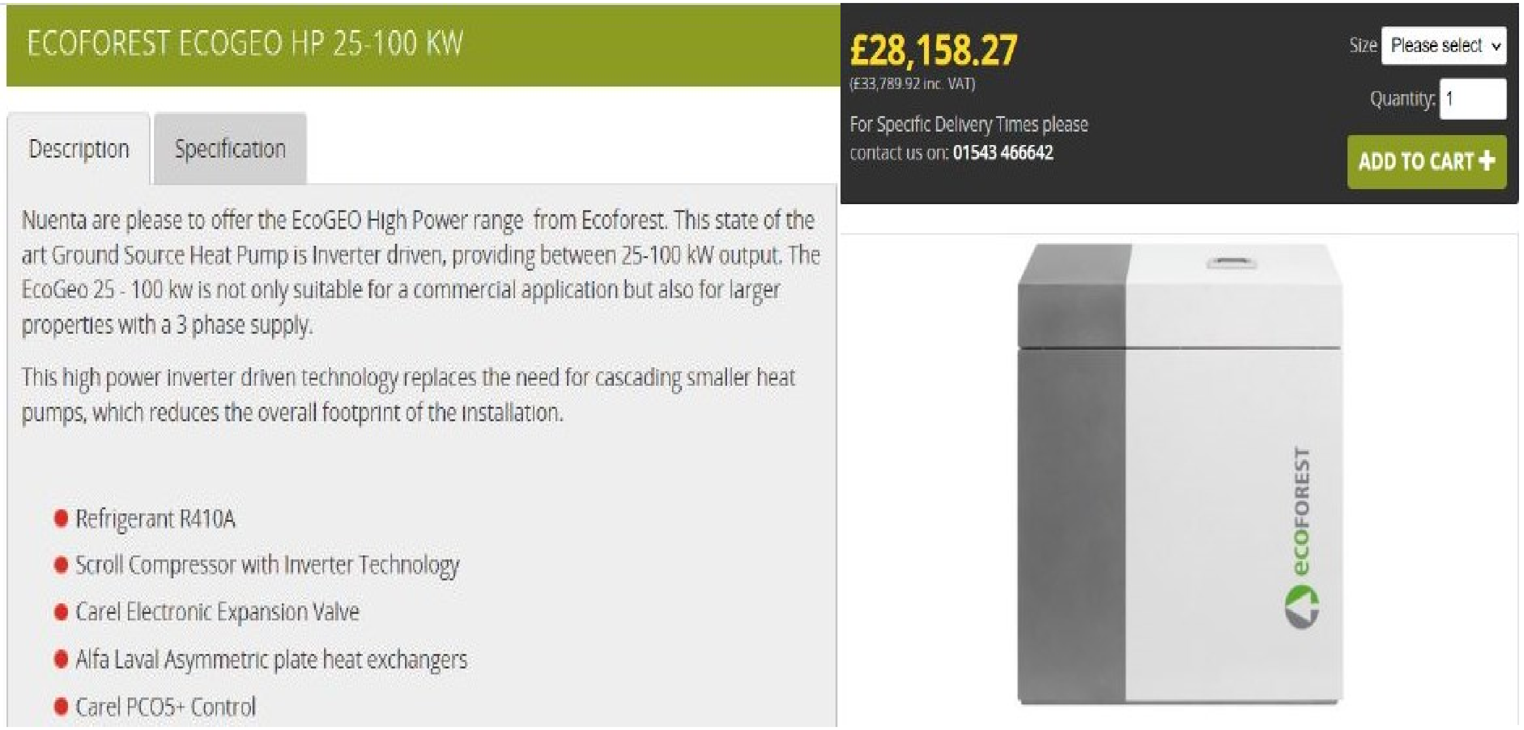
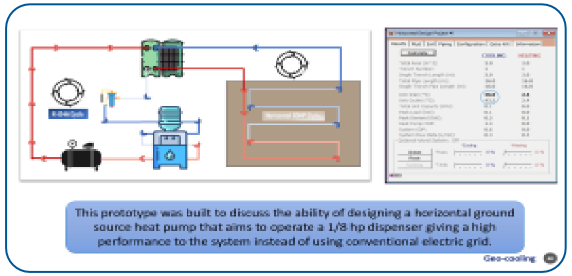
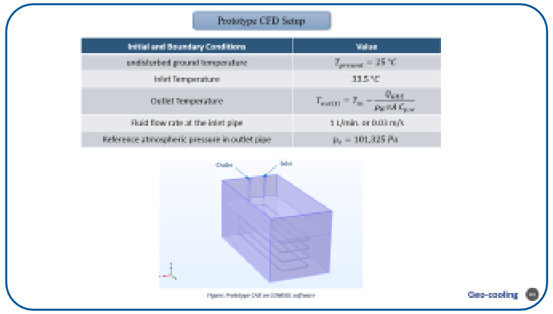


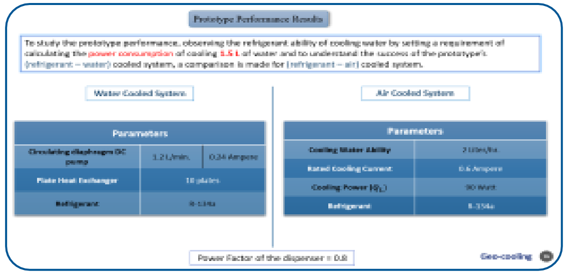
Figure: Acoustic Building Heat pump specifications

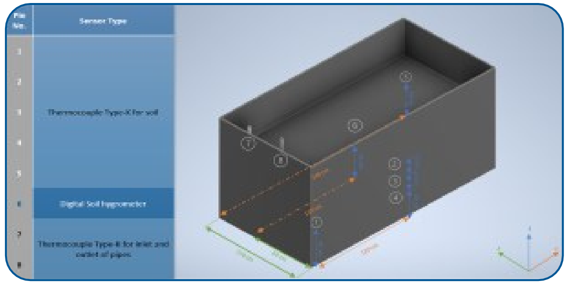
Prototype

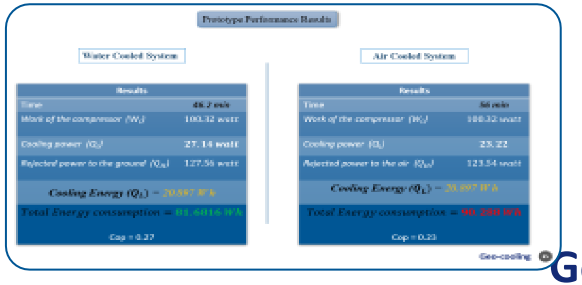

This prototype was built to discuss the ability of designing a horizontal ground source heat pump that aims to operate a 1/8 hp dispenser giving a high performance to the system instead of using conventional electric grid.
Geo-cooling

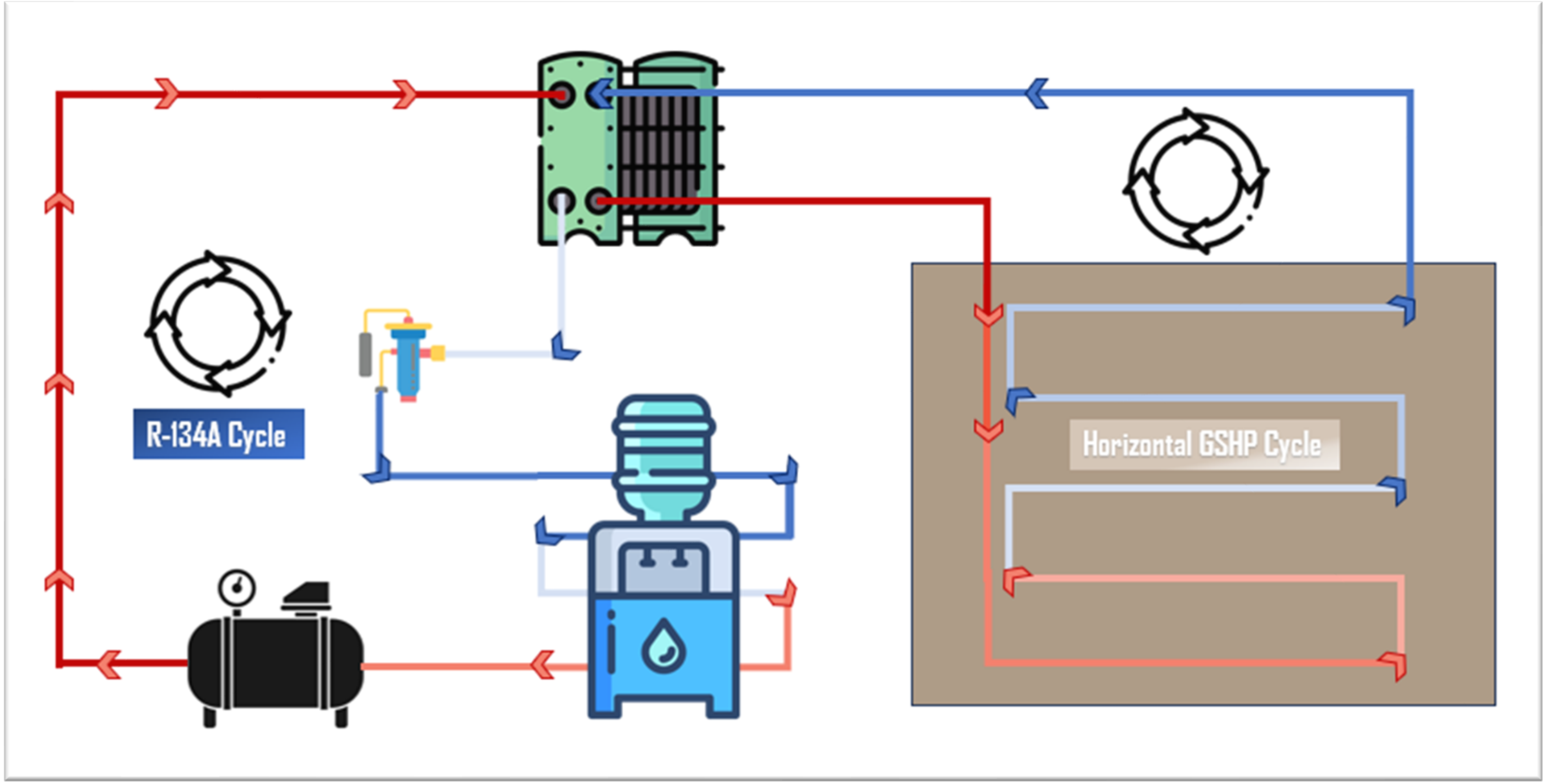

Prototype CFD Setup
Initial and Boundary Conditions
Value
Geo-cooling

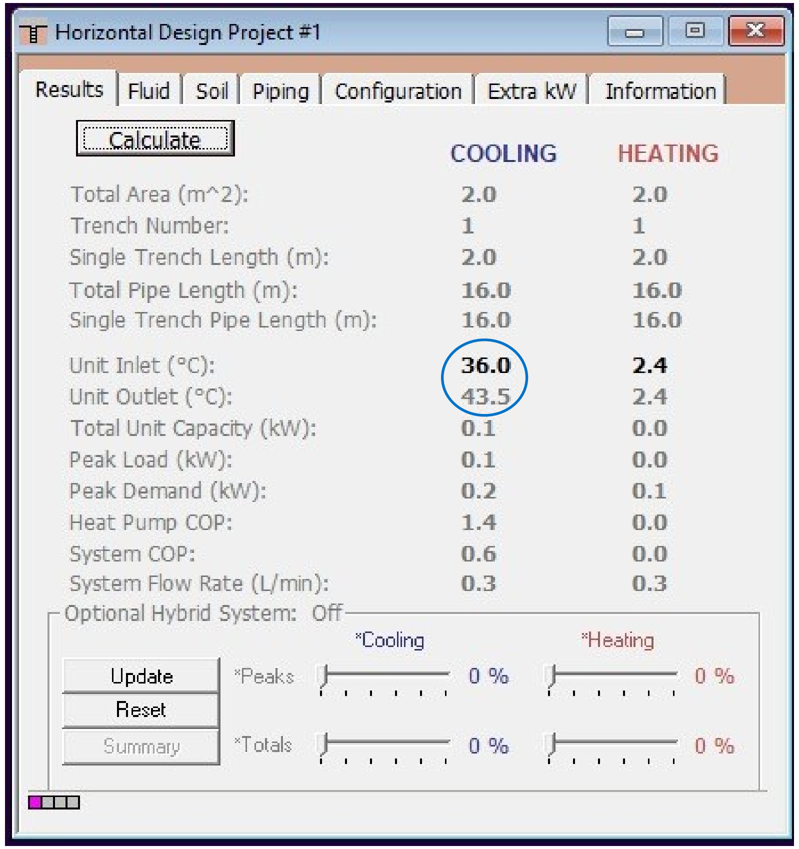

Components
Water Dispenser
Plate Heat Exchanger
Soil trench
Water circulating pump
UPVC U-shaped loops
Thermocouples
Glass wool insulation
Geo-cooling


Prototype Performance Results
Water Cooled System
Air Cooled System
Parameters
Geo-cooling


Sensor Type


Prototype Performance Results
Water Cooled System
Air Cooled System
Results
Geo-cooling





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	$T_{ground} = 25\,°C$
Inlet Temperature	$33.5\,°C$
Outlet Temperature	$T_{out(t)} = T_{in} - \frac{Q_{GHE}}{\rho_W vA\, C_{p,w}}$
Fluid flow rate at the inlet pipe	1 L/min. or 0.03 m/s
Reference atmospheric pressure in outlet pipe	$p_o = 101{,}325\ Pa$

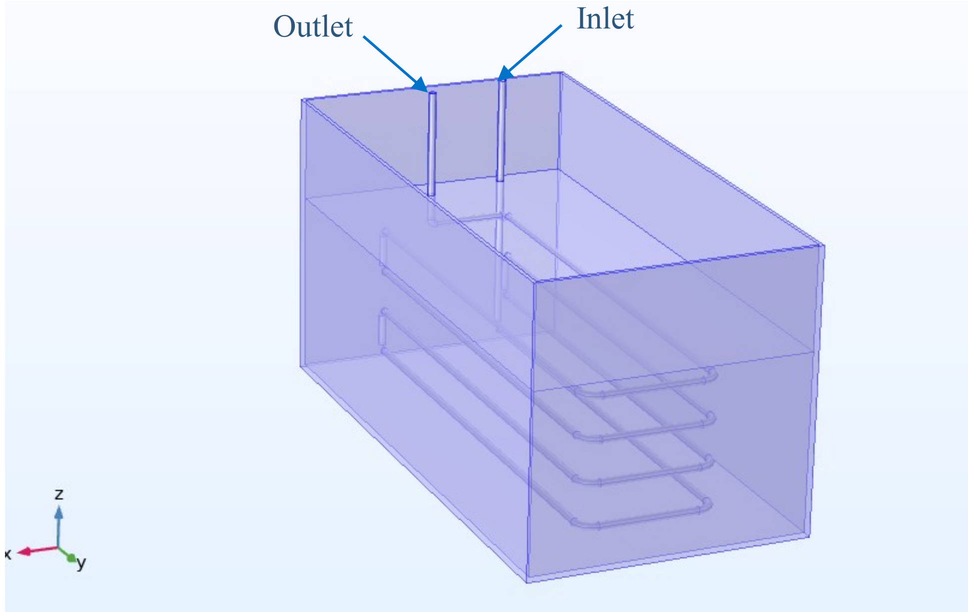


Figure: Prototype CAD on COMSOL software

Prototype Meshing

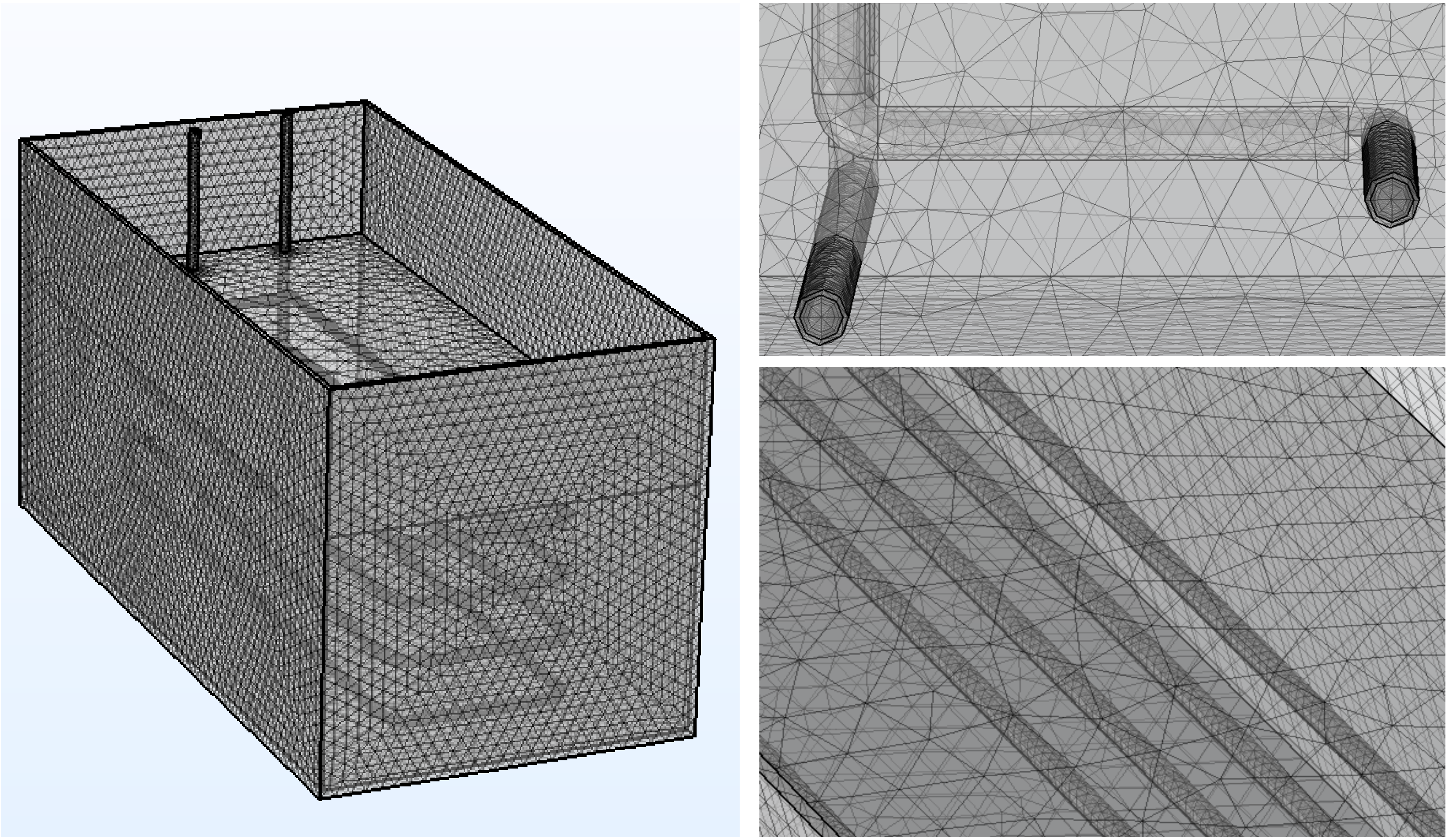


Figure: ASU Prototype Meshing

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.

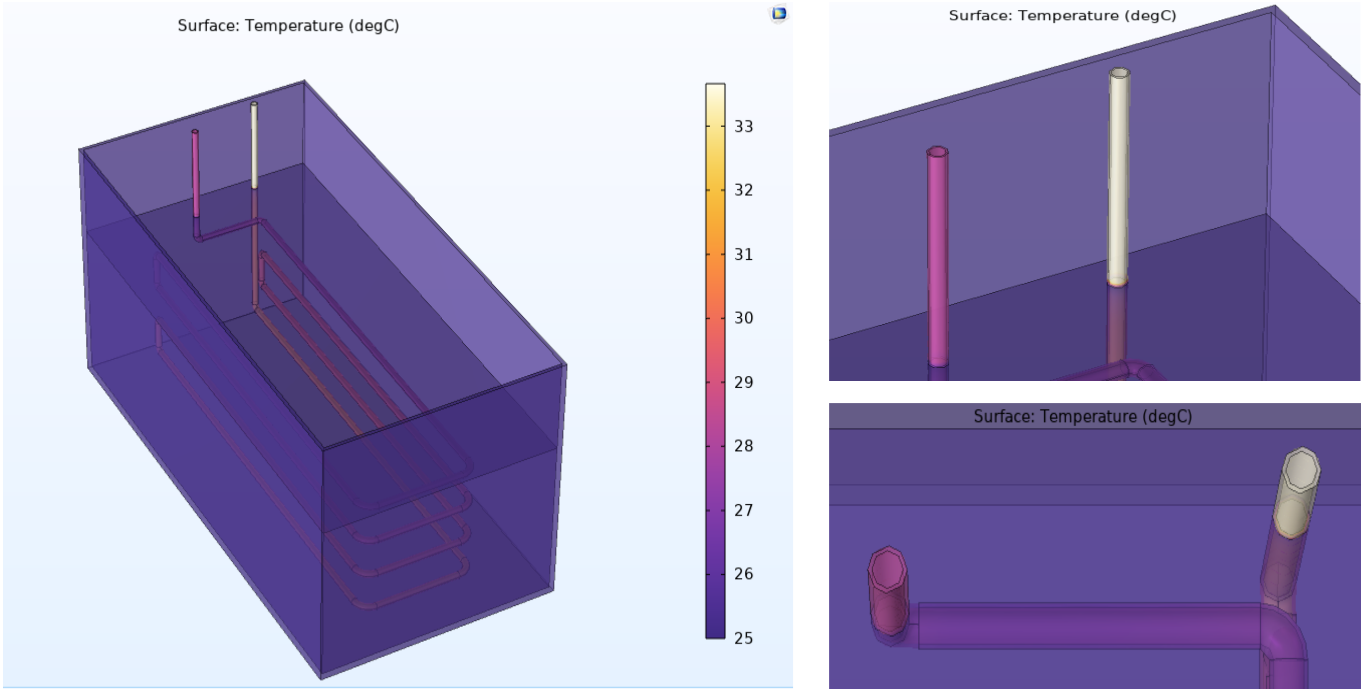


Figure: Steady state solution - Temperature distribution (°C)

Prototype Steady state solution

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

$$T_{out} = 28.896\ °C$$

And since the inlet fluid temperature is $33.5\ °C$ and the undistributed ground temperature is $25\ °C$, then the simulated effectiveness will be:

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

And the temperature difference is:

$$\Delta T = 33.5 - 28.896 = 4.604\ °C$$

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 $°C$
- 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

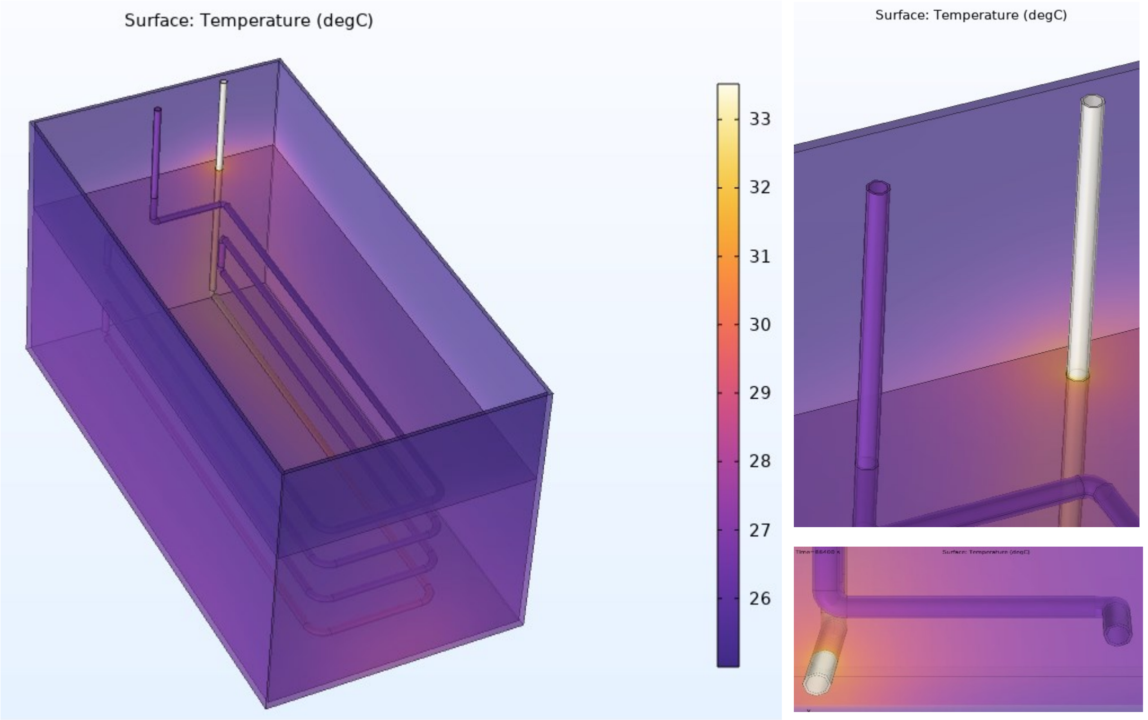


Figure: Transient solution after passing 24 hours- Temperature distribution (°C)

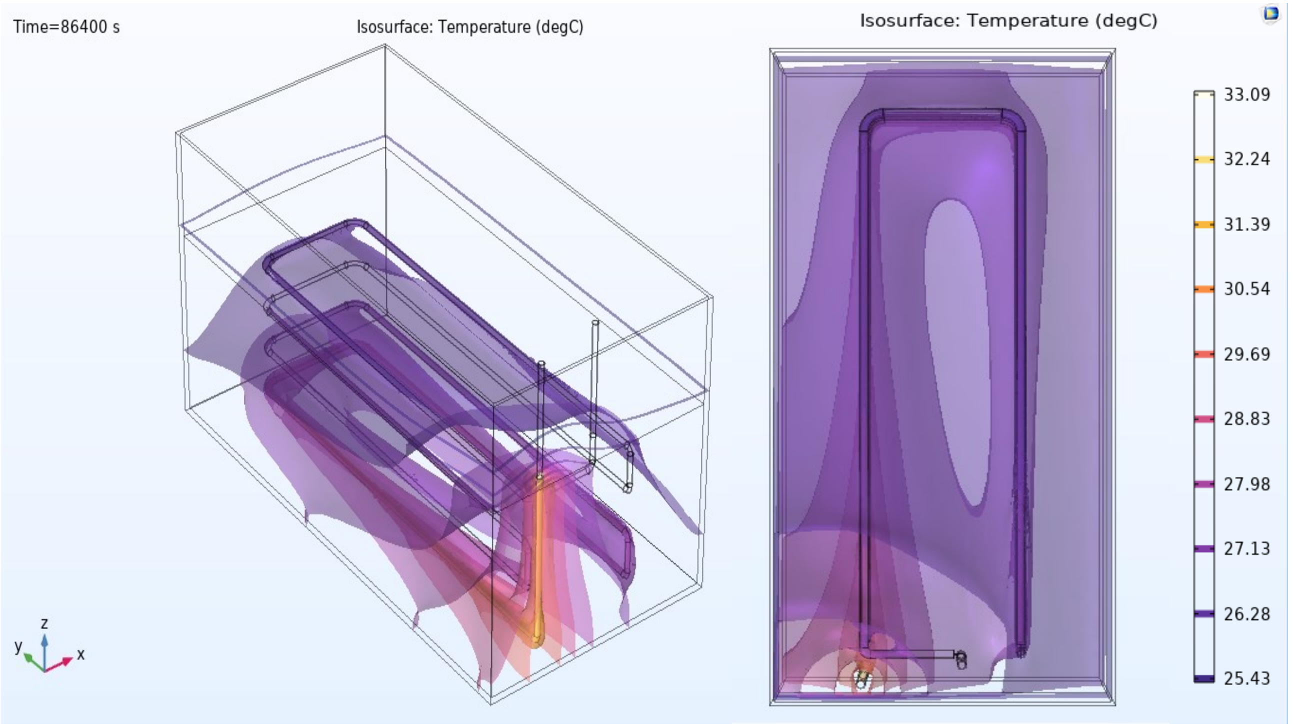


Figure: Isothermal Contours of prototype after 24 hours

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:

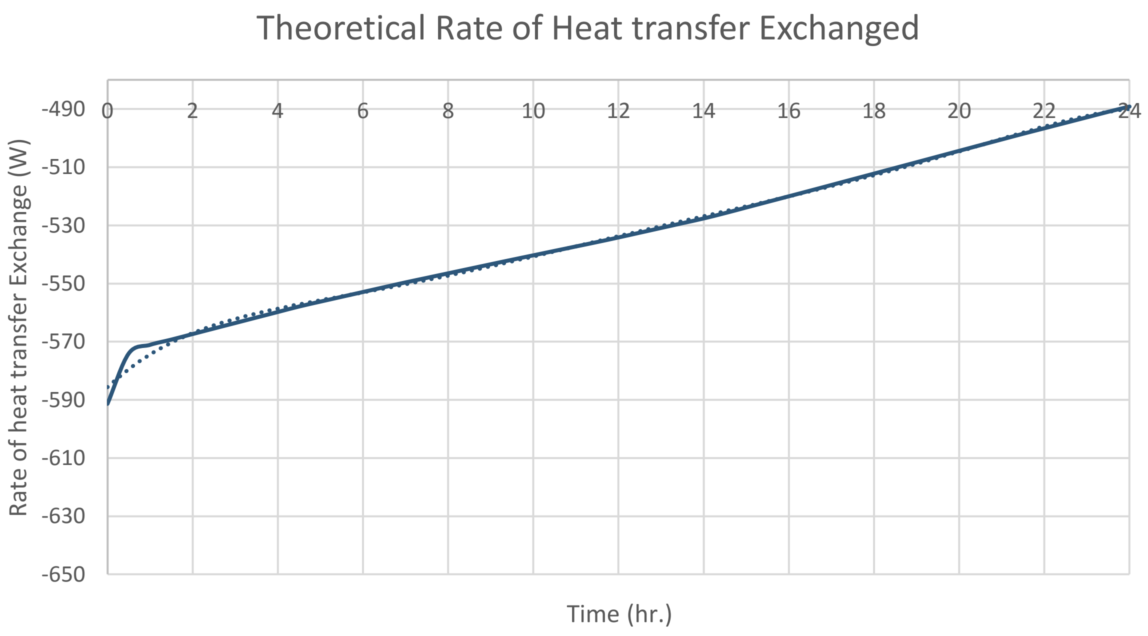


Figure: Rate of heat transfer Exchange Vs Time - 24 hr. simulation

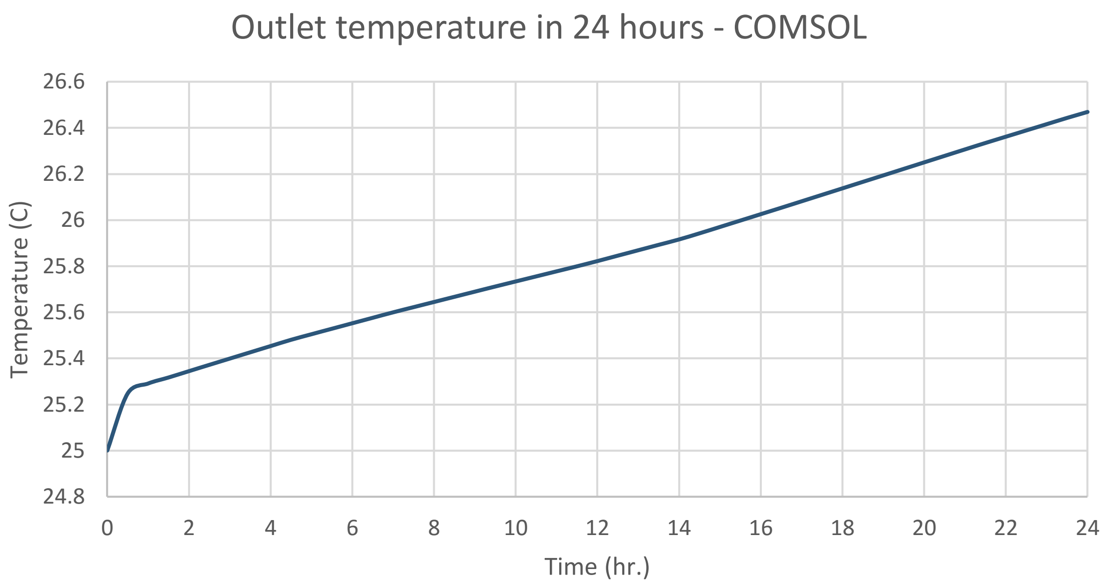
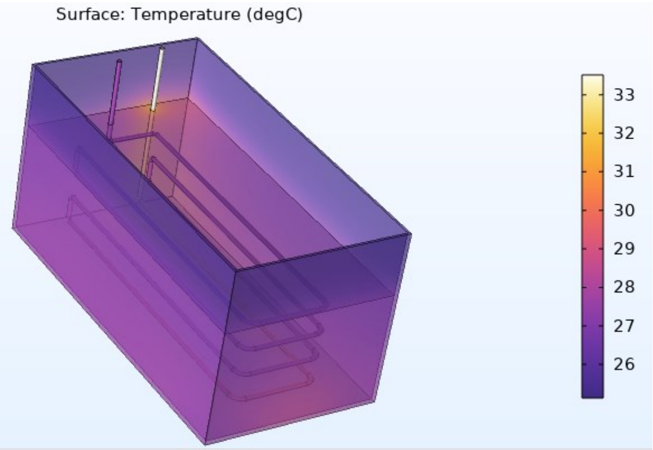


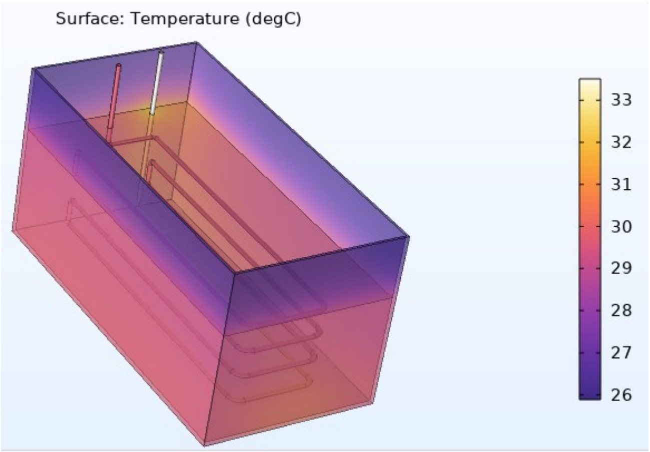
Figure: Temperature vs Time - 24 hr. simulation

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)

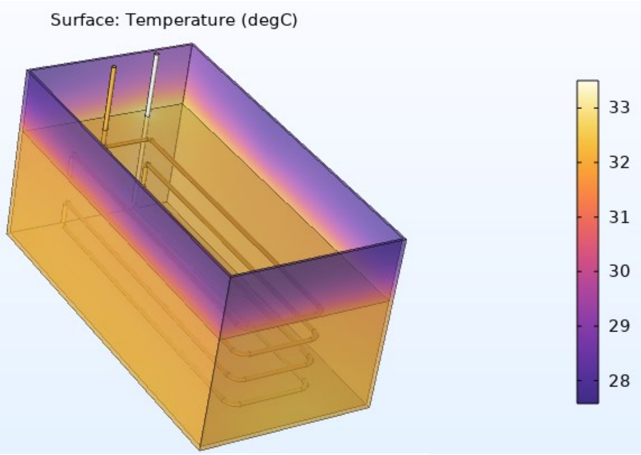
30-day time interval Results



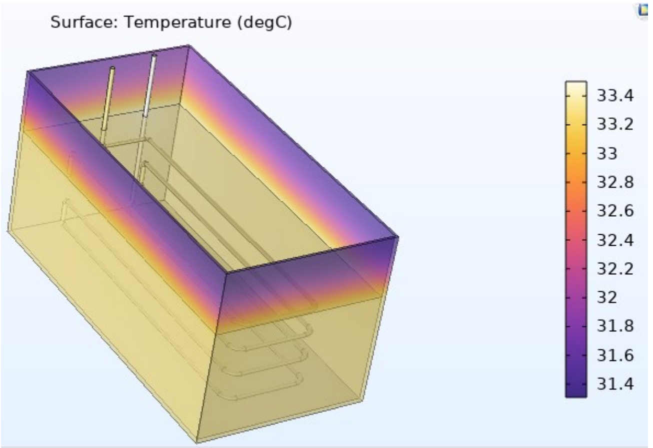
After 2 days



After 5 days



After 10 days



After 20 days

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:

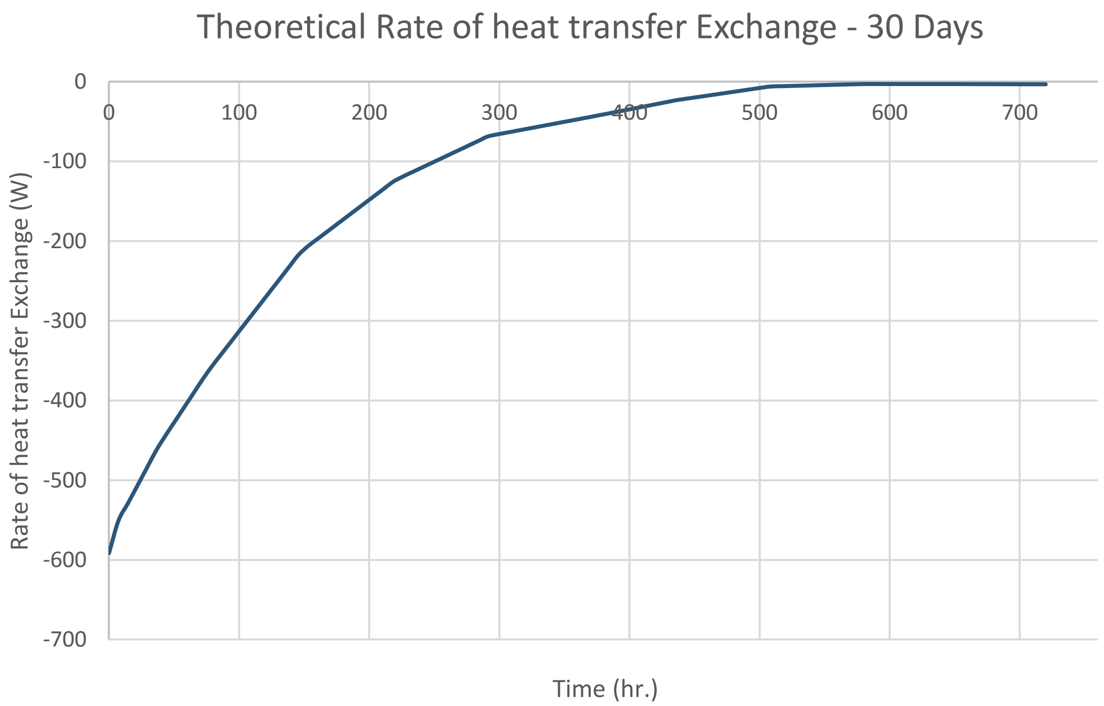


Figure: Rate of heat transfer Exchange Vs Time - 30 days' simulation

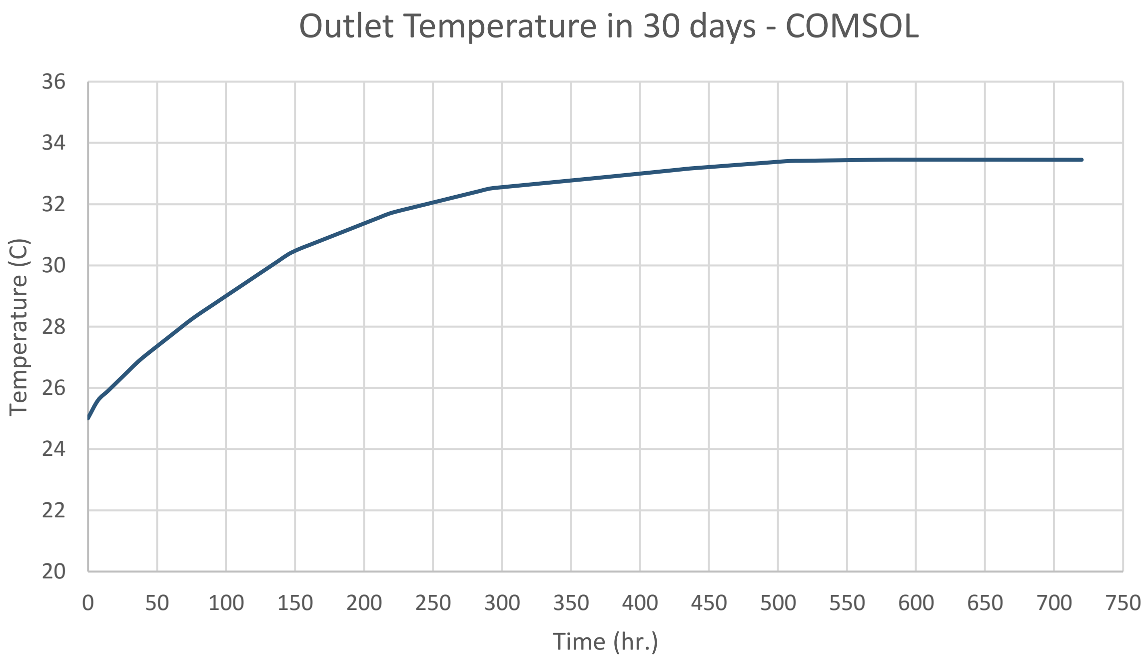
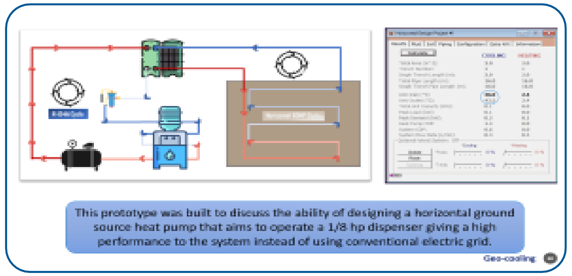
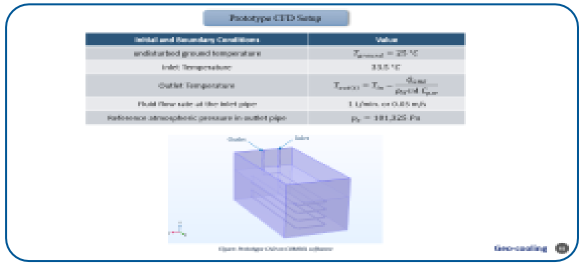


Figure: Temperature vs time - 30 days' simulation

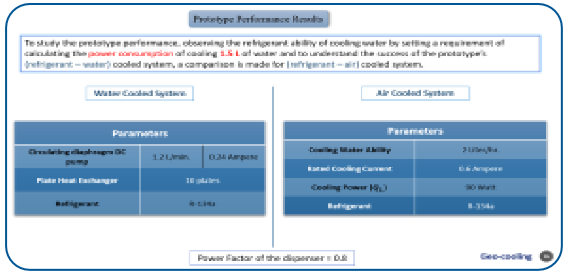
By using surface integration for power per unit area has a function of:
*(T-306.65)*spf.U*spf.rho*comp1.mat1.def.Cp(T)* as unit is in Watts (W)

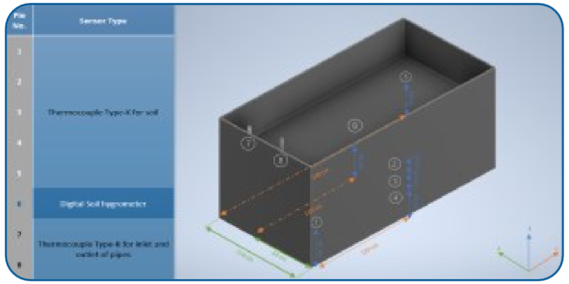
Prototype

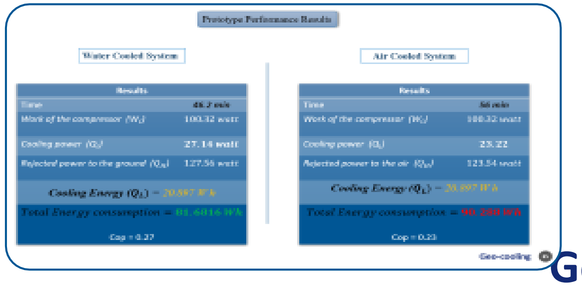

This prototype was built to discuss the ability of designing a horizontal ground source heat pump that aims to operate a 1/8 hp dispenser giving a high performance to the system instead of using conventional electric grid.
Geo-cooling


Prototype CFD Setup
Geo-cooling


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


Prototype Performance Results
Water Cooled System
Air Cooled System
Parameters
Geo-cooling


Sensor Type

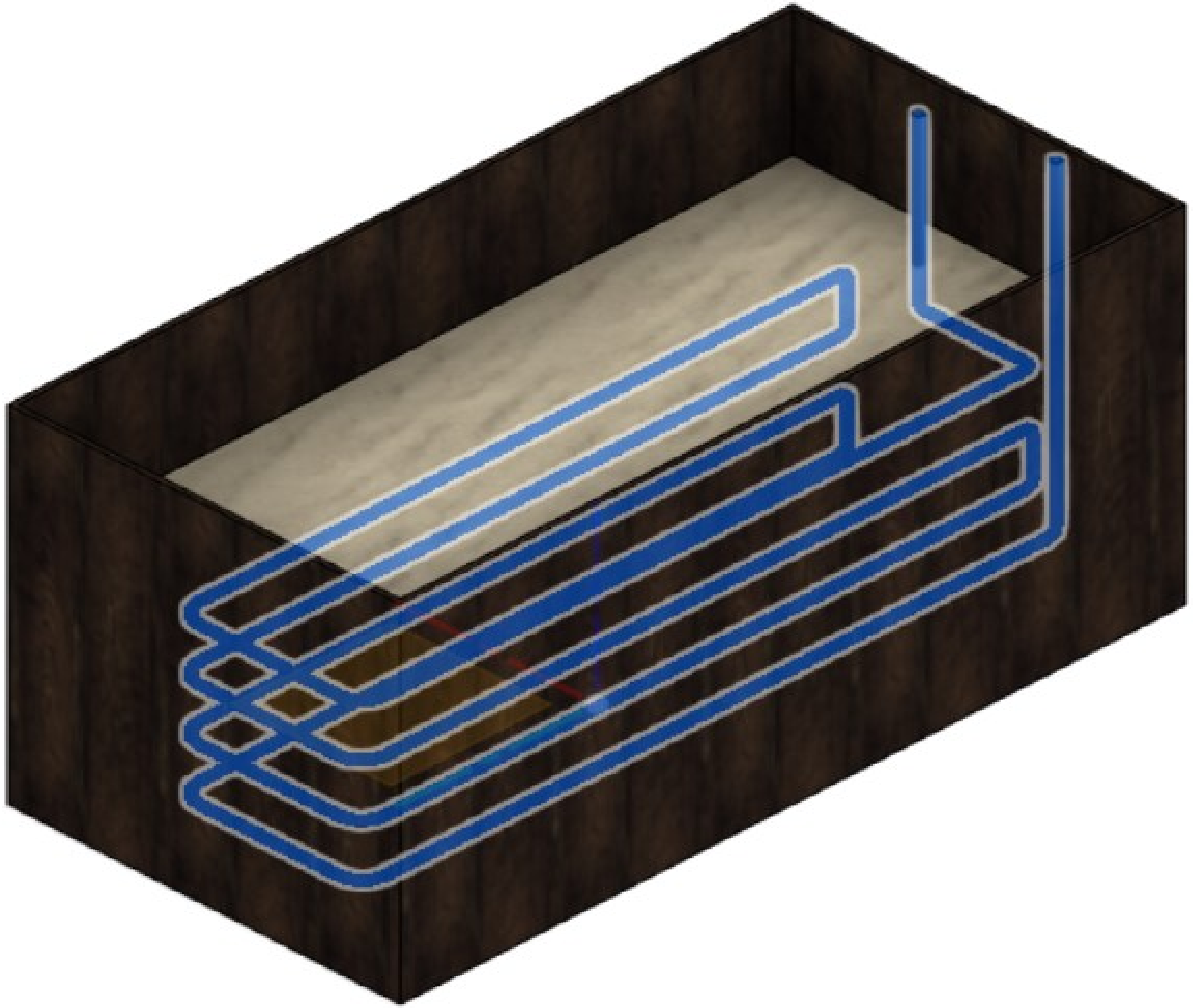

Prototype Performance Results
Water Cooled System
Air Cooled System
Results
Geo-cooling

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

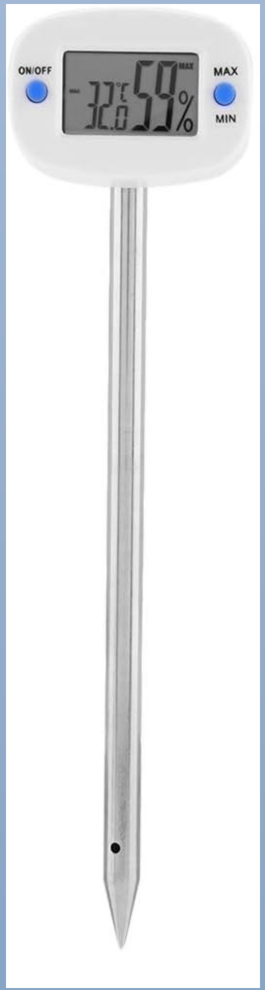
Components
Water Dispenser
Plate Heat Exchanger
Soil trench
Water circulating pump
UPVC U-shaped loops
Thermocouples
Glass wool insulation



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

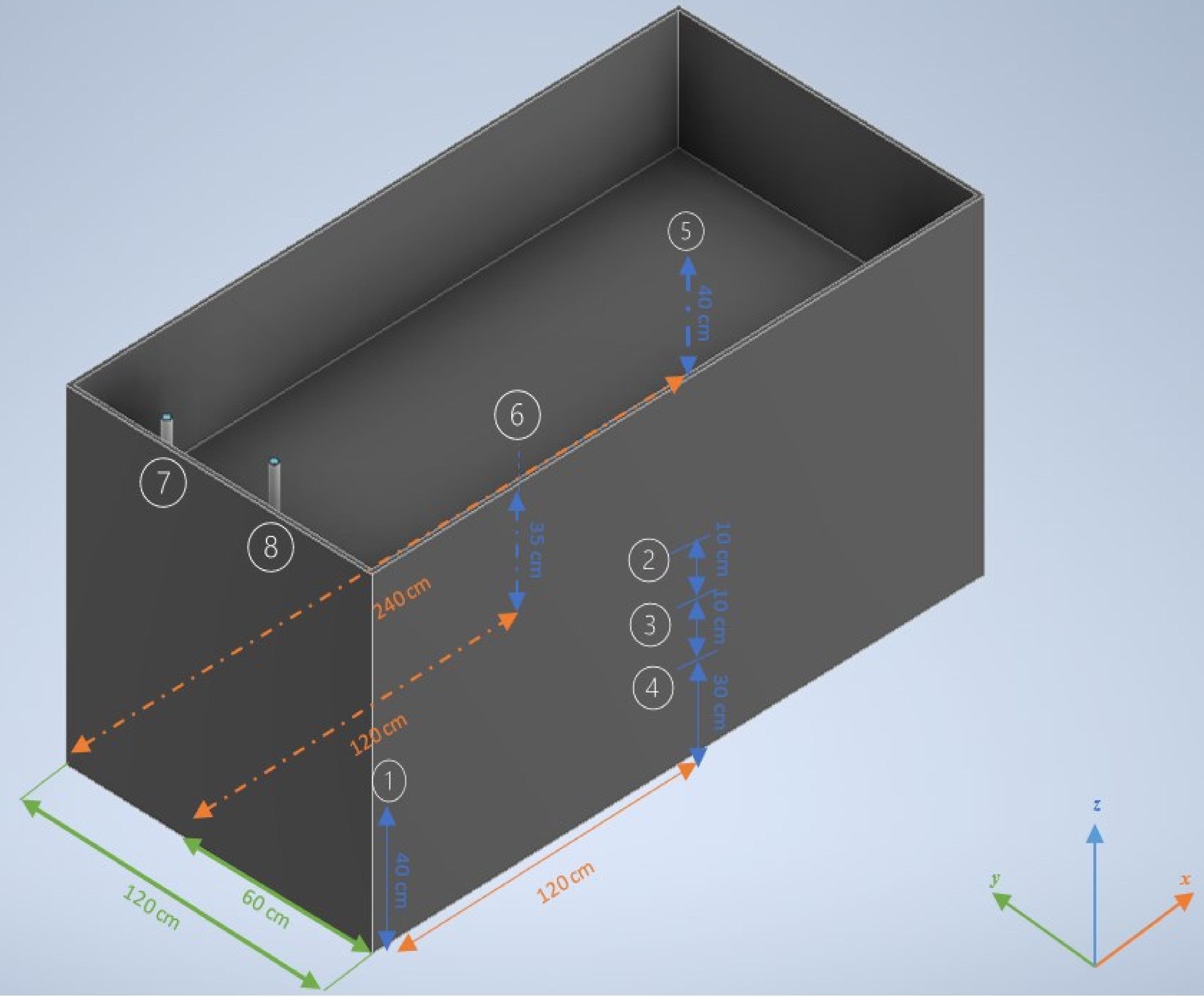
Parameters		
Circulating diaphragm DC pump	1.2 L/min.	0.24 Ampere
Plate Heat Exchanger	10 plates	
Refrigerant	R-134a	

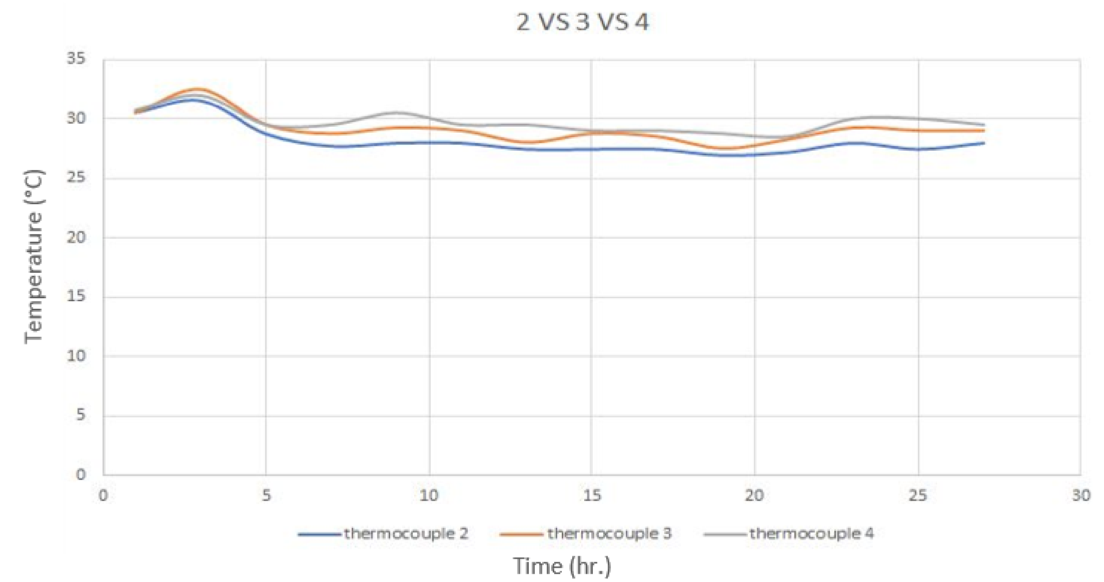
Air Cooled System

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

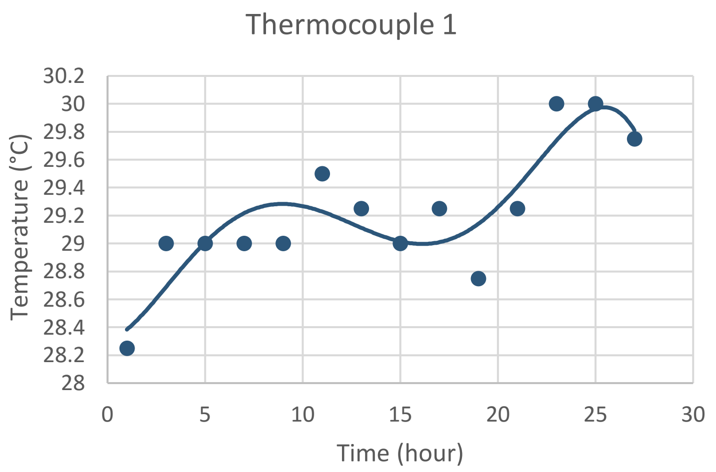
Pin No.	Sensor Type
1	Thermocouple Type-K for soil
2	
3	
4	
5	
6	Digital Soil hygrometer
7	Thermocouple Type-K for inlet and outlet of pipes
8	

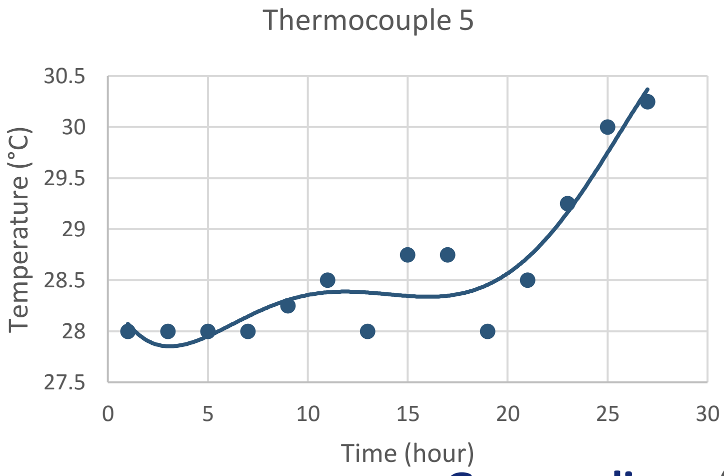




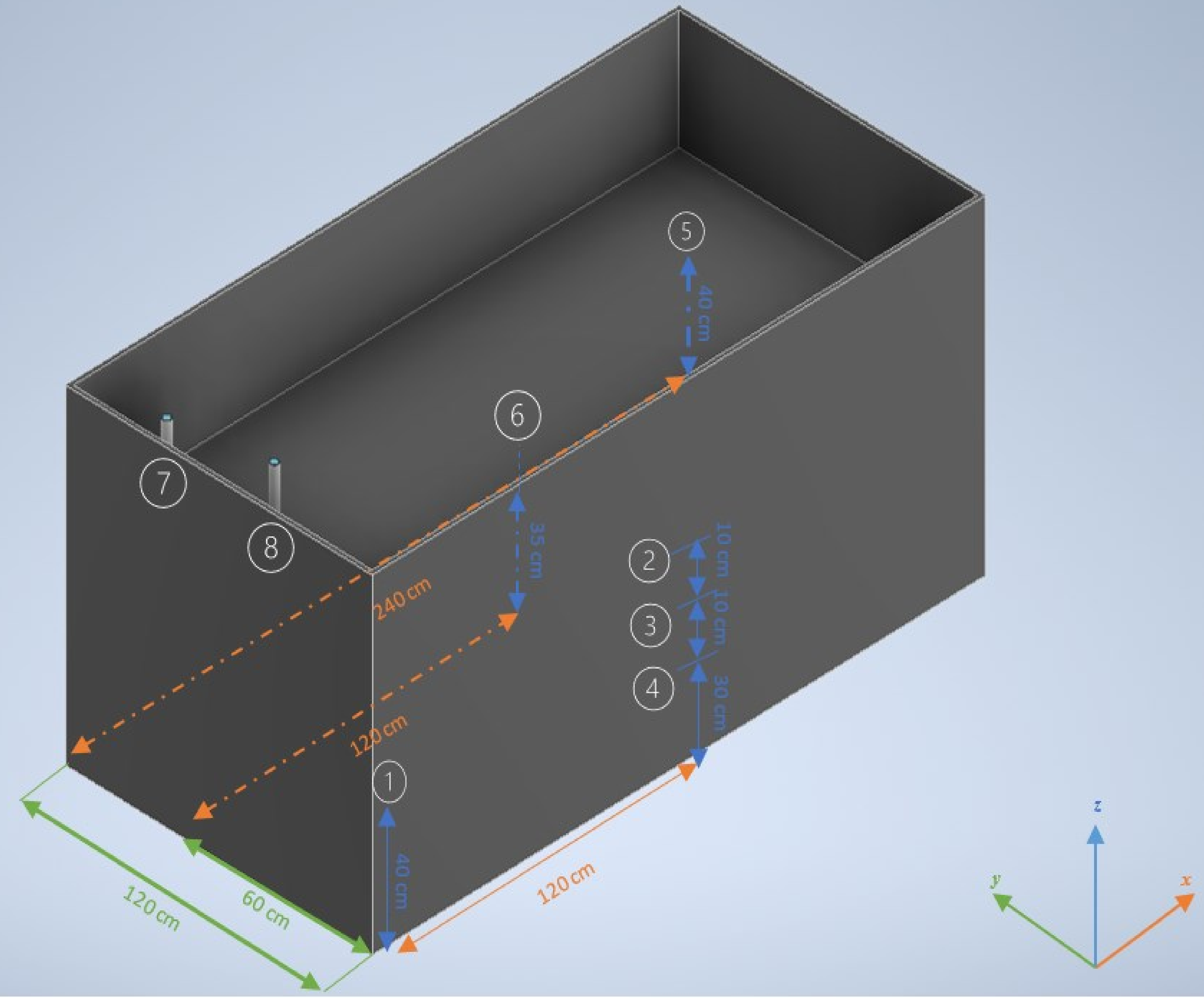
For every *10 cm* in the vertical direction, there is a temperature difference of about $[0.5 - 1.5]\ °C$

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

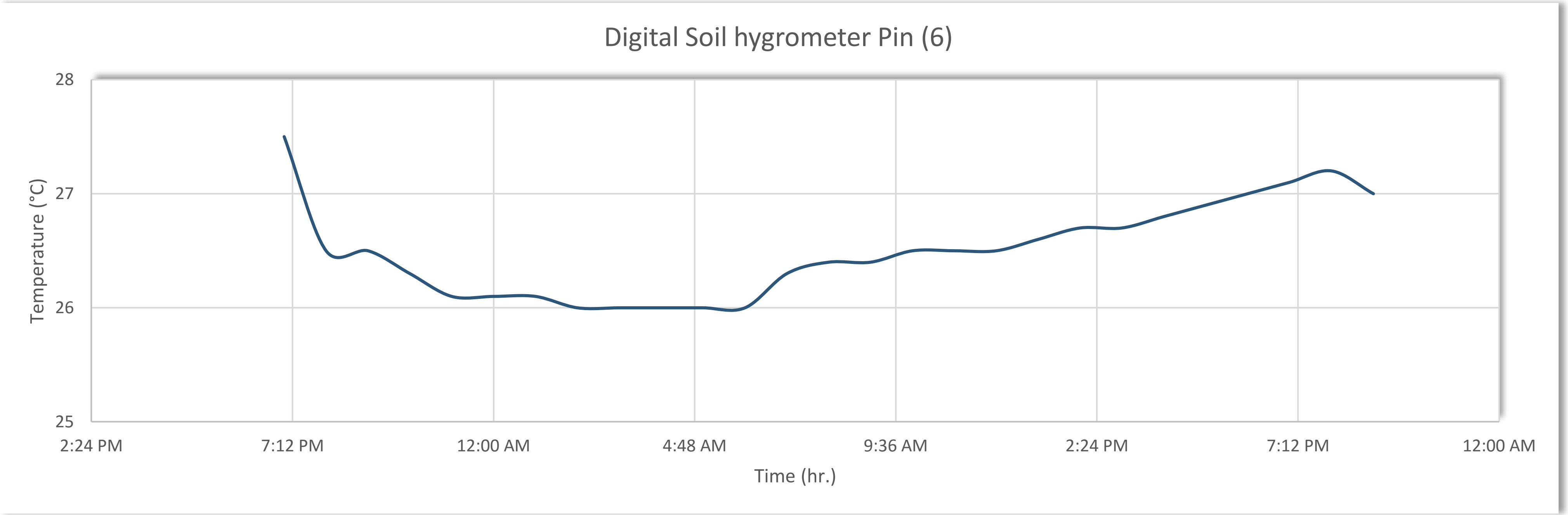




Pin No.	Sensor Type
1	Thermocouple Type-K for soil
2	
3	
4	
5	
6	Digital Soil hygrometer
7	Thermocouple Type-K for inlet and outlet of pipes
8	



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:

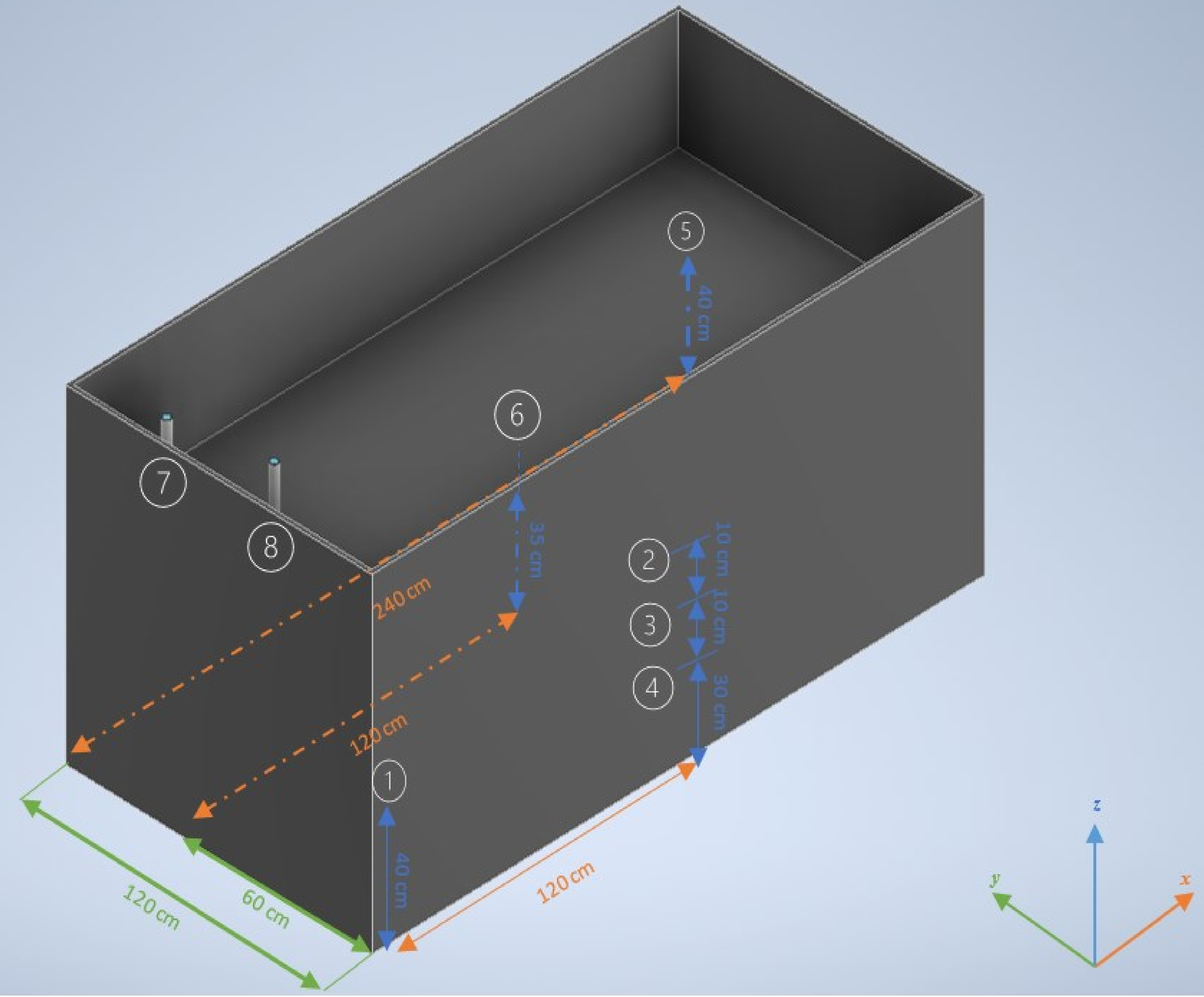
Experimental diffusion time=0.5 day

For knowing thermal diffusivity = 0.058 m^2/day

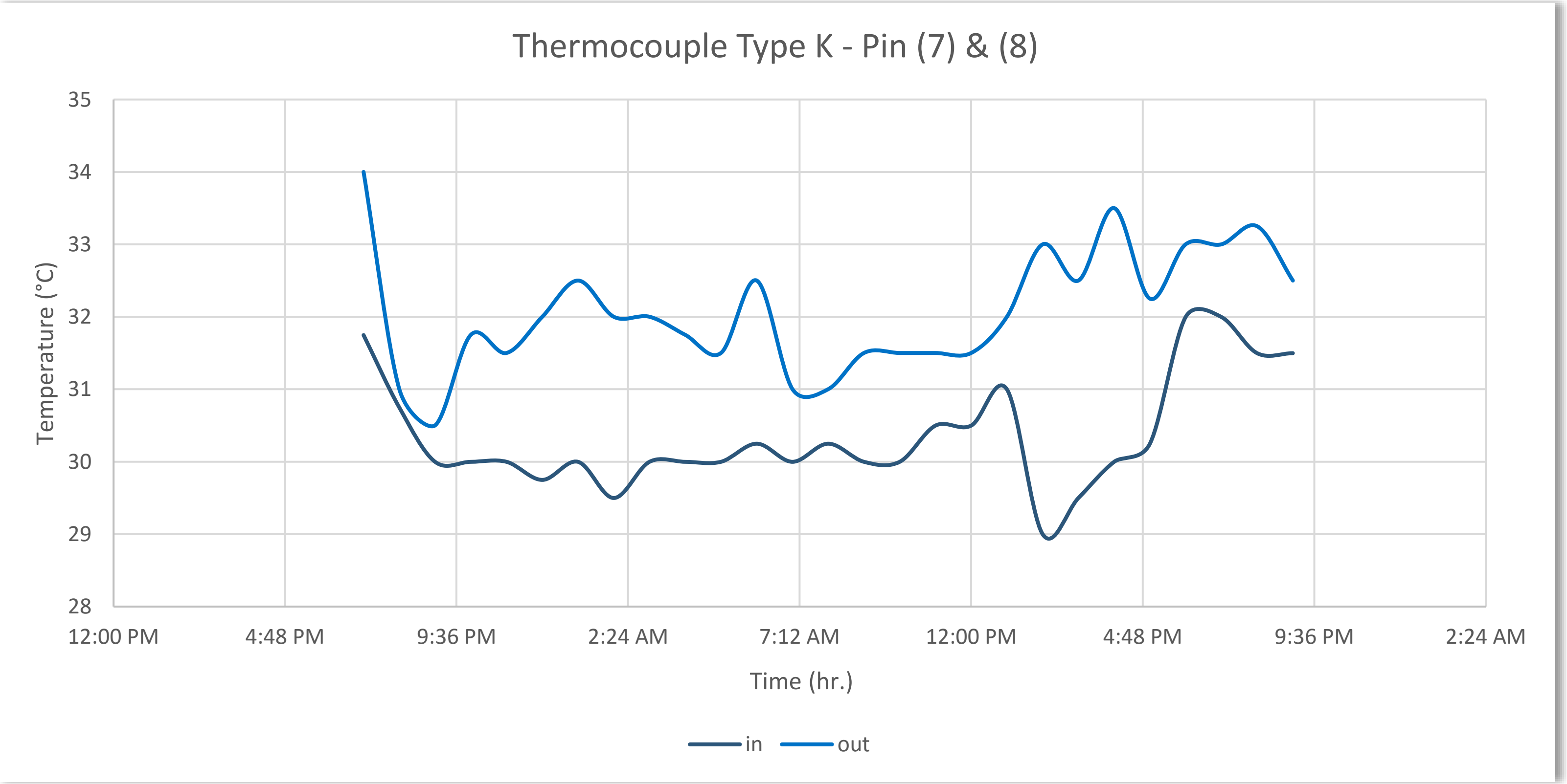
Theoretical Diffusion time=(Characteristic Length)^2/(Thermal Diffusivity)=(0.18)^2/0.058=0.558 day

% 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	



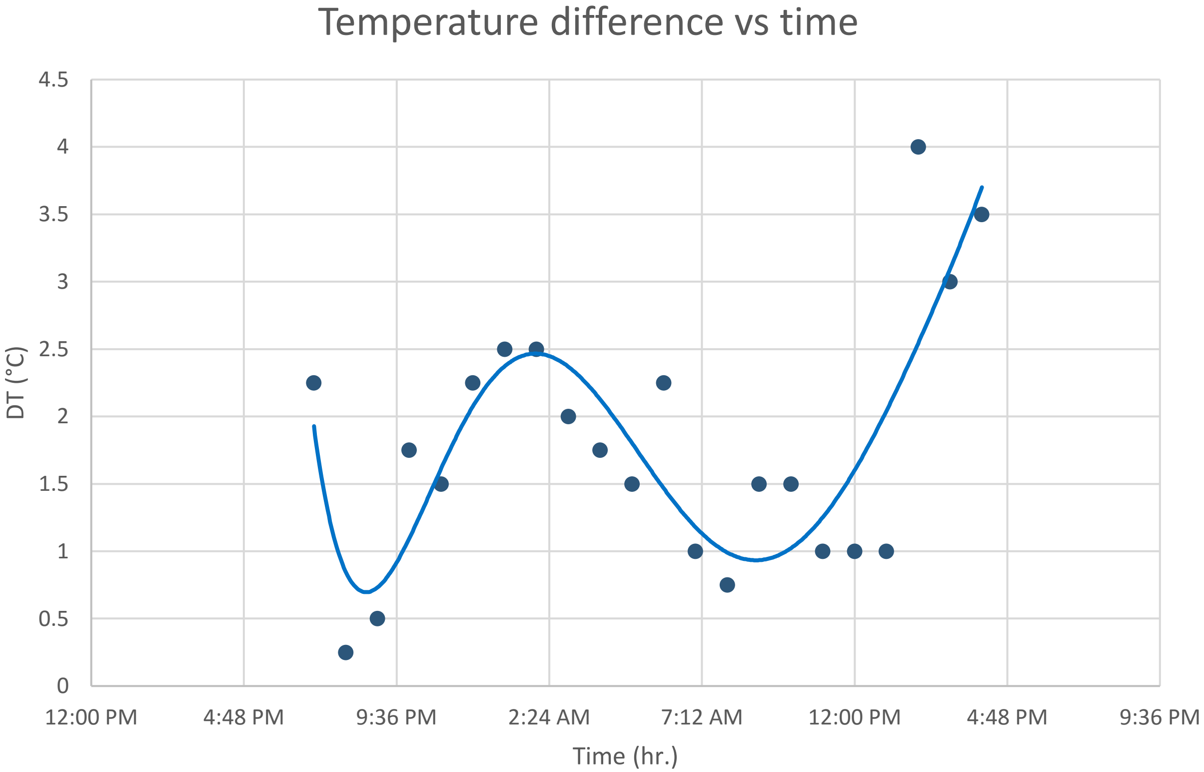
Pin (7) and Pin (8) represents the **inlet** and **outlet** water temperature entering and exiting from the heat pump, where results have shown that:

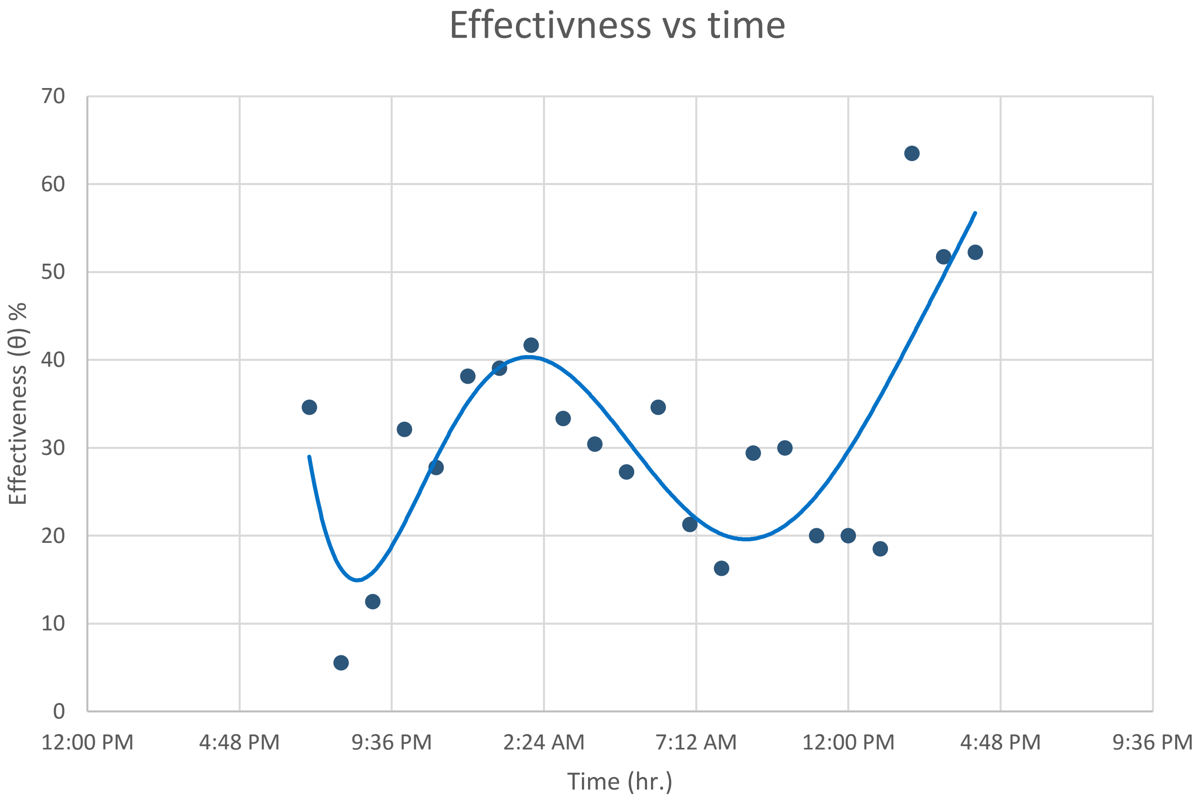


To explain the value of the temperature readings, the effectiveness of the ground heat exchanger should be measured

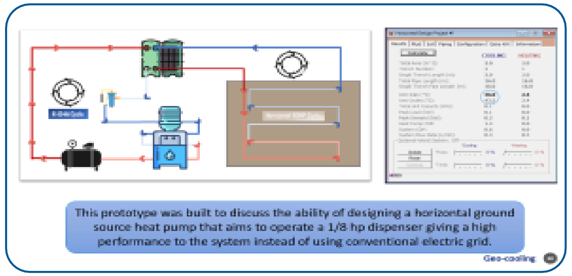
$$\theta\ (\%) = \frac{T_{in} - T_{out}}{T_{in} - T_{ground}} \times 100$$

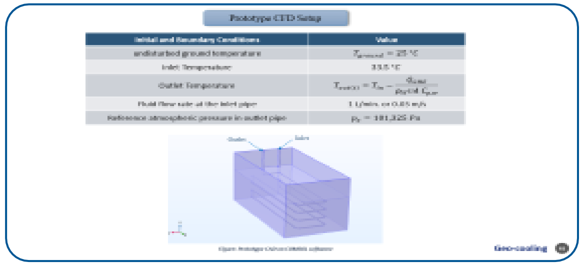
By considering T_{ground} is a function of pin (6), then from the following graph, valuable data can be analysed to understand the performance of the prototype system:



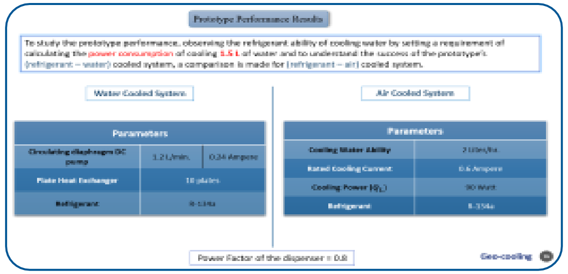


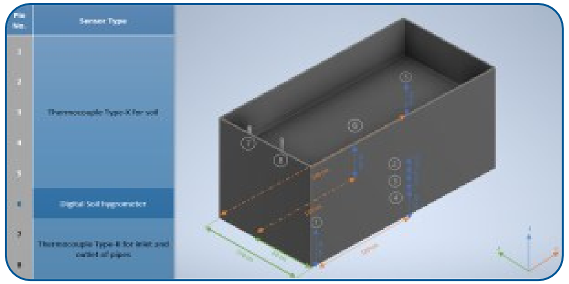
Prototype

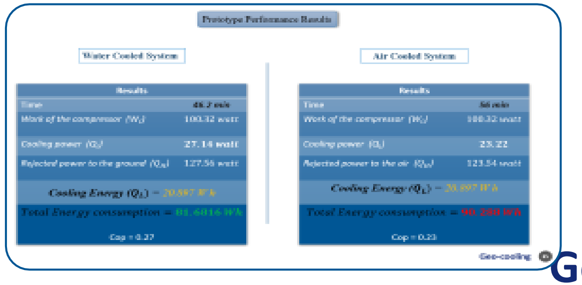

This prototype was built to discuss the ability of designing a horizontal ground source heat pump that aims to operate a 1/8 hp dispenser giving a high performance to the system instead of using conventional electric grid.
Geo-cooling


Prototype CFD Setup
Geo-cooling


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


Prototype Performance Results
Water Cooled System
Air Cooled System
Parameters
Geo-cooling




Prototype Performance Results
Water Cooled System
Air Cooled System
Results
Geo-cooling

Prototype Performance Results

Water Cooled System

Results	
Time	***46.2 min***
Work of the compressor (W_C)	$100.32\ watt$
Cooling power (Q_L)	$\mathbf{27.14\ watt}$
Rejected power to the ground (Q_H)	$127.56\ watt$
$\boldsymbol{Cooling\ Energy\ (Q_L)} = 20.897\ W\ h$	
$Total\ Energy\ consumption = \mathbf{81.6816\ Wh}$	
Cop = 0.27	

Air Cooled System

Results	
Time	***56 min***
Work of the compressor (W_C)	$100.32\ watt$
Cooling power (Q_L)	$\mathbf{23.22}$
Rejected power to the air (Q_H)	$123.54\ watt$
$\boldsymbol{Cooling\ Energy\ (Q_L)} = 20.897\ W\ h$	
$Total\ Energy\ consumption = \mathbf{90.288\ Wh}$	
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

Thank You