Potential of Geothermal Systems for Energy Saving in Qatar

[1]Mohamad Kharseh, [2]Abdulrhman Alzaeem

[1]Willy's Clean Tech AB, Sweden

[1-2]Qatar University, Qatar

[1]kharseh@qu.edu.qa

[1]mohamad@wctab.se

[2]a.b_zaeem@hotmail.com

Doha 2013 05 27

Presentation structure

1. Energy Survey

   Why

2. Geothermal Energy

   How

3. Aims

   Findings

4. Future Work

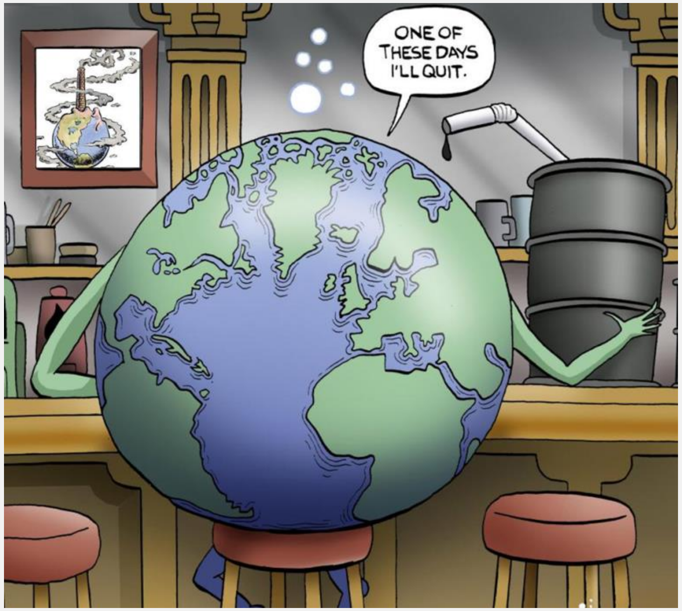
   International collaboration

Energy Survey

- ✓ World# $>15 \cdot 10^{10}$ MWh/year
  - 22 MWh/year.Capita
- ✓ Qatar# $4.4 \cdot 10^{8}$ MWh/year
  - 225 MWh/year.Capita
- ✓ >86 Mbbl/day oil consumption

Of total energy used
World
Fossil # 85%
Oil # 40%

Qatar
Fossil # 100%



Climate Consequences

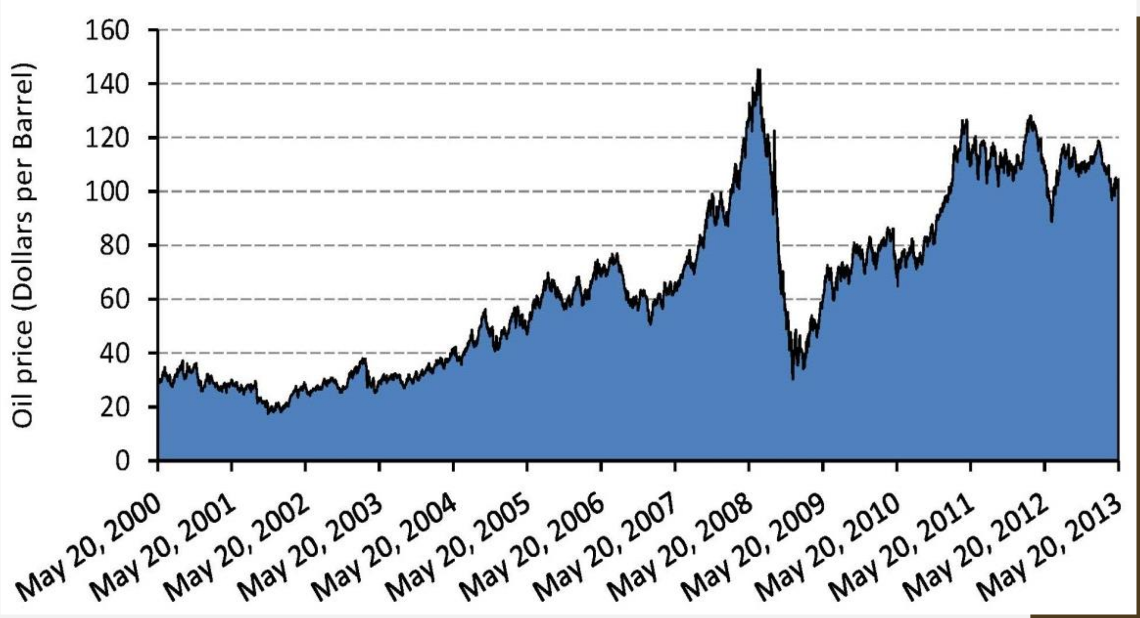
annual emission of CO_2

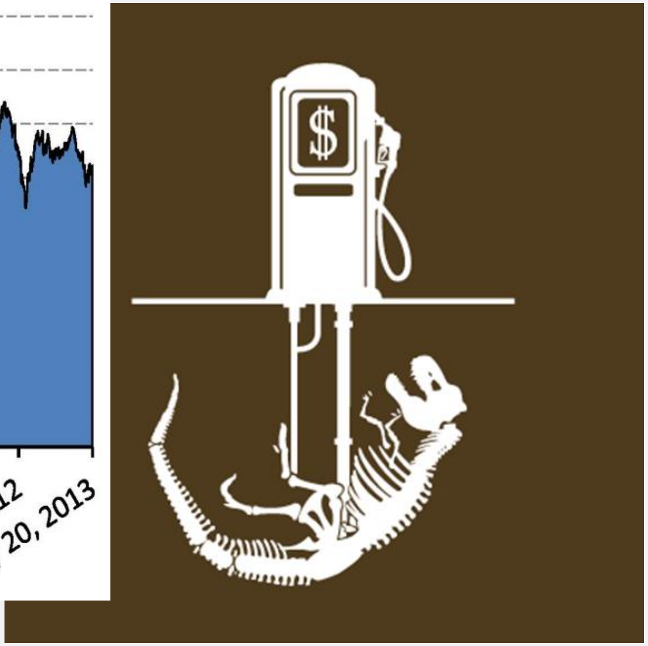
- World >30 000 Mtons/y
  - **4** tons/capita/y
- Qatar >65 Mtons/y
  - **32** tons/capita/y

X8

Economic Consequences

-> ***The oil price will increase and become more unstable***





Thus

More energy= more CO_2 = more extreme climate = more unstable economy

Utilizing renewable energy resources is urgent to have sustainable future.

How

Geothermal Energy

Geothermal refers to existing of energy under our feet.

It's clean and renewable since the tapped heat is continuously renovated by natural processes

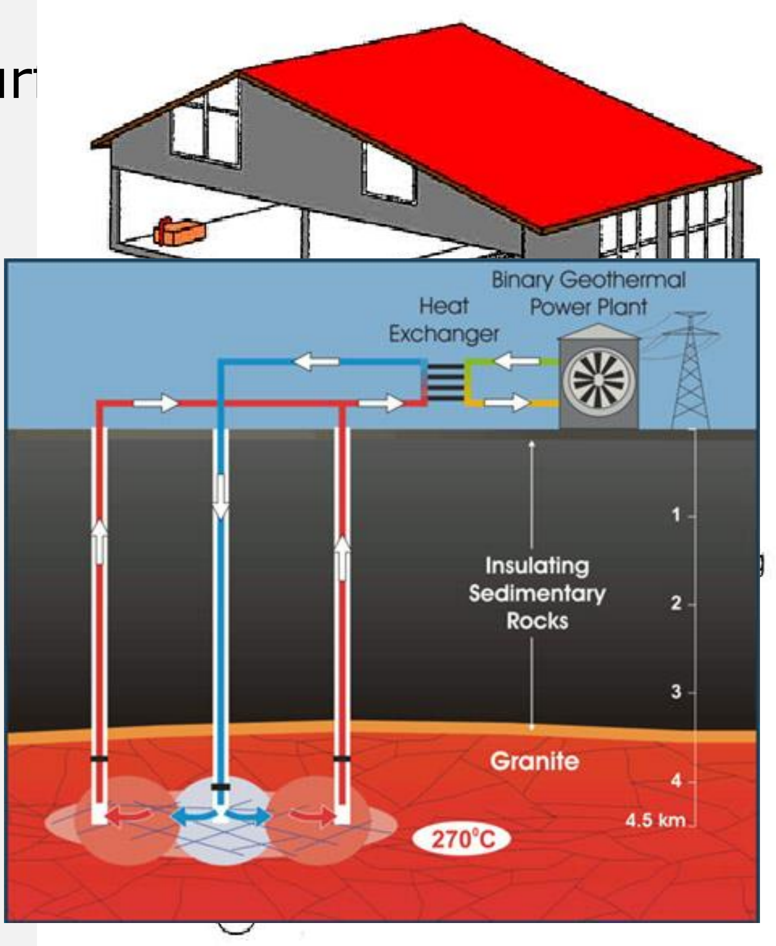
Based on the depth below the Earth's sur of GE:

1. Shallow system (hundreds meters)

   <u>Heat comes from above</u>

2. Deep system (3-10 km)

   <u>Heat comes directly from magma</u>



How

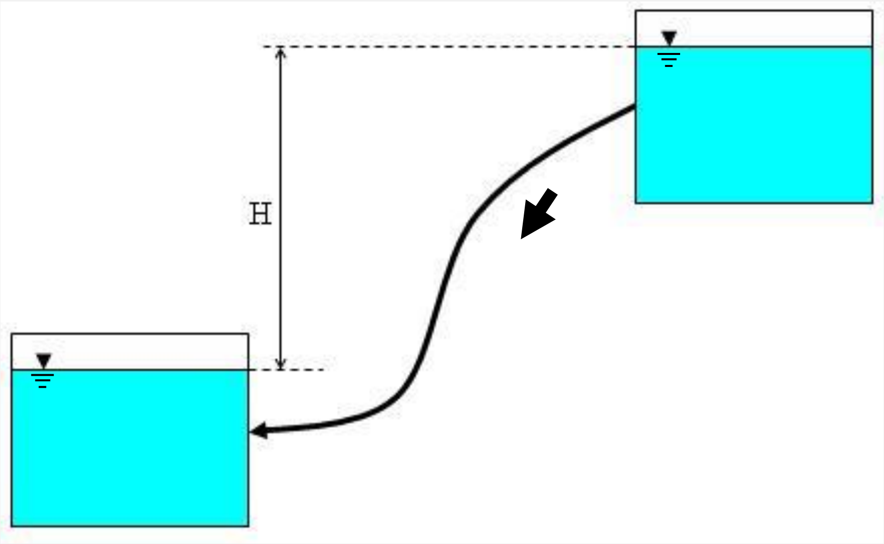
1. Shallow System

It can be used anywhere in the world (With **sufficient** annual temperature amplitude) for heating and cooling purposes by means of heat pump to save energy and environment.

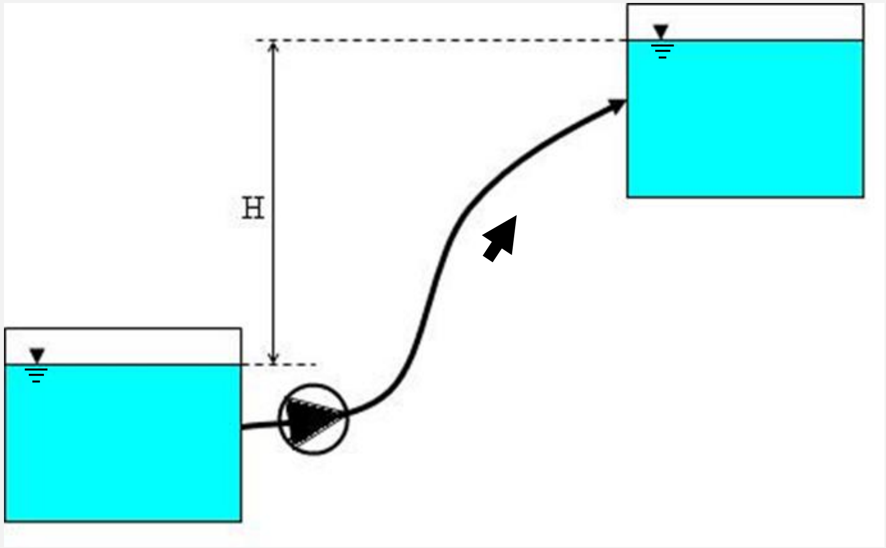
current installed capacity >70 GW

with annual growth of >12%

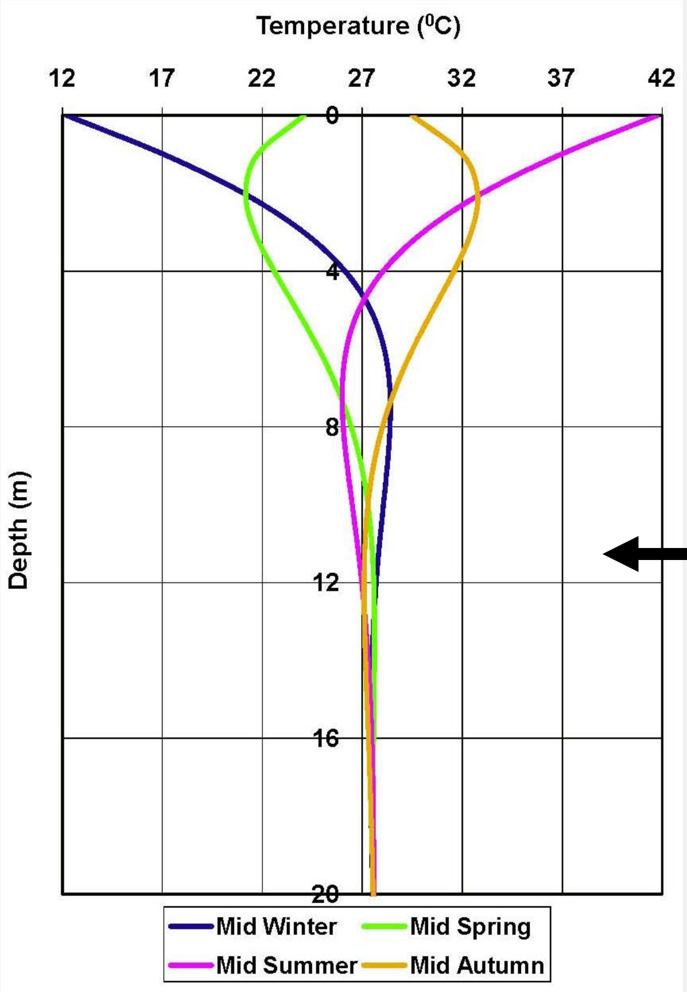
Concept of GSHP

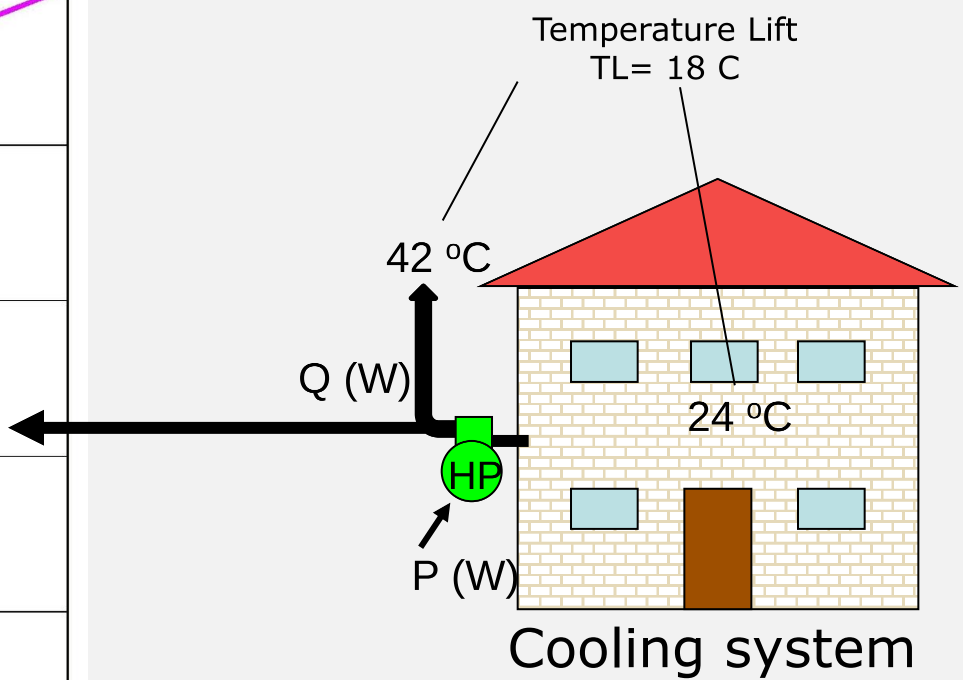


$$P \sim H$$



Concept of GSHP

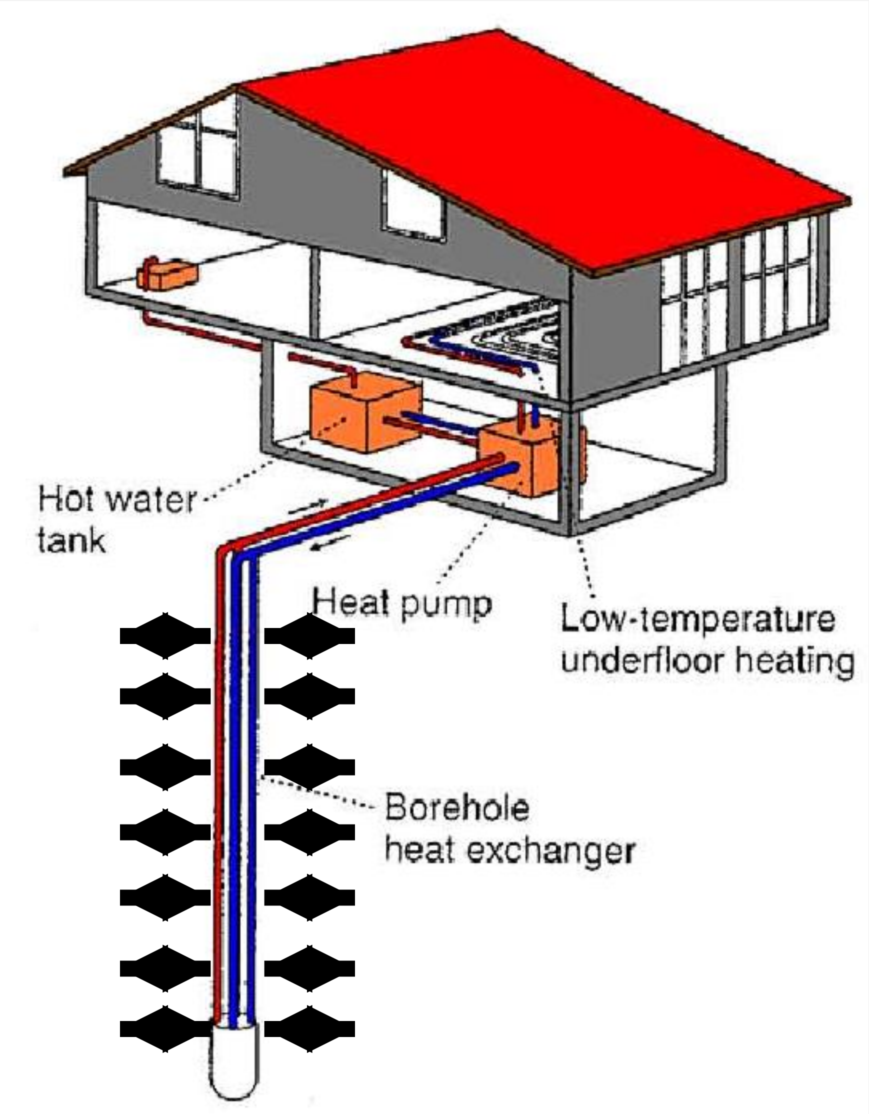




$$P \sim TL$$

Example of horizontal and vertical GSHP

- Heating mode
- Cooling mode

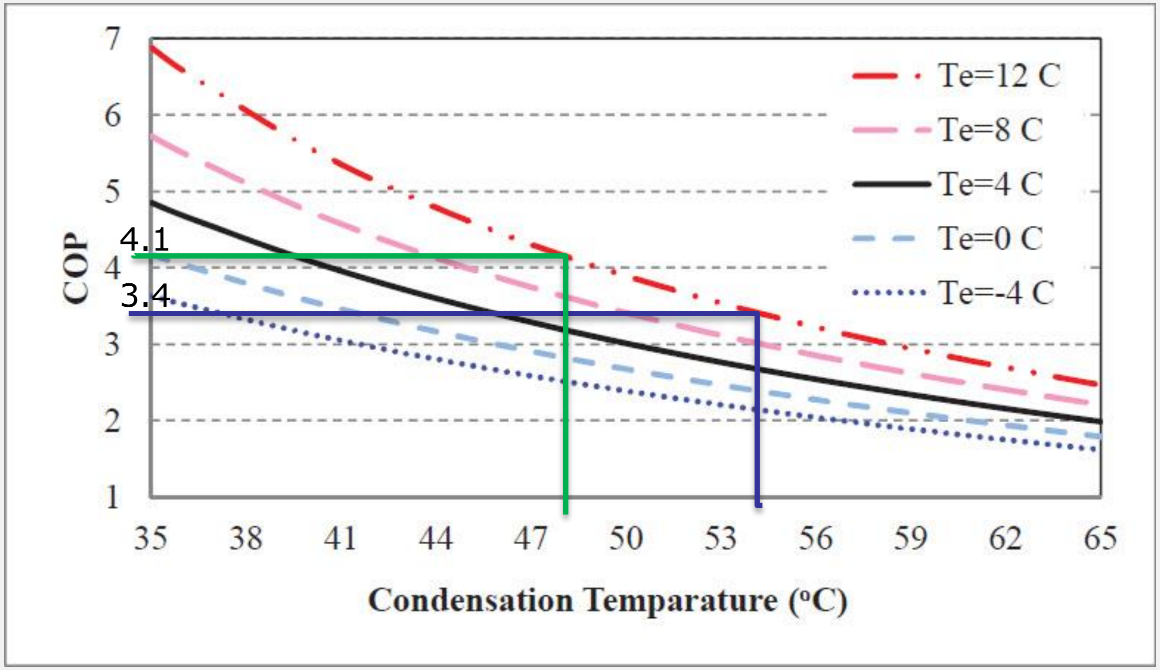


How

Benefit of GSHP

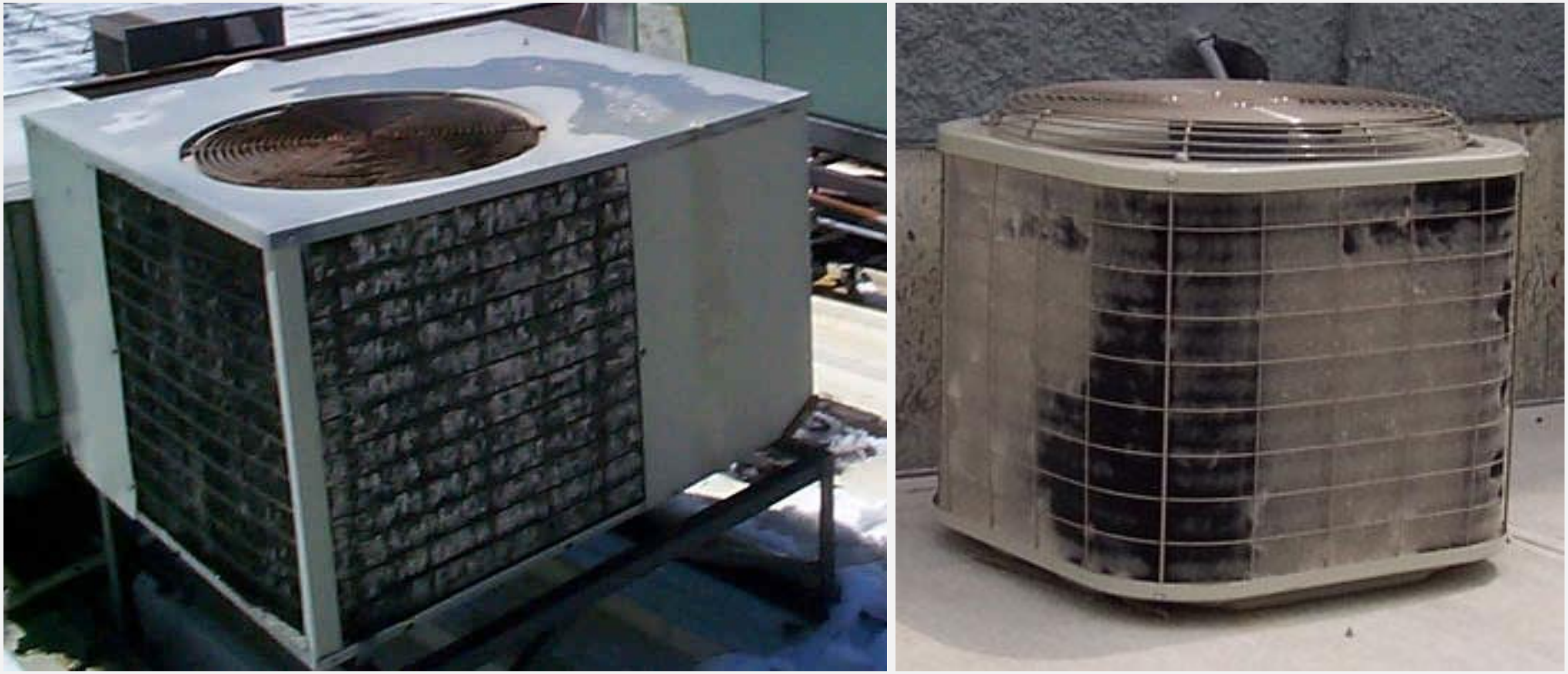
Smaller temperature lift leads to improve the COP

COP = cooling load/driving energy



How

Additional benefits of GSHP



- ❖ Stable operation conditions
- ❖ Eliminating outdoor mechanical equipment,
  - more reliable, reduces maintenance, and longer lifetime

How

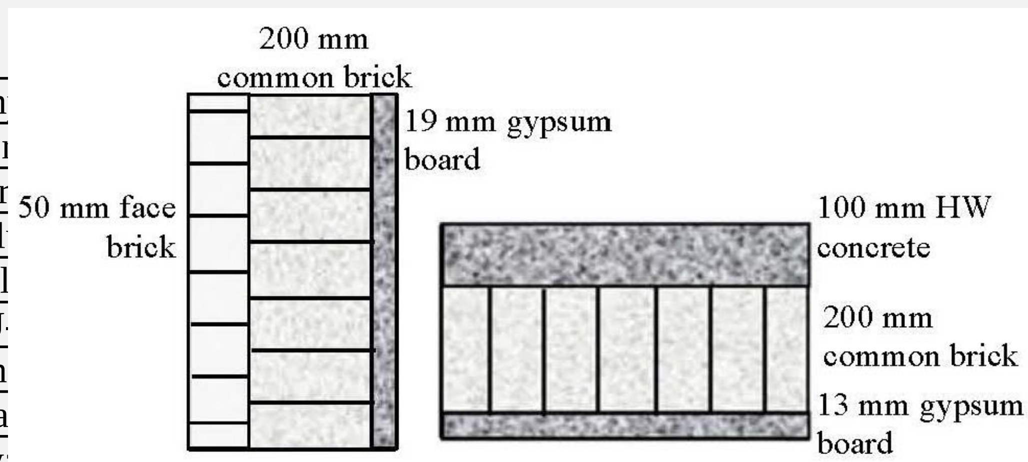
GSHP in Qatar

Three steps were taken:

1. show the contribution of ground source heat pumps in saving energy and environment at Qatar conditions
2. The possibility of improving GSHP performance at operation conditions of Qatar
3. The economic viability of GSHP

Case study

In order to show the contribution of GSHP in saving energy and environment, a common type of house located in Doha, was chosen as case study. The model house consists of four identical external walls, 12 m in length and 3 m in height, with a total window opening of 5 m^2 on each wall.



Indoor tem				58
Throttling r				46
Building ar				6
Wall U-val				27
Roof U-val				0.45
Window U-				0.45
Widows sh				2
Windows a				6
External wa		Building weight(kg/m^2)		500
space volume (m^3)	388.8		Roof	623
Wall heat capacity (kJ/kg.K)	0.864	Roof heat capacity (kJ/kg.K)		0.85

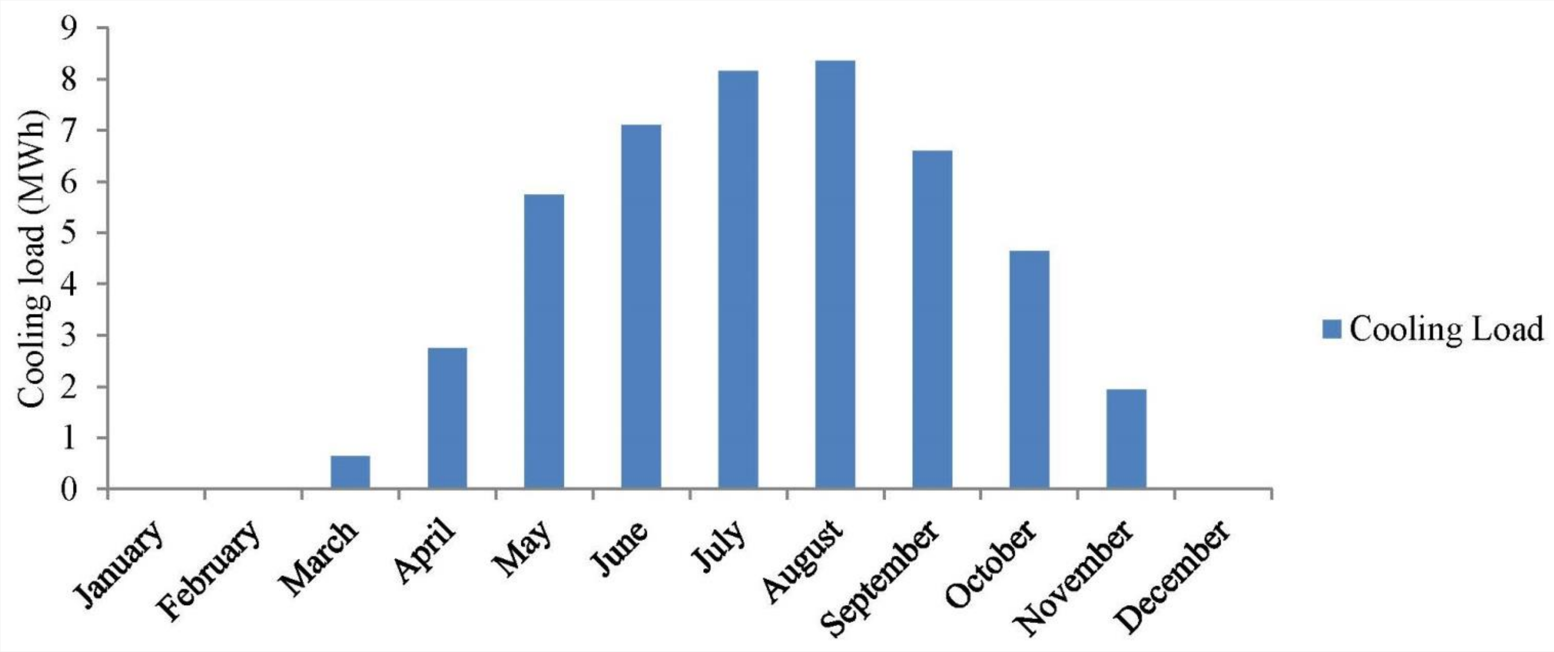
Cooling Load Calculation

The commercial model hourly analysis program (HAP) was used for the estimation of cooling load:

- developed by Carrier Corporation
- using ASHRAE calculations method
- hour-by-hour energy simulation

Cooling Calculation Results

Annual Cooling load (MWh)	45.93
Number of cooling hours (hours)	6205
Maximum cooling capacity (kW)	20.2
Time of occur max. cooling capacity	On 16 July At 15:00



Design borehole heat exchanger

Designing GSHP system means determination of:

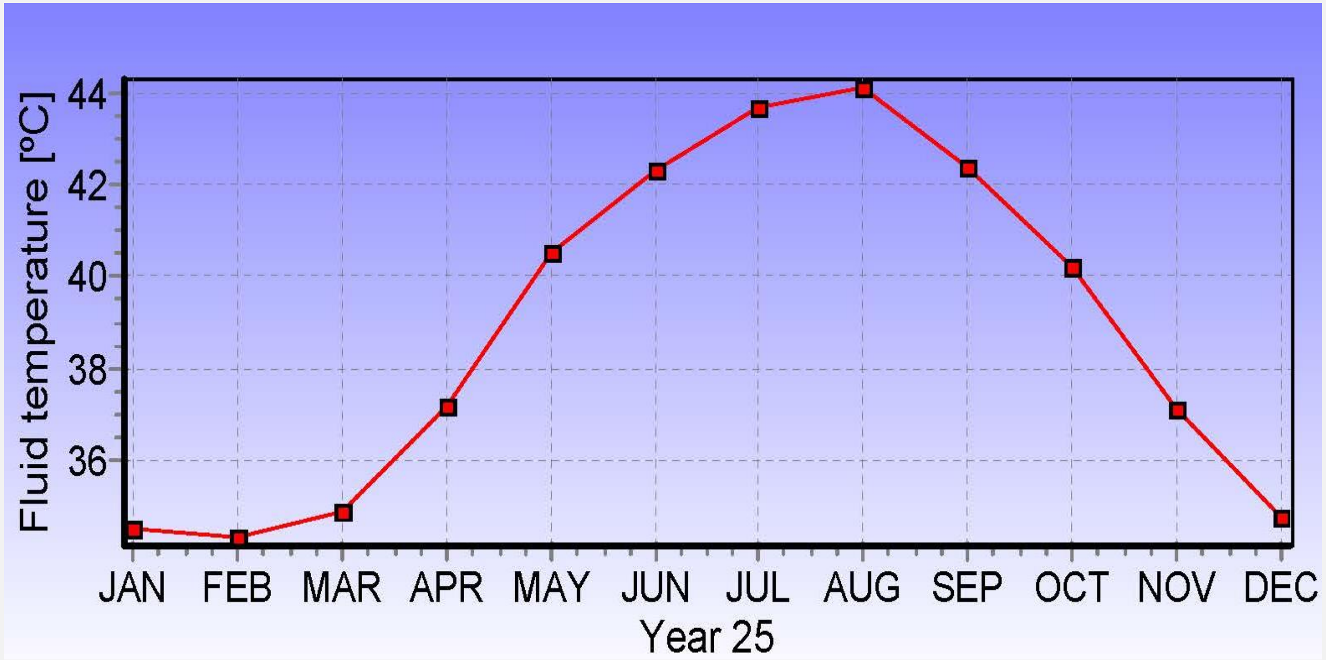
- ✓ the total borehole length that would be able to provide the cooling load.
- ✓ The annual fluid temperature

For this goal, the Earth Energy Design model (EED) was used. The table shows assumptions made in this study

Ground temp. (°C)	29	Pipe outer diameter of pipe (m)	0.032
Borehole type	Single-U	Pipe wall thickness (m)	0.003
Borehole Configuration	2x2 rectangle	Thermal conductivity of pipe (W/m,K)	0.42
Borehole Spacing (m)	12	Pipe shank spacing (m)	0.07
Borehole Diameter (m)	0.11	Filling thermal conductivity (W/m,K)	0.622
Flow rate (m^3/s)	0.002	Ground thermal conductivity (W/m,K)	2.63
Contact resistance (m,K/W)	0	Ground heat capacity conductivity (MJ/m^3,K)	2.45

Design borehole heat exchanger Results

- The total borehole length is 600 m.



Determination of COP

The annual operating air temperature (AOAT) of ASHP system is:

$$AOAT = \frac{\sum_{i=1}^{8760} T_{a,i} \cdot q_{hc,i}}{Q_c} + 15$$

The annual operating ground temperature (AOGT) of GSHP system is:

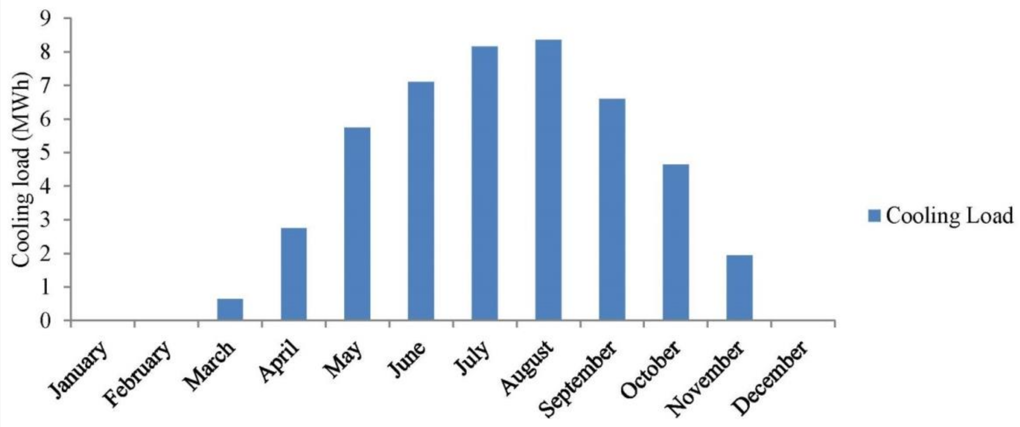
$$AOGT = \frac{\sum_{i=1}^{12} T_{f,i} \cdot q_{mc,i}}{Q_c} + 10$$

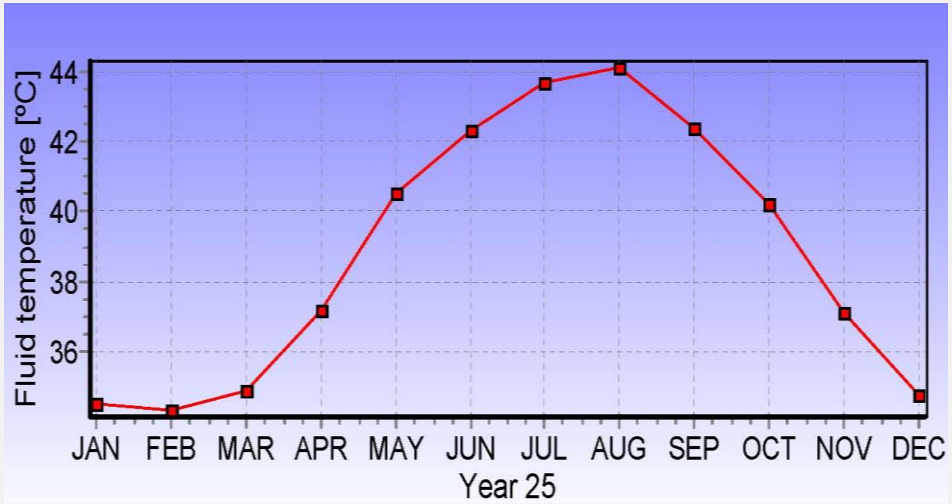
Where $T_{a,i}$ is the outdoor temperature at hour *i* in the year; $q_{hc,i}$ is the cooling demand at hour *i*; $T_{f,i}$ is the fluid temperature in the month *i*; $q_{mc,i}$ the cooling load of the month *i*.

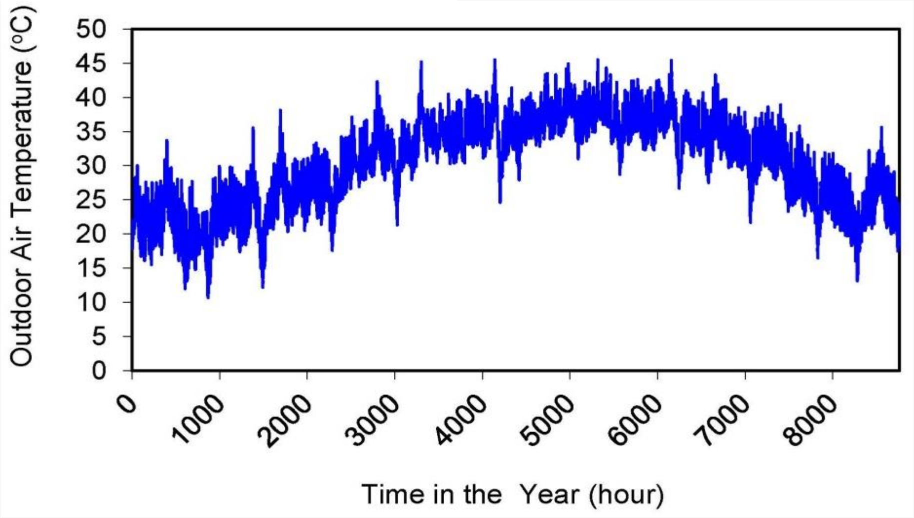
The annual operating temperature

while the annual operating air temperature of ASHP is 54^{o}C

The annual operating ground temperature of GSHP is 48^{o}C

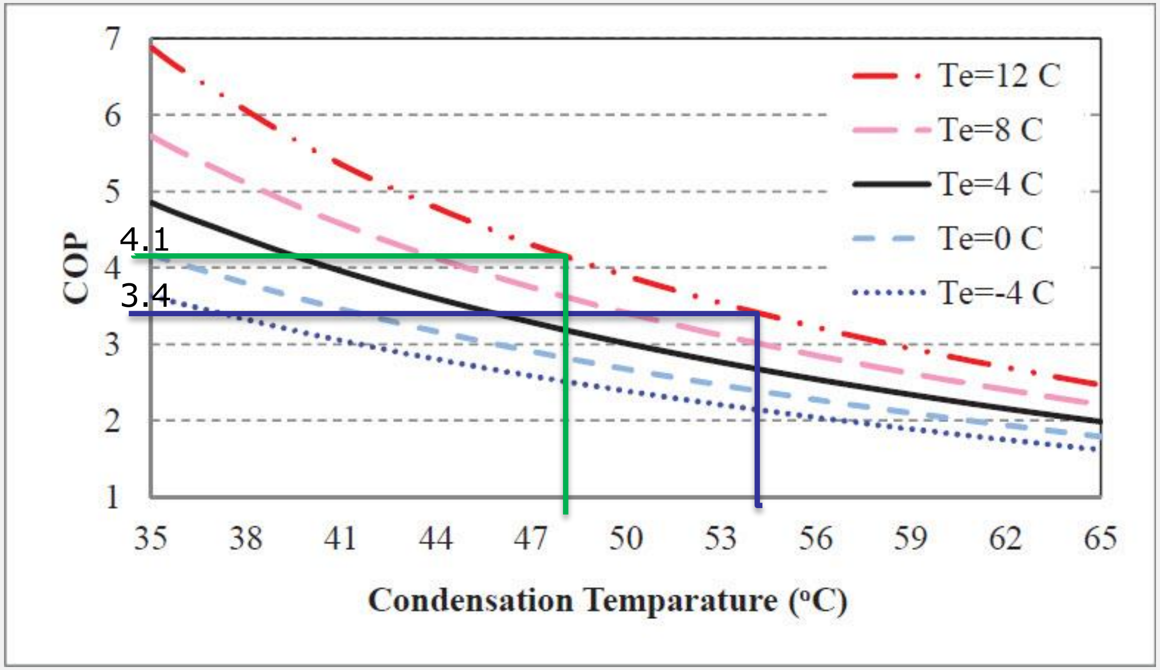






Annual COP

Based on the fluid temperature coming to the condenser of the heat pump the coefficient of performance of the heat pump (COP) can be calculated using



Driving Energy of A/C System

The energy of the GSHP system to provide the building with the required cooling load was calculated as follows:

$$E = \frac{Q_c}{COP}$$

This way, the annual saving ($C_{s,an}$) due to using GSHP system instead of ASHP in USD is

$$C_{s,an} = \frac{Q_c}{1.7 \cdot \eta_{pp} \cdot \eta_{ds}} \left(\frac{1}{COP_{\boldsymbol{A}}} - \frac{1}{COP_{\boldsymbol{G}}}\right) \cdot C_{oil}$$

Results

The simulation shows that :

- The cooling load in Qatar is about **319** kWh/m^2.y
- Each meter length of ground heat exchanger can provide with **76.5** kWh cooling load
- The COP_A of ASHP system at is **3.4**, while the COP_G of GSHP system is **4.11**.
- Consequently, the annual energy consumption could be reduced by **17** % and, consequently, annual emission of greenhouse gases is reduced at the same rate.

Results

The economic analysis shows that

- Required borehole's length is **13** m per MWh of cooling load
- GHE's cost is $ **119** per MWh of cooling load.
- At the current cost of oil ($105/barrel), the pay-back time of GSHP system is **15.7** years.

Possibility of Improvement

Let us assume that the U-values of the wall and the roof of the case study was upgraded from 1.78 and 1.74, respectively, to 0.573 W/m^2.K (mandated by KAHROMA)

Indoor temperature (^oC)	24	Outdoor ventilation air flow (l/s)		58
Throttling range (^oC)	1	Designing outdoor temperature (^oC)		46
Building area (m^2)	144	Number of people		6
Wall U-value (W/m^2.K)	0.573	Unoccupied indoor temperature (^oC)		27
Roof U-value (W/m^2.K)	0.573	Absorptivity	Wall	0.45
Window U-value (W/m^2.K)	4.675		Roof	0.45
Widows shade coefficient	0.6	Internal load (W/m^2)	Lighting	2
Windows area (m^2)	20		Equipment	6
External walls area (m^2)	144	Building weight(kg/m^2)	External wall	500
space volume (m^3)	388.8		Roof	623
Wall heat capacity (kJ/kg.K)	0.864	Roof heat capacity (kJ/kg.K)		0.85

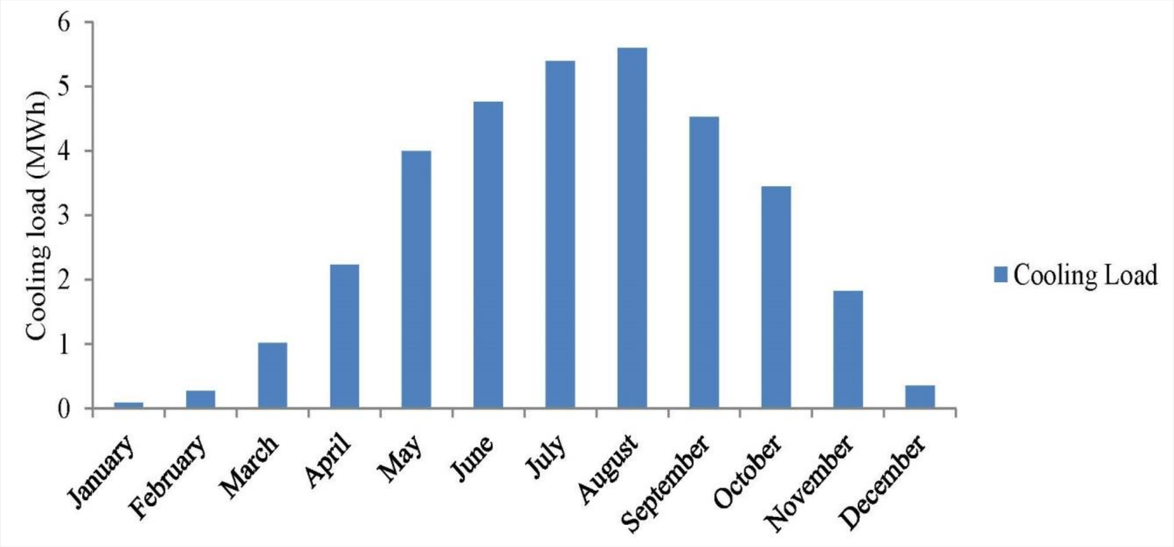
Possibility of Improvement

This can be achieved by just adding 35 mm of Polyurethane, which in current case means 302 kg.

Insulation	Thermal conductivity	Density	Price
Polyurethane	W/m.K	Kg/m^3	$/kg
	0.03	30	4.25

Possibility of Improvement

In this case the cooling load reduced from 45.93 MWh to **38.72** MWh (16 %).



Possibility of Improvement

Design borehole heat exchanger

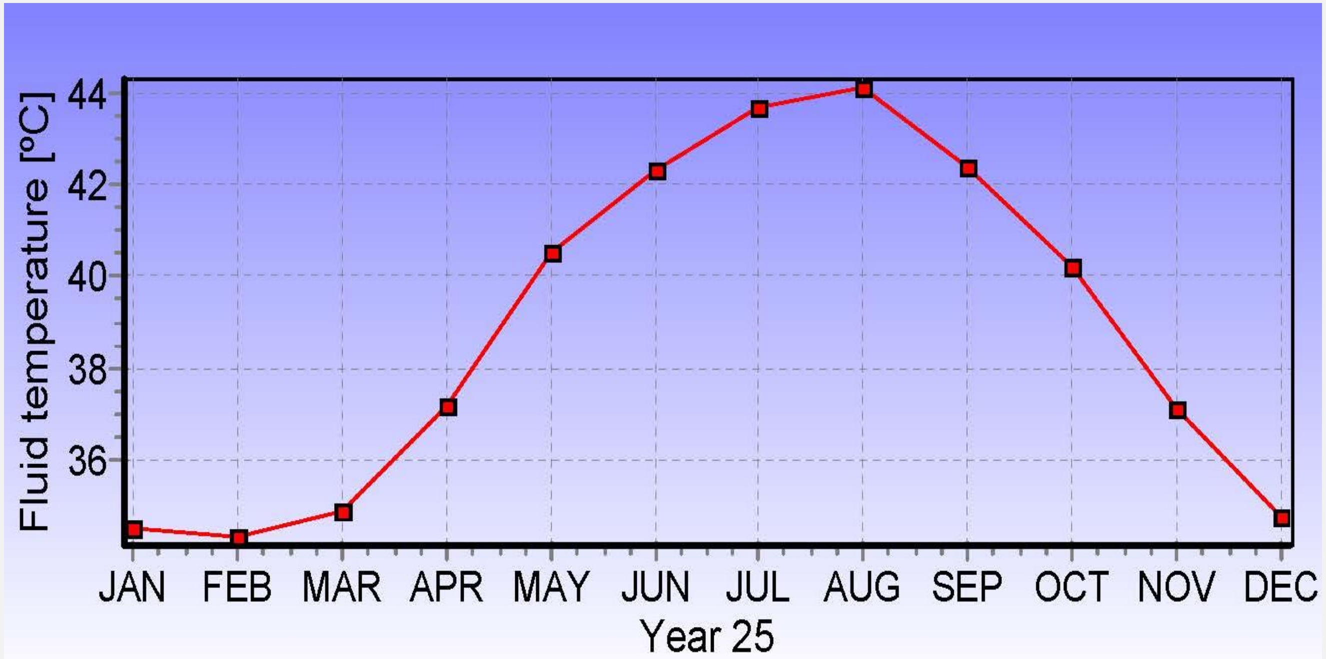
The table shows assumptions made in this study (same assumptions)

Ground temp. (^oC)	29	Pipe outer diameter of pipe (m)	0.032
Borehole type	Single-U	Pipe wall thickness (m)	0.003
Borehole Configuration	2x2 rectangle	Thermal conductivity of pipe (W/m,K)	0.42
Borehole Spacing (m)	12	Pipe shank spacing (m)	0.07
Borehole Diameter (m)	0.11	Filling thermal conductivity (W/m,K)	0.622
Flow rate (m^3/s)	0.002	Ground thermal conductivity (W/m,K)	2.63
Contact resistance (m,K/W)	0	Ground heat capacity conductivity (MJ/m^3,K)	2.45

Possibility of Improvement

Design borehole heat exchanger

The total borehole length is 440 m (it was 600 m)



- The annual operating ground temperature of GSHP is 48^{o}C

Possibility of Improvement

Results

The economic analysis shows that

- The cooling load becomes **268** kWh/m^2.y (319)
- By adding **35** mm of insulation the cooling load can be reduced by **16**%.
- The insulation cost is about $ **9** per square meter of the building.

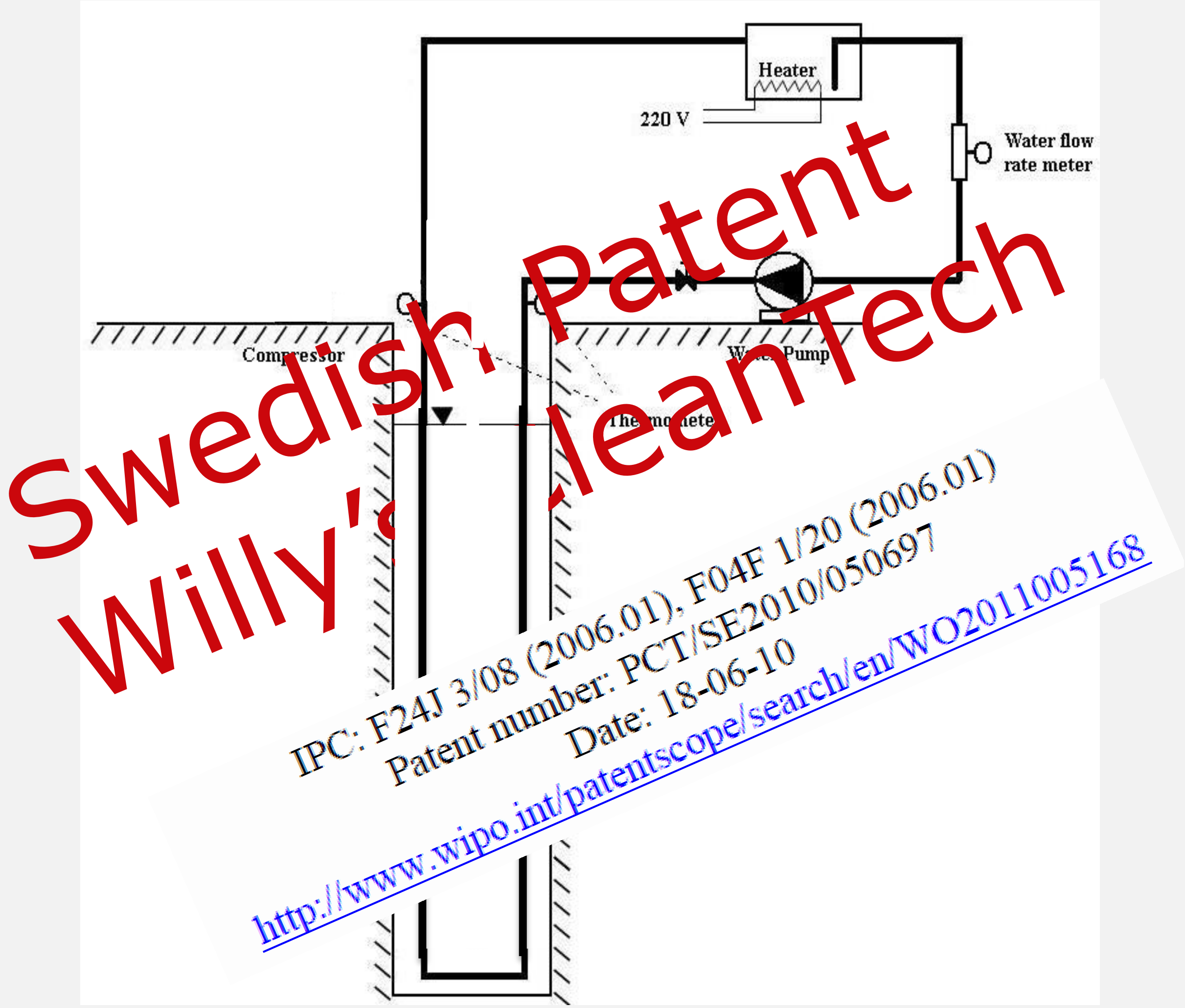
Possibility of Improvement

Results

- Each meter length of ground heat exchanger can provide the **88** kWh cooling load (76.5)
- Required borehole's length is **11** m per MWh of cooling (13)
- GHE's cost is $ **103** per MWh of cooling load (119)
- At the current cost of oil ($105/barrel), the pay-back time of GSHP system is **8.7** years (it was 15.7).
- The payback time of the insulation itself is **4** years.

Possibility of Improvement

Energy Booster:
Improving the thermal characteristics of BHE



Energy Booster

Energy Booster

- ✓ Improve the effective thermal conductivity
- ✓ Reduce BHE thermal resistance
  - Consequently, improve the performance of A/C systems

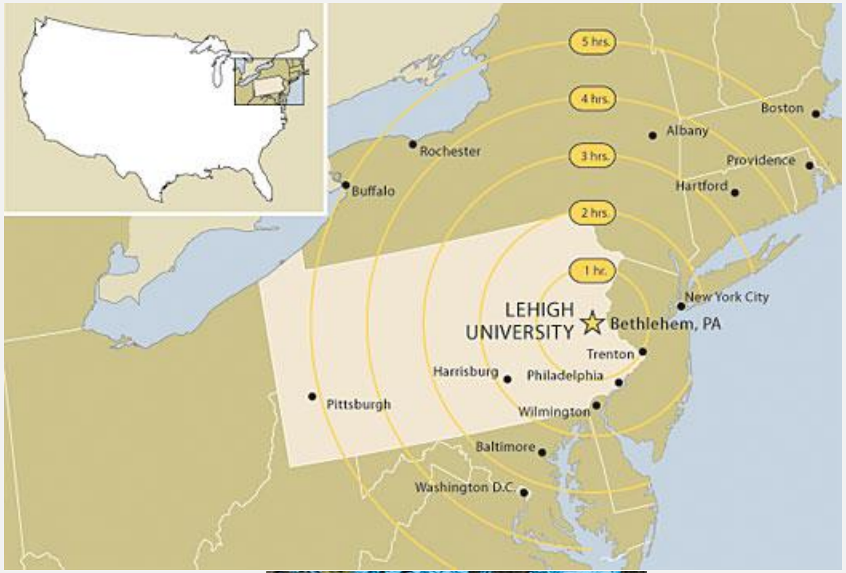
Future Work

Utilizing the deep foundation of high building for air conditioning applications (**Energy Piles)**

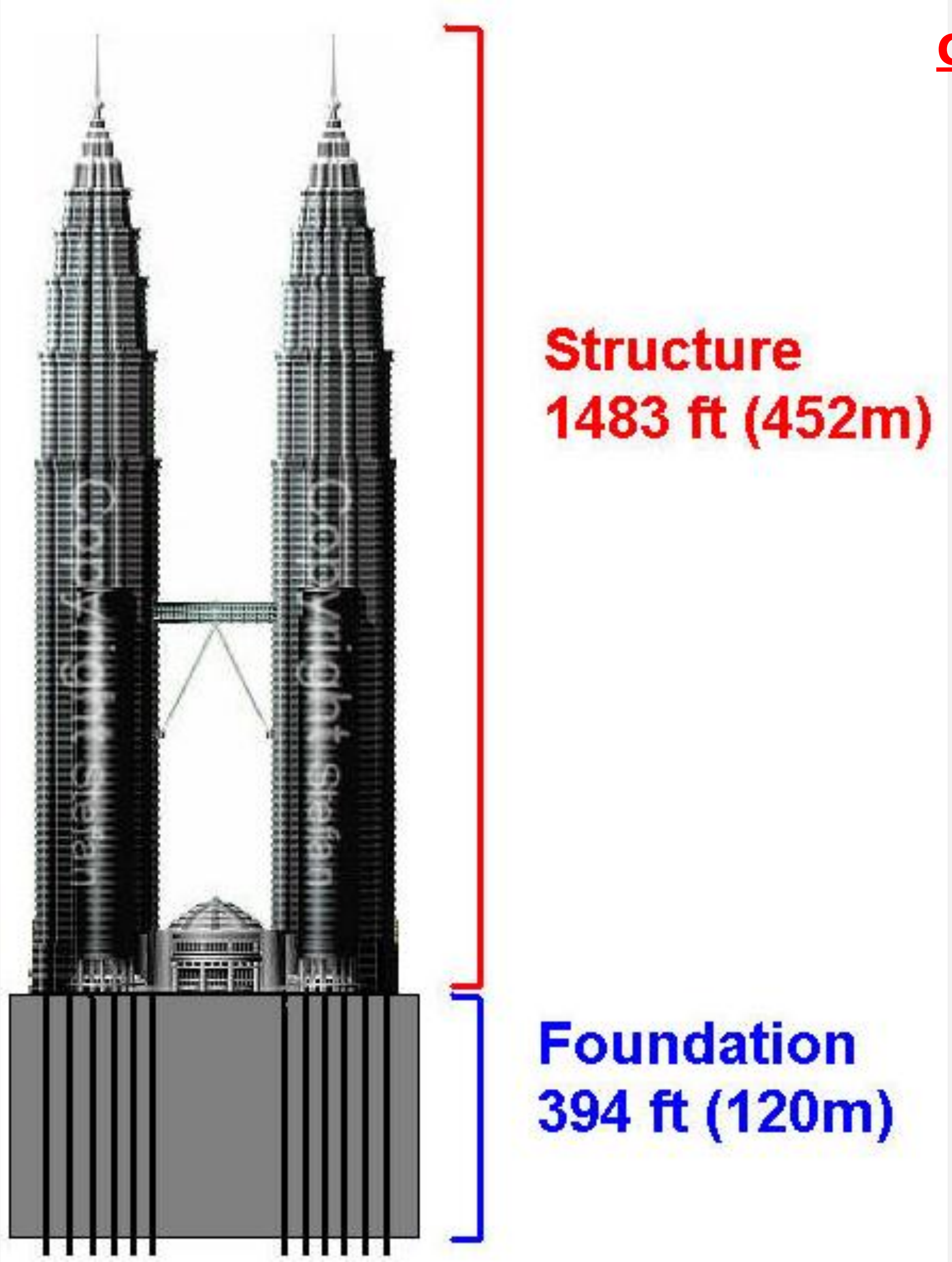
Collaboration with Lehigh University (Dr. Muhannad Suleiman)

Lehigh at a Glance

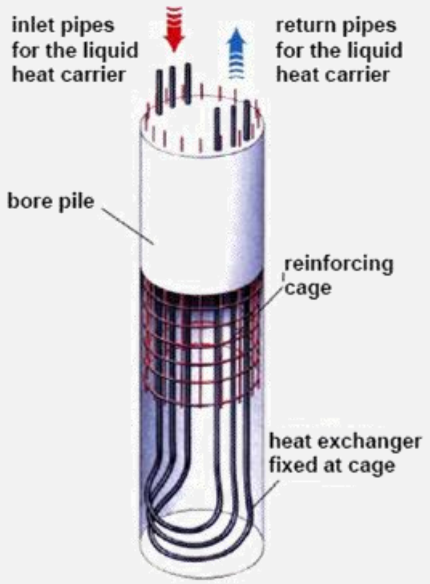
- Located in Bethlehem, Pennsylvania, 90 minutes from both New York City and Philadelphia
- Among the most selective, highly ranked private research universities in the United States
- Founded in 1865
- Ranking top 20 universities for Civil Engineering
- Degrees
  - 86 undergraduate majors and programs (40% study abroad, 6% international)
  - 84 master's programs
  - 32 doctoral programs

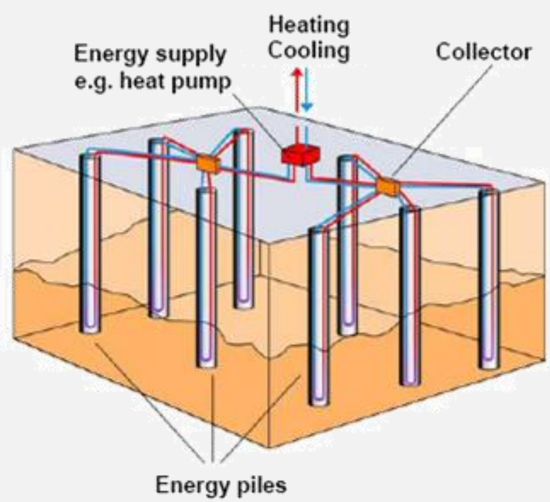


Collaboration



Geothermal Deep Foundations (Energy Piles)





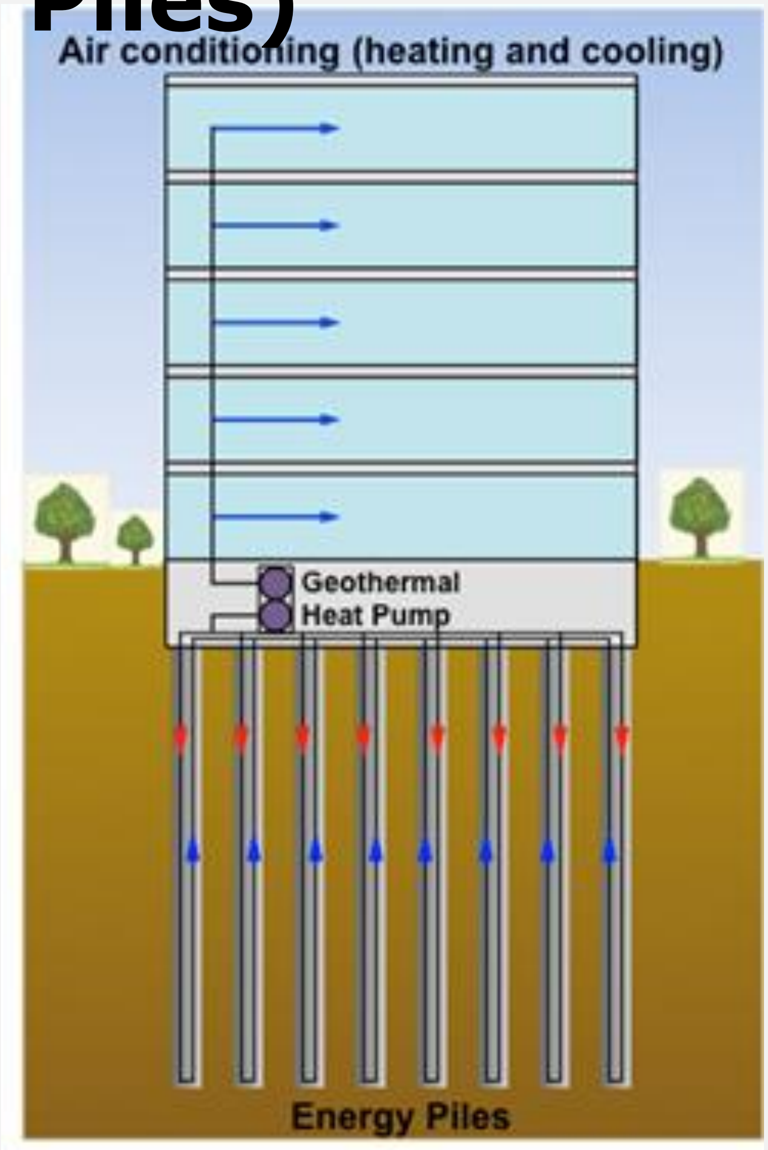
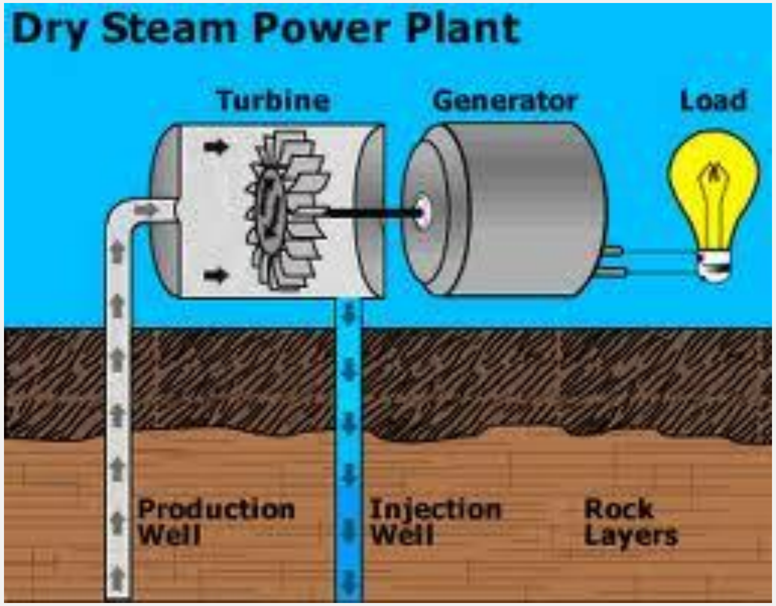
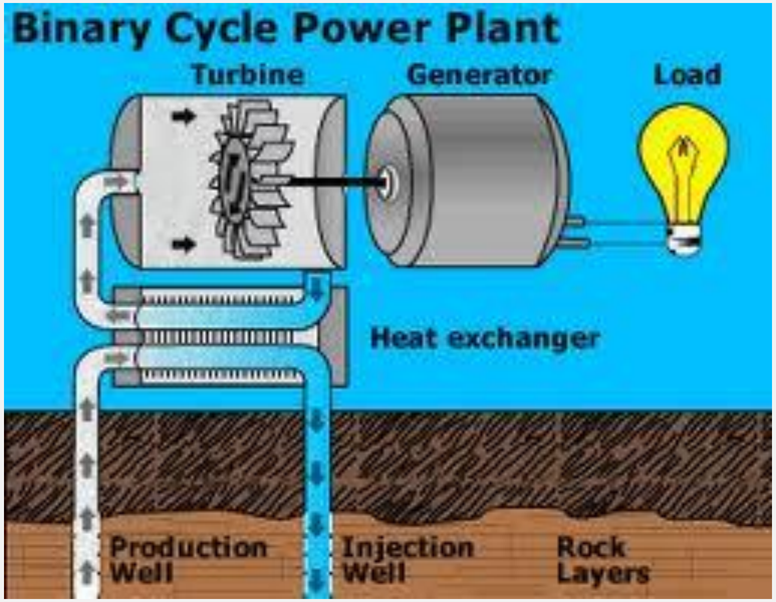


Photo: Courtesy of Olgun

Next Presentation:
2. Deep System

Geothermal power plants use the steam from a reservoir to power a turbine/generator, while others use the hot water to boil a working fluid, usually an organic compound with a low boiling point, that is vaporized and then used to turn a turbine.





Specific Aims

Within the frame of the current work the following Aims will be fulfilled:

1. Conduct a survey of Qatar’s geothermal resources,
2. Study and evaluate the use of the Organic Rankine Cycle to produce electricity from oil wells
3. Defined the optimal working conditions

Thank you for your attention