

Types of Ground Source Heat Exchanger (GSHE)

Horizontal

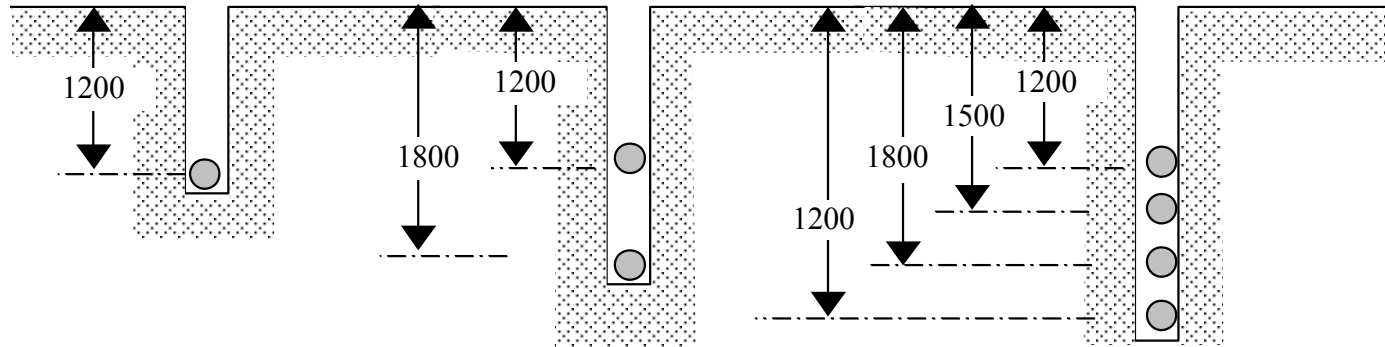
Vertical

Spiral / slinky

Horizontal GSHE



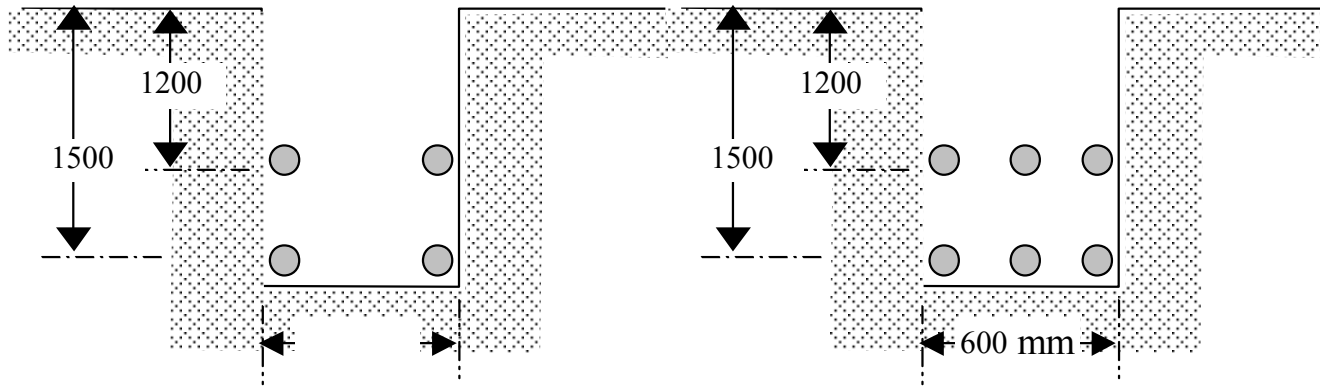
Horizontal GSHE



a. One pipe per trench

b. Two pipes per trench

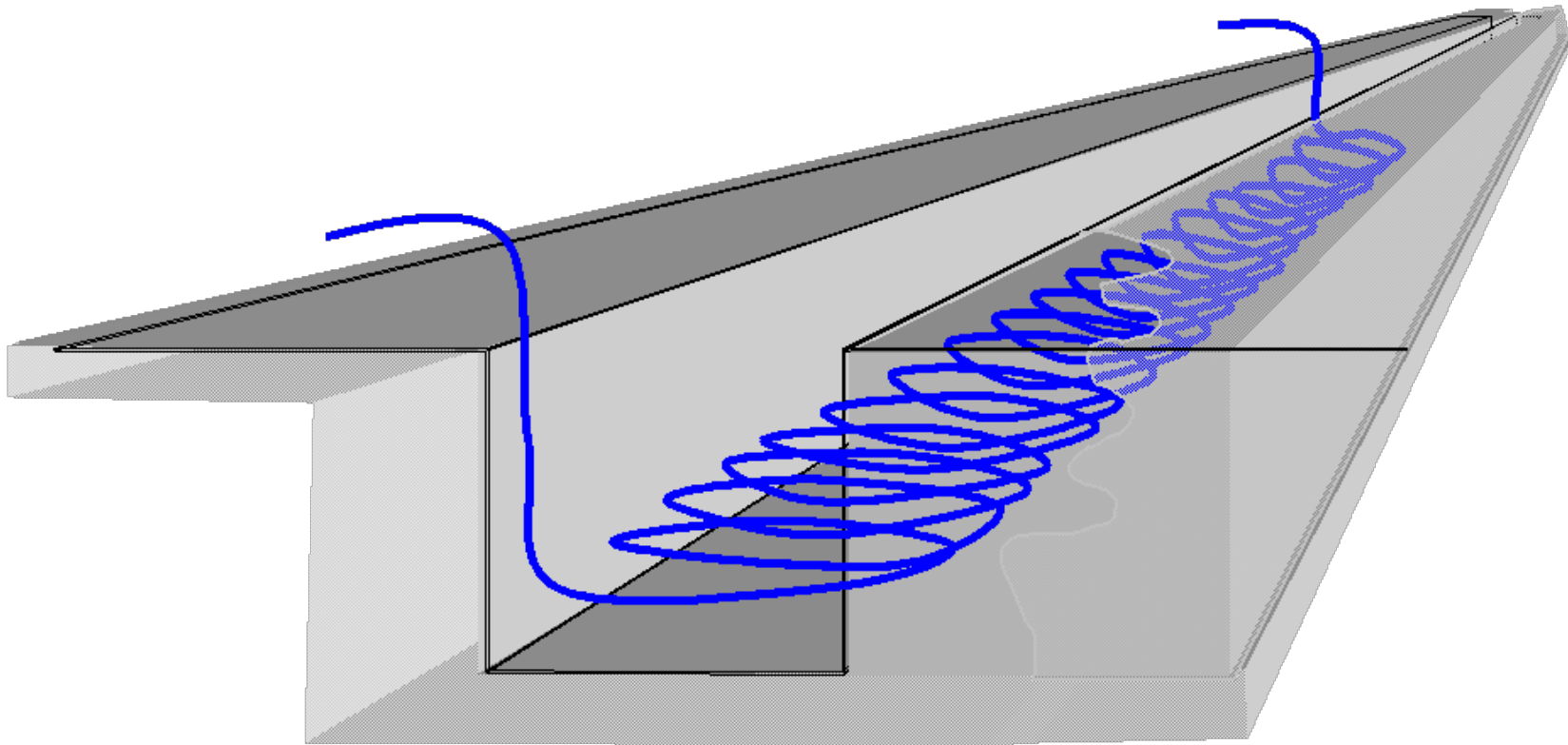
c. Three pipes per trench



d. Four pipes per trench

e. Six pipes per trench

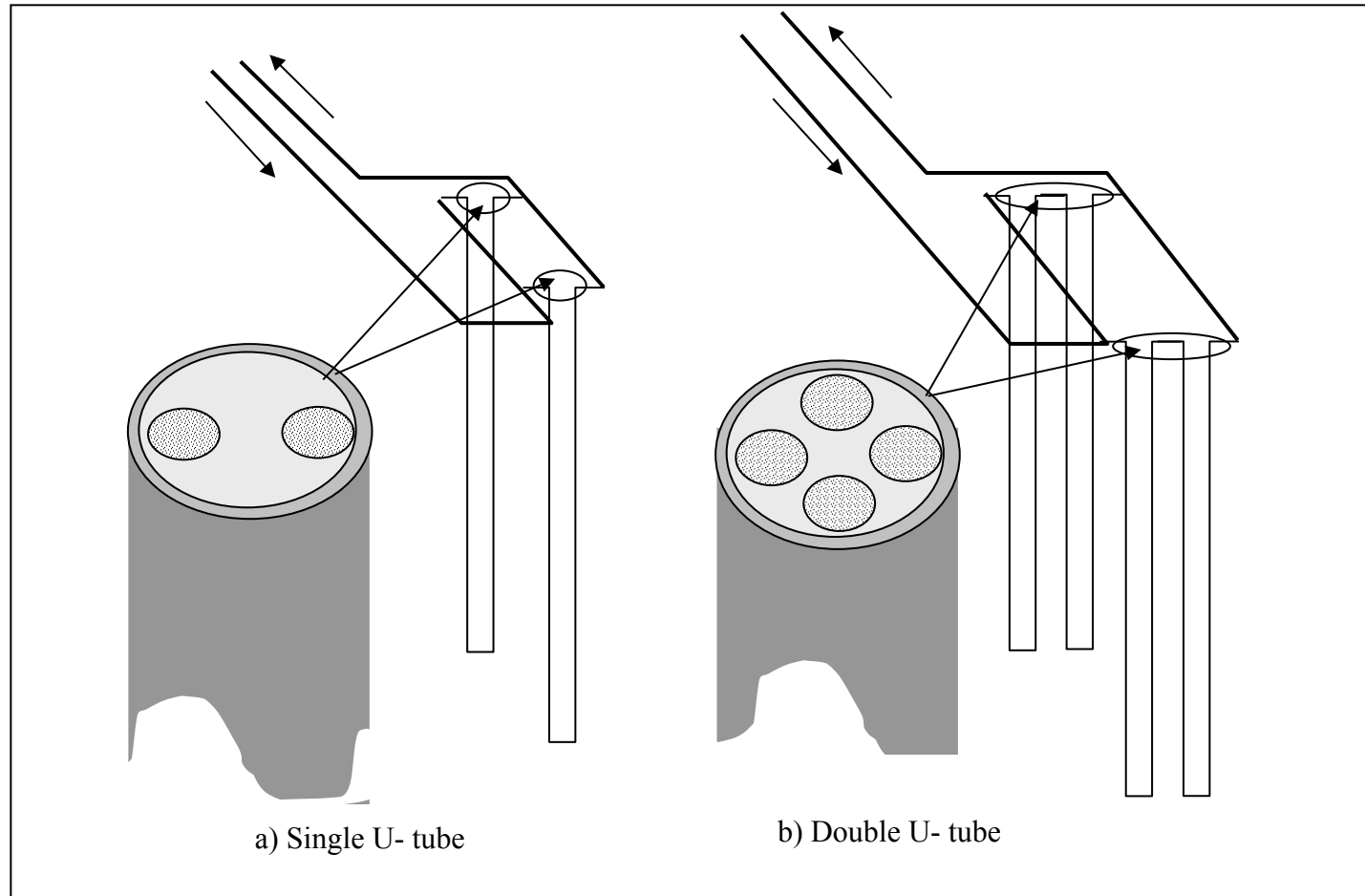
Spiral or Slinky GSHE



f. Slinky trench

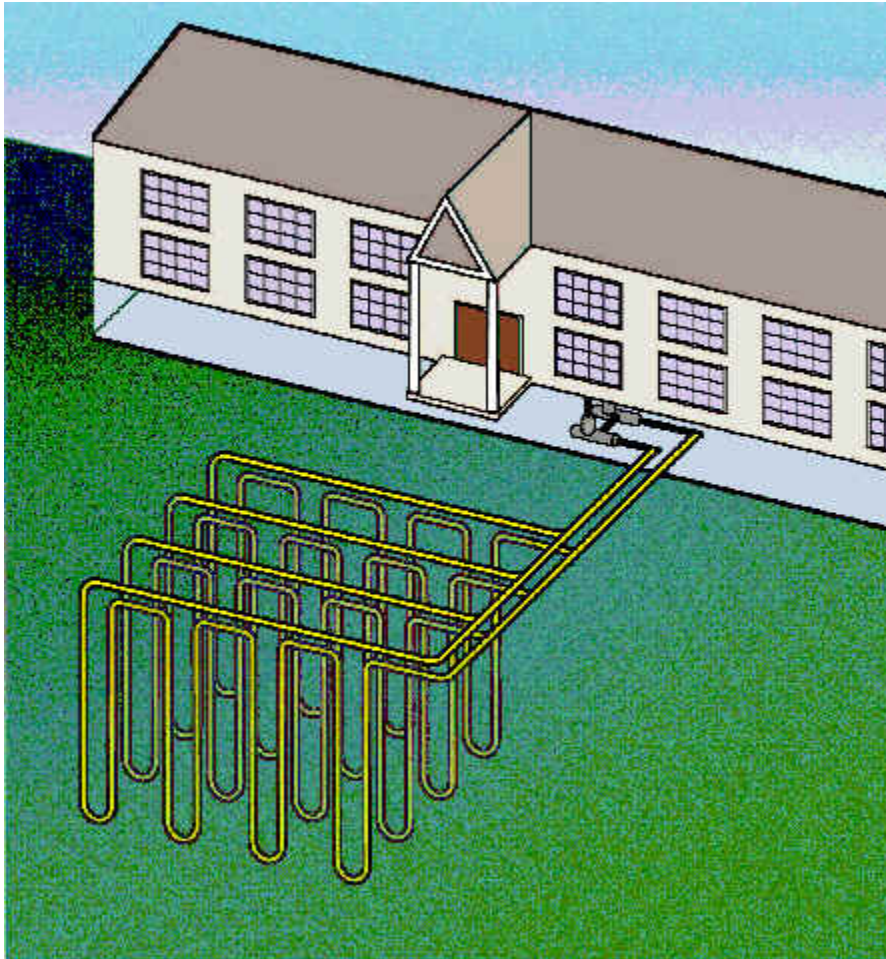
**Compared with horizontal,
slinky requires about 30%
trench length**

Vertical GSHE



- **15- 150 m deep**
- **100-150 mm diameter**

Vertical GSHE



- 15- 150 m deep
- 100-150 mm diameter

Comparison between GSHE types

- **Footprint**
 - horizontal 30 W/m²
 - slinky 100 W/m²
 - vertical 500 W/m²
- **Construction cost**
- **Design software**
 - GLHEPRO
 - EED

Trenching



Ramming



Augering



Limitations to applications

- **Low heat transfer means**
 - **High temperature difference**
 - **Cooling output maximum 40 W/m of GSHE**
 - **More surface required**
 - **Borehole cost £1000/ kW**
- **But.....**
COP > 40

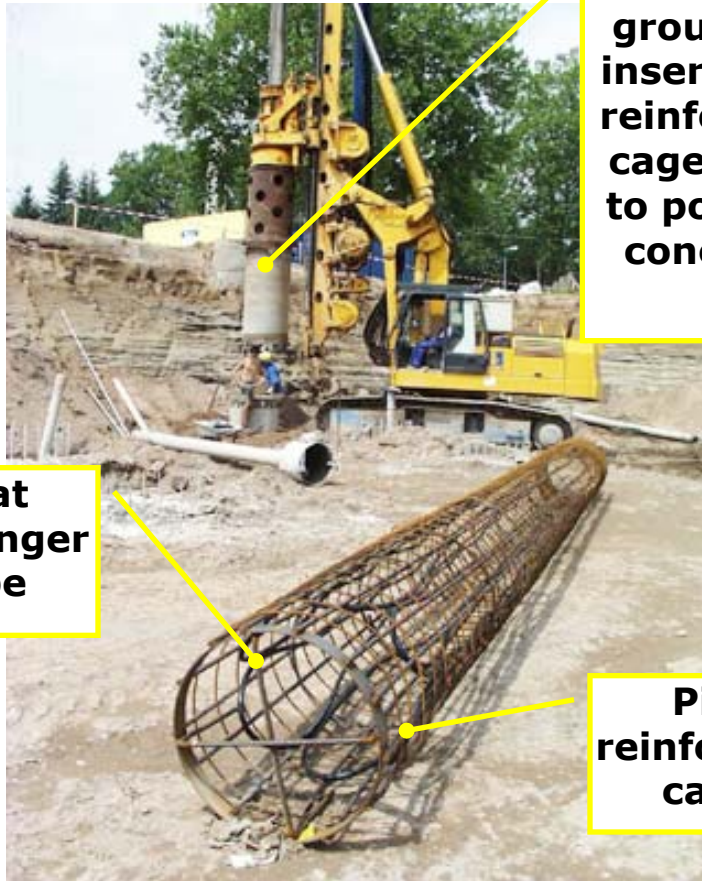
One way to increase ground heat transfer at marginal cost is.....

Thermopiles



90 piles 50 kW cooling

Thermopiles



**Drilling
ground to
insert pile-
reinforcing
cage prior
to pouring
concrete**

**Heat
exchanger
tube**

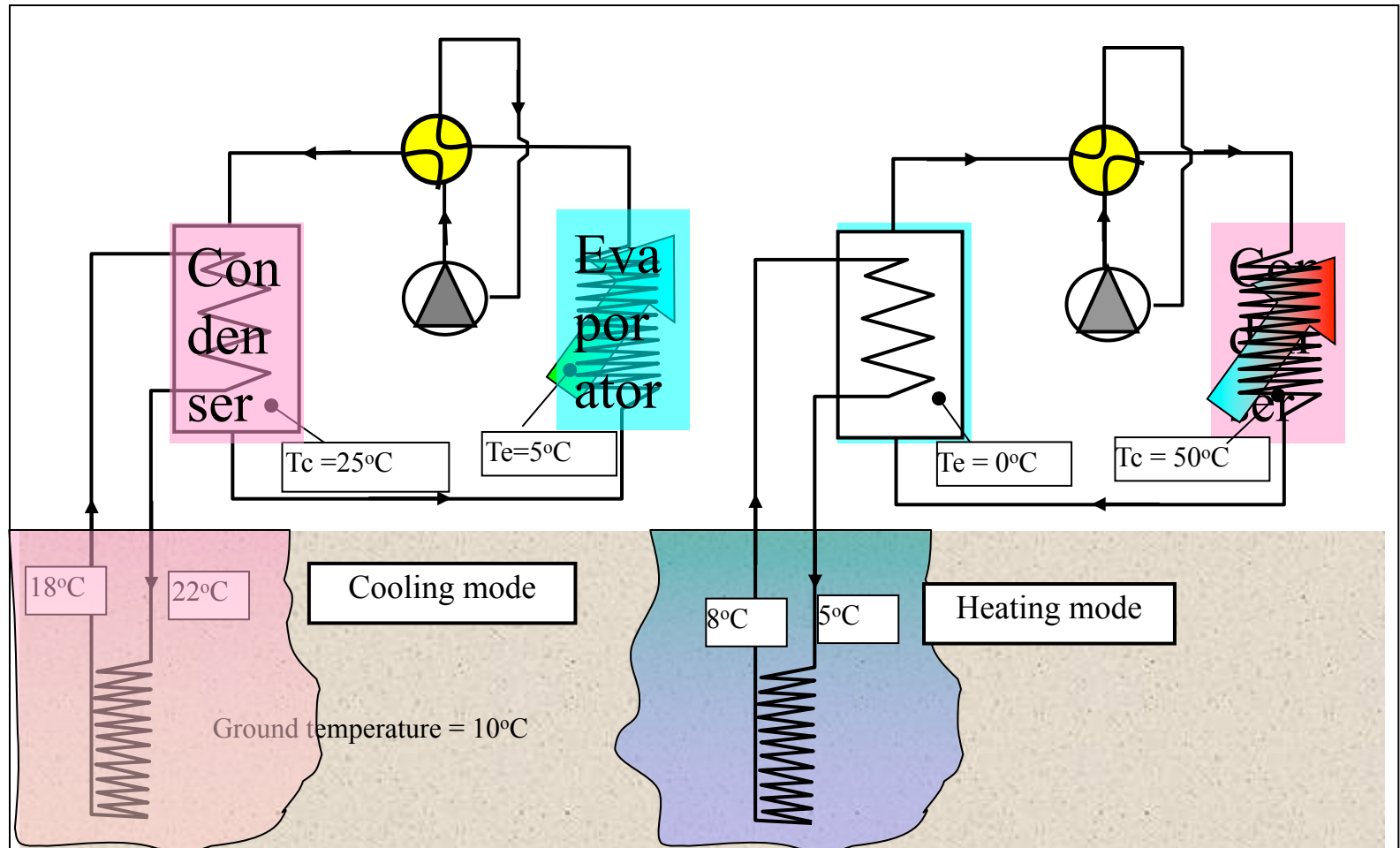
**Pile
reinforcing
cage**



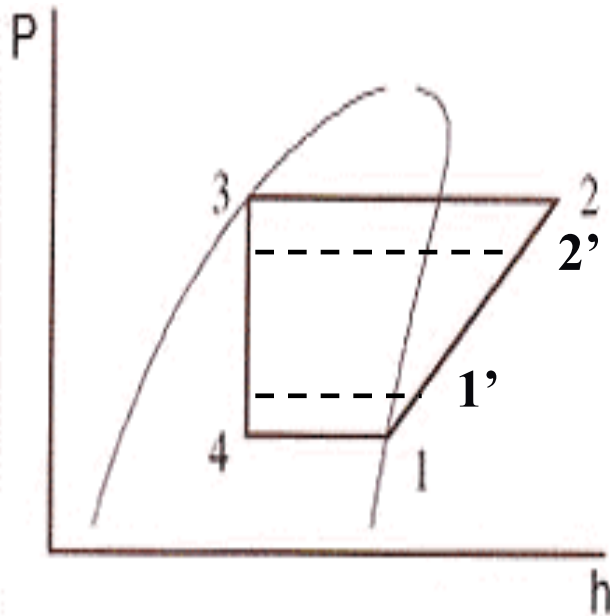
Another way to increase heat transfer is Ground source heat pumps GSHP

- Further temperature amplification (doubles the temperature difference)**
- Can achieve heating and cooling from one system**
- Requires a 4 way reversing valve**

Ground source heat pumps GSHP



Energy efficiency of GSHP



—— Air source HP
 - - - - Ground source HP

Compressor work, $W = h_2 - h_1$

$Q_{\text{evap}} = h_1 - h_4$

$Q_{\text{cond}} = h_2 - h_3$

$\text{COP} = Q_{\text{evap}} / W$ (cooling)

$\text{COP} = Q_{\text{cond}} / W$ (heating)

T_g : Ground water temperature

T_a : Air temperature

$T_g < T_a$ in summer $\implies$ lower condensation pressure

$W = (h_{2'} - h_1) < h_2 - h_1 \implies$ higher cooling COP

$T_g > T_a$ in winter $\implies$ higher evaporation pressure

$W = (h_2 - h_{1'}) < h_2 - h_1 \implies$ higher heating COP

Cost comparison for heating

	New boiler (condensing)	Ground source heat pump
Heating load	100 kWh	100 kWh
Seasonal efficiency	88%	400%
Energy input, kWh	113.6	25
Cost of energy, p/kWh	3.1p	8.2 p
Cost of input energy £	£3.52	£2.05
CO2 emitted	21.6 kg	10.75 kg

Cost comparison for air conditioning

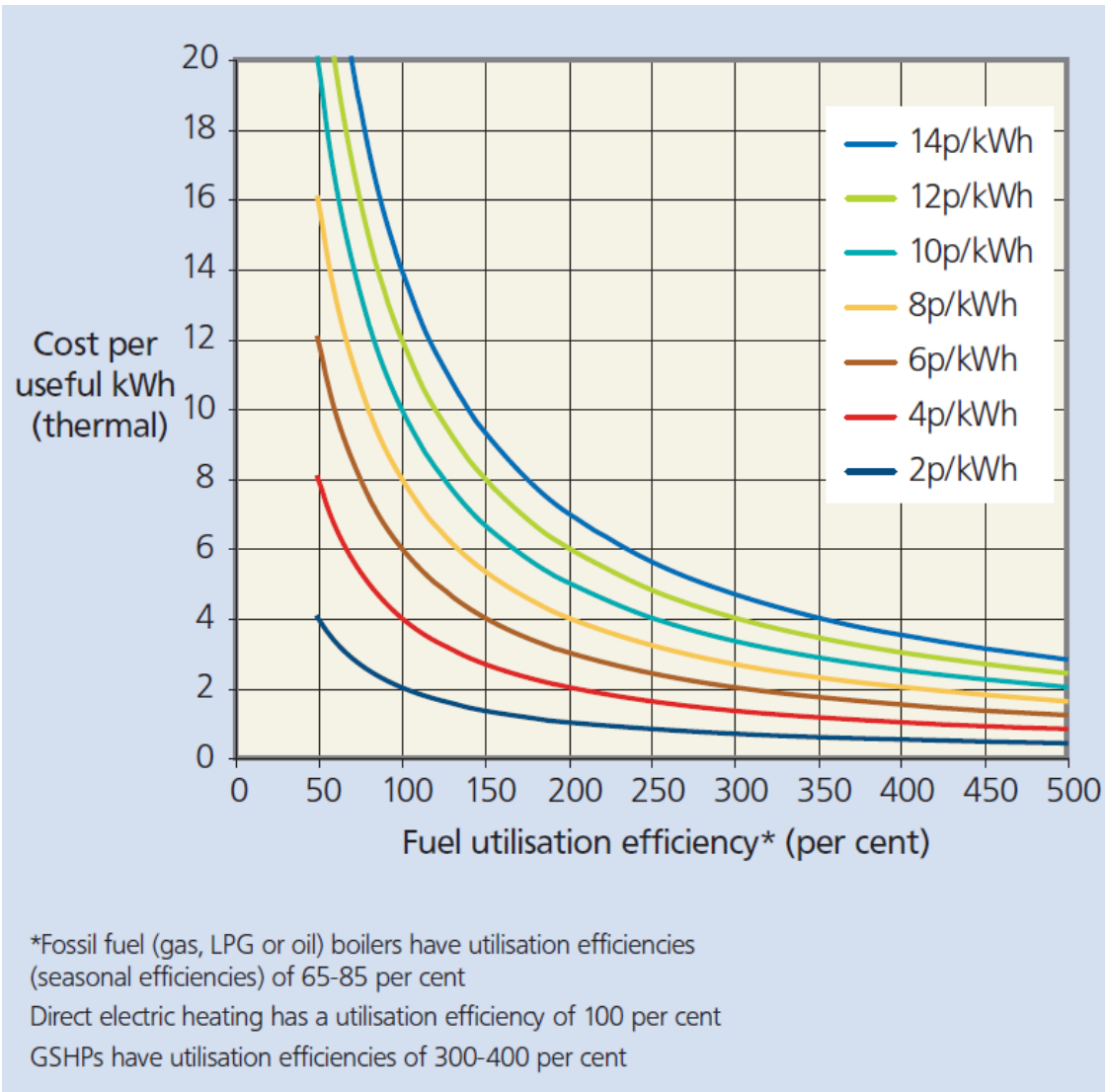
	Air source heat pump	Ground source heat pump
Cooling load	100 kWh	100 kWh
Seasonal efficiency	280%	320%
Energy input, kWh	35.7	31.25
Cost of energy, p/kWh	8.2 p	8.2 p
Cost of input energy	£2.93	£2.56
CO2 emitted	15.3 kg	13.2 kg

Cost estimation

Indicative capital costs* for individual ground-to-water heat pump systems

System type	Ground coil costs (£/kW)	Heat pump costs (£/kW)	Total system costs (£/kW)
Horizontal	250-400	350-750	600-1150
Vertical	550-750	300-750	850-1500
*Costs include installation and commissioning of the heat pump and ground loop but exclude costs for the heat distribution system.			

Cost estimation



Domestic fuel costs (p/kWh of useful heat) versus fuel utilisation for a range of fuel prices

Cost estimation

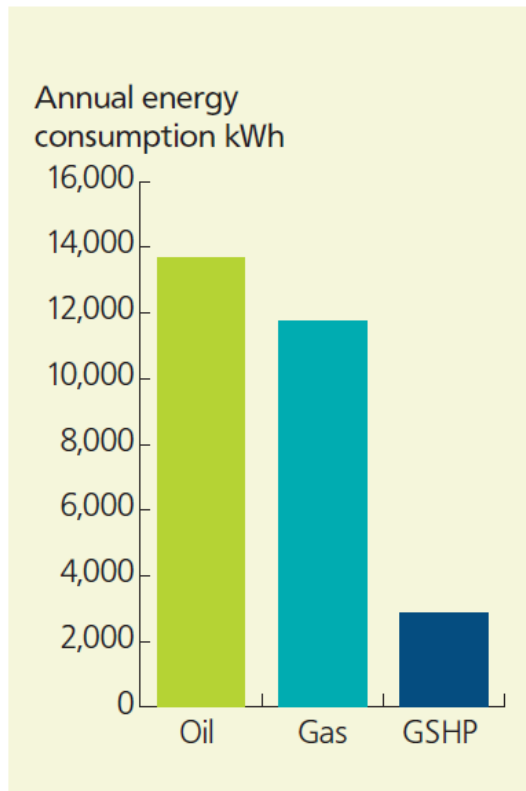


Figure 7 Annual energy consumption to provide 10,000kWh useful heat

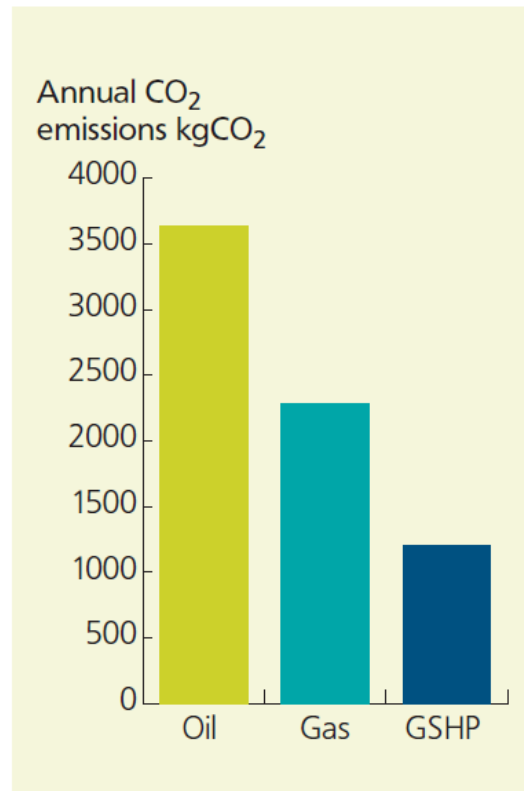


Figure 8 Annual CO₂ emissions to provide 10,000 kWh useful heat

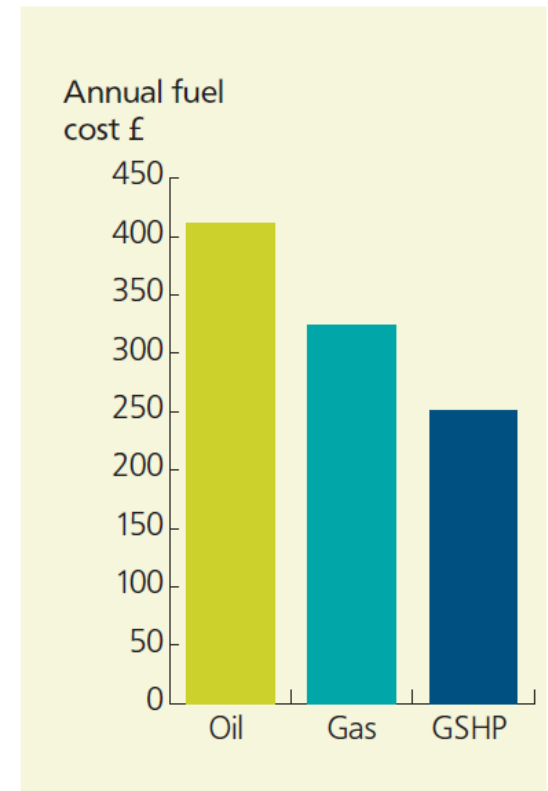


Figure 9 Annual cost to provide 10,000 kWh useful heat

Assumptions:

Oil – efficiency 73 per cent, 0.265kg CO₂/kWh, 3p/kWh

Gas – efficiency 85 per cent, 0.194kg CO₂/kWh, 2.75p/kWh

GSHP – efficiency 330 per cent, 0.422kg CO₂/kWh, 8.8p/kWh

Application of GSHP

- We can install the GSHE under the car park of a supermarket and have a ice free surface in winter!



Limitation 1 to application

Low COP means no carbon saving!



Trench (200 m tubes buried in 1 m down to the earth), COP of 3.16 reported



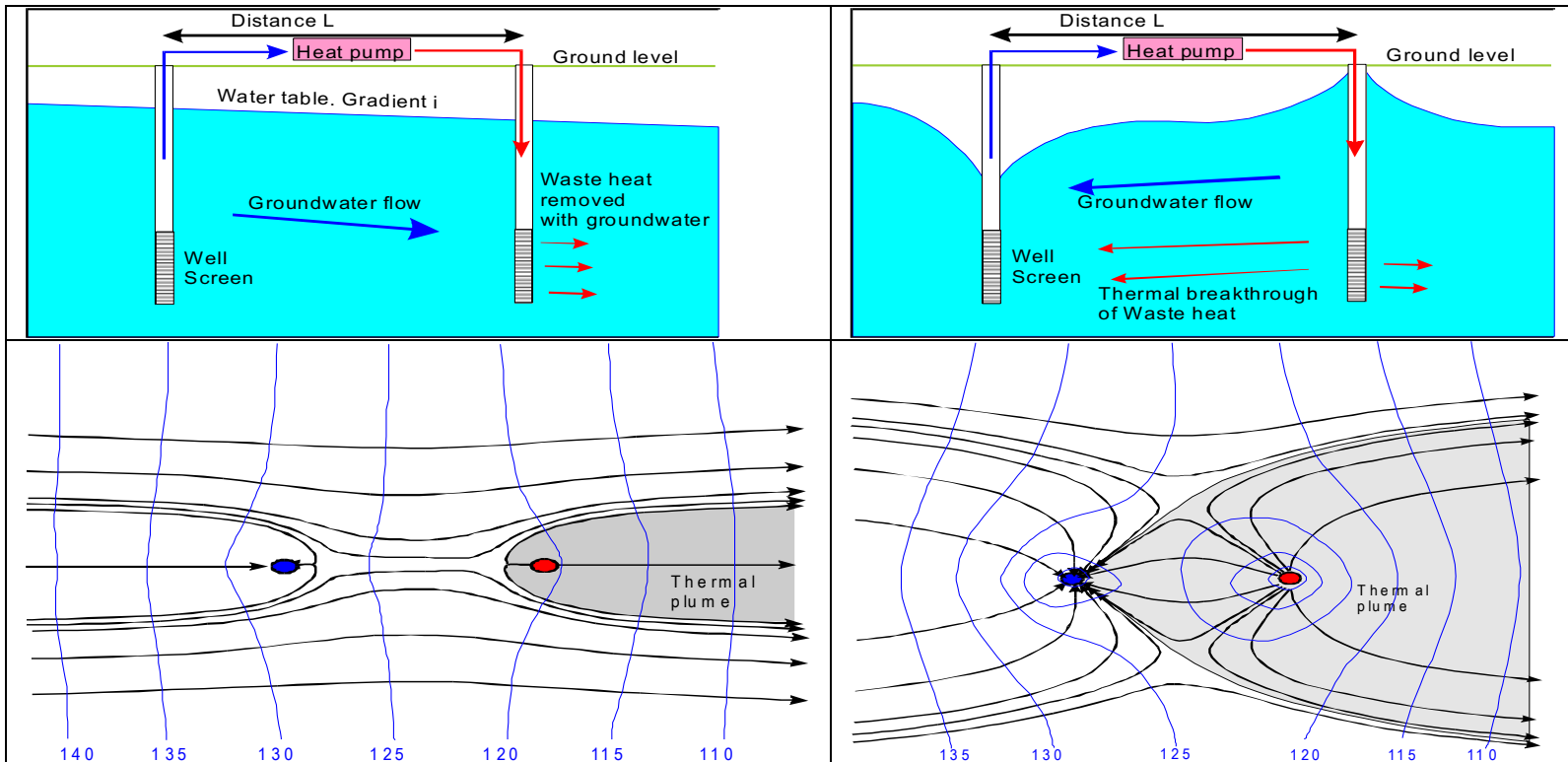
Open loop system (18 units) COP of 4.5 reported



Borehole system (18 m) COP of 2.5 reported

Limitation 2 to application

Heat pollution

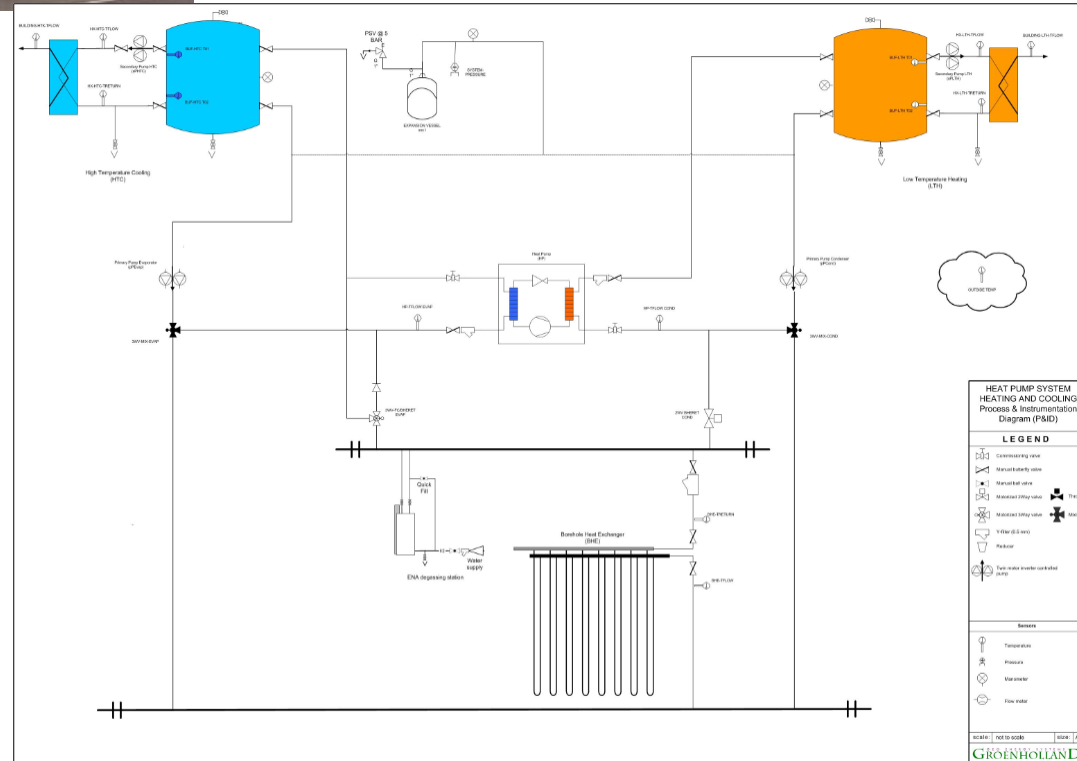


HP BTES system at Queen Mary



One well HP-BTES system

Comparison between
simulations and
measurements?



Conclusions

- **The ground is at constant temperature suitable for cooling and pre-heating**
- **Ground source systems save significant carbon and energy**
- **Application and economics determine the type of system to be used**
- **Use a specialist consultant to justify a good performance, carefully modelled!!!**
- **Speak to the Environment Agency**