ENGR-3000:
Renewable Energy, Technology, and Resource Economics

Geothermal Heat Pump Systems

S. David Dvorak. Ph.D, P.E.

World Learning SIT Study Abroad

5 June 2019
Ísafjörður, Iceland

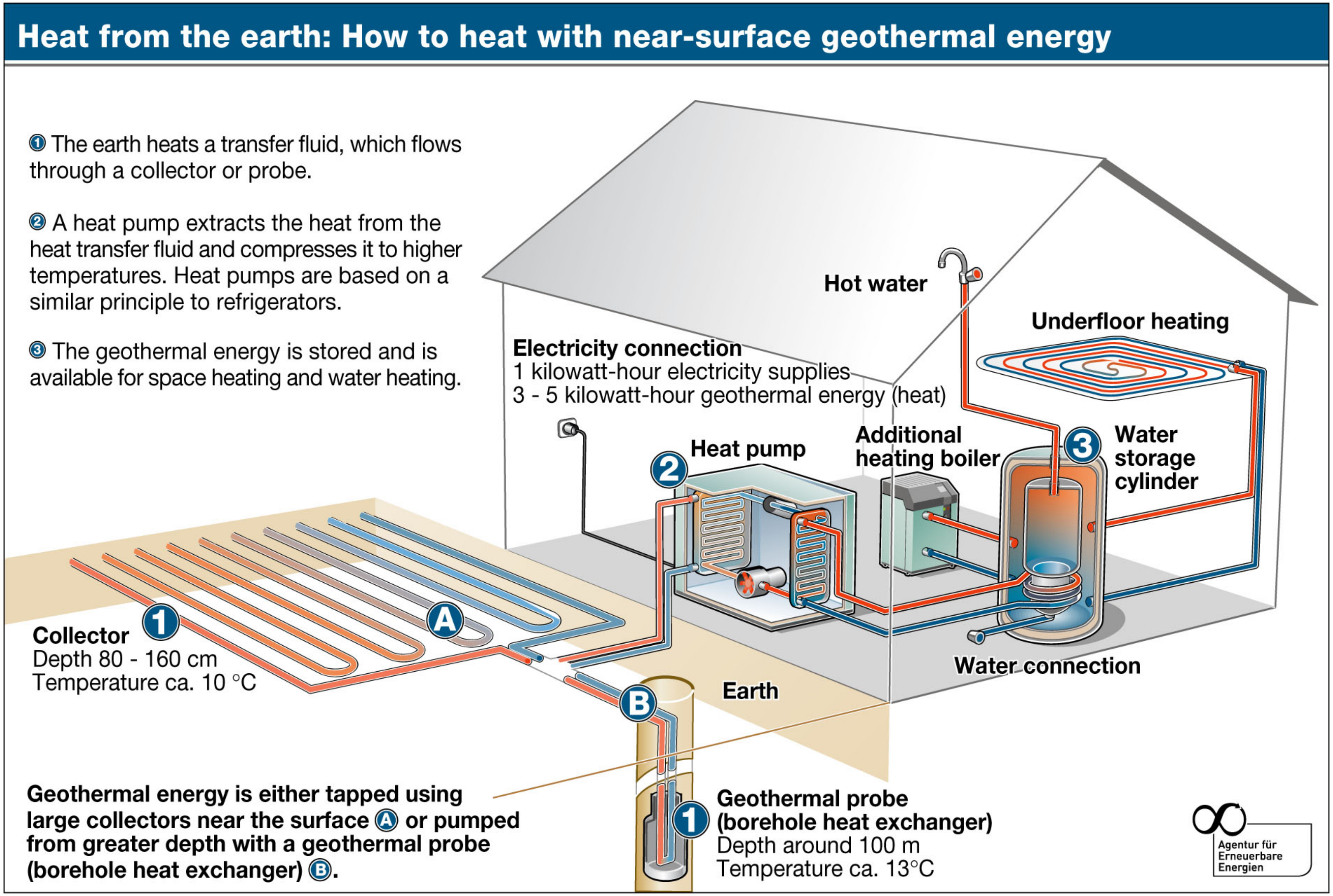
1865 THE UNIVERSITY OF MAINE

Geothermal Heat Pumps: Outline

- Types of ground loop systems.
- Temperature variations in wells
- Vapor compression cycle
- Coefficient of performance
- Maximum theoretical performance (Carnot)

Geothermal Heat Pump Systems

- 51% of incident solar energy is absorbed by the earth



Types of Ground Loop Systems

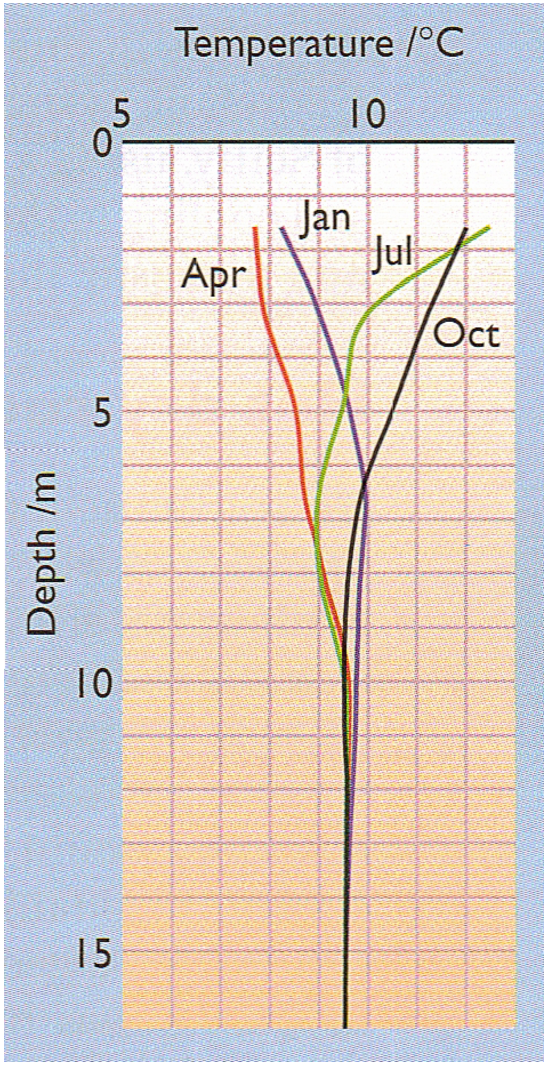
- Horizontal Loops
  - About 400-600 ft/Ton

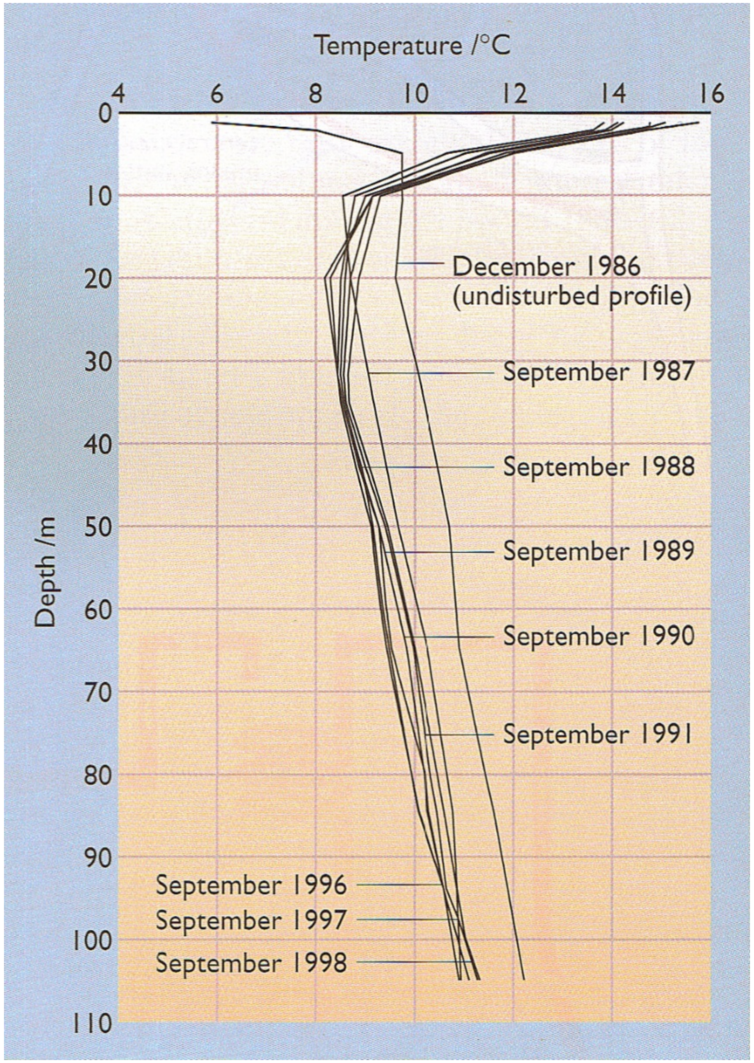
- Vertical Loops
  - About 150-450 ft deep

- Pond Loops
  - At least 15 ft deep!

Temperature Variations in Heat Pump Wells

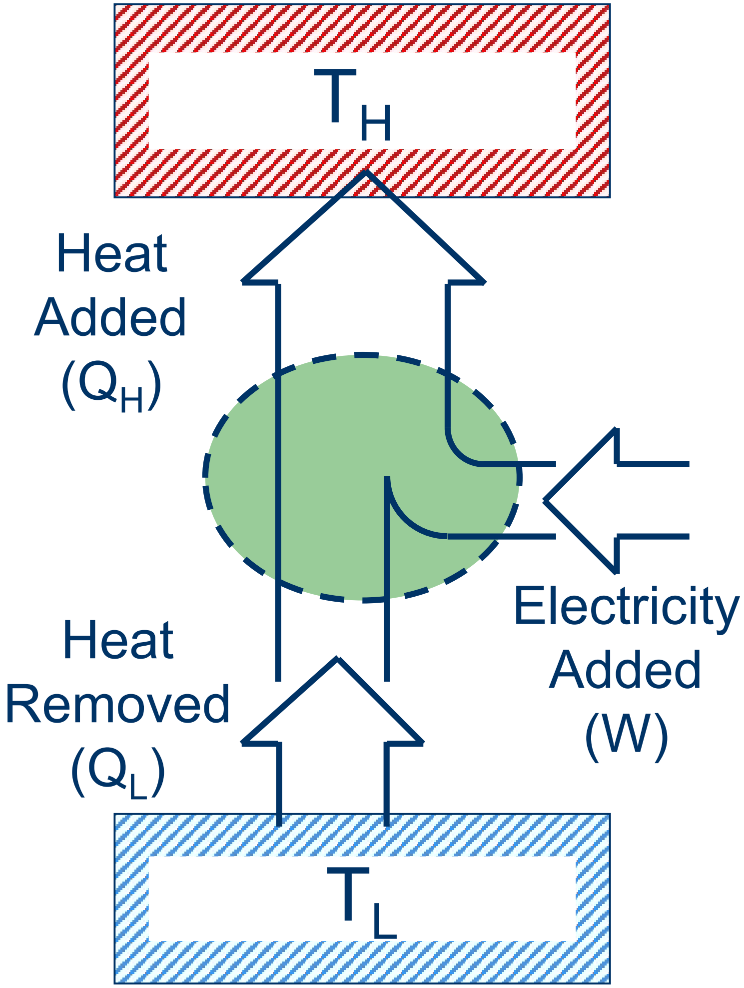
- Location: Northern Europe

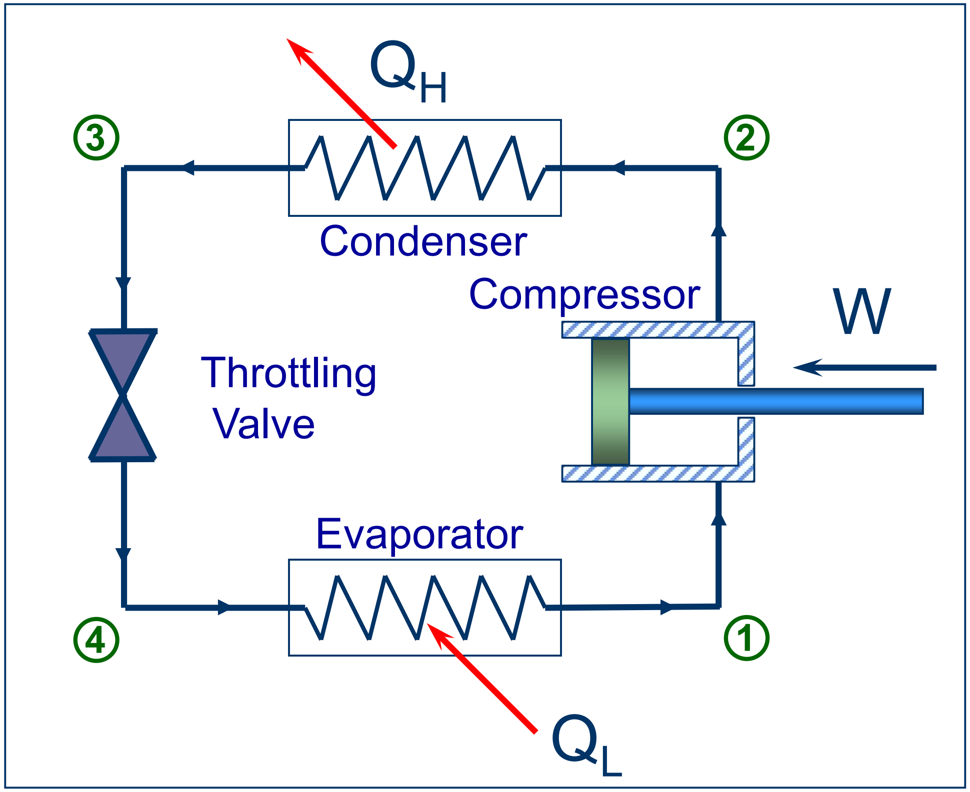




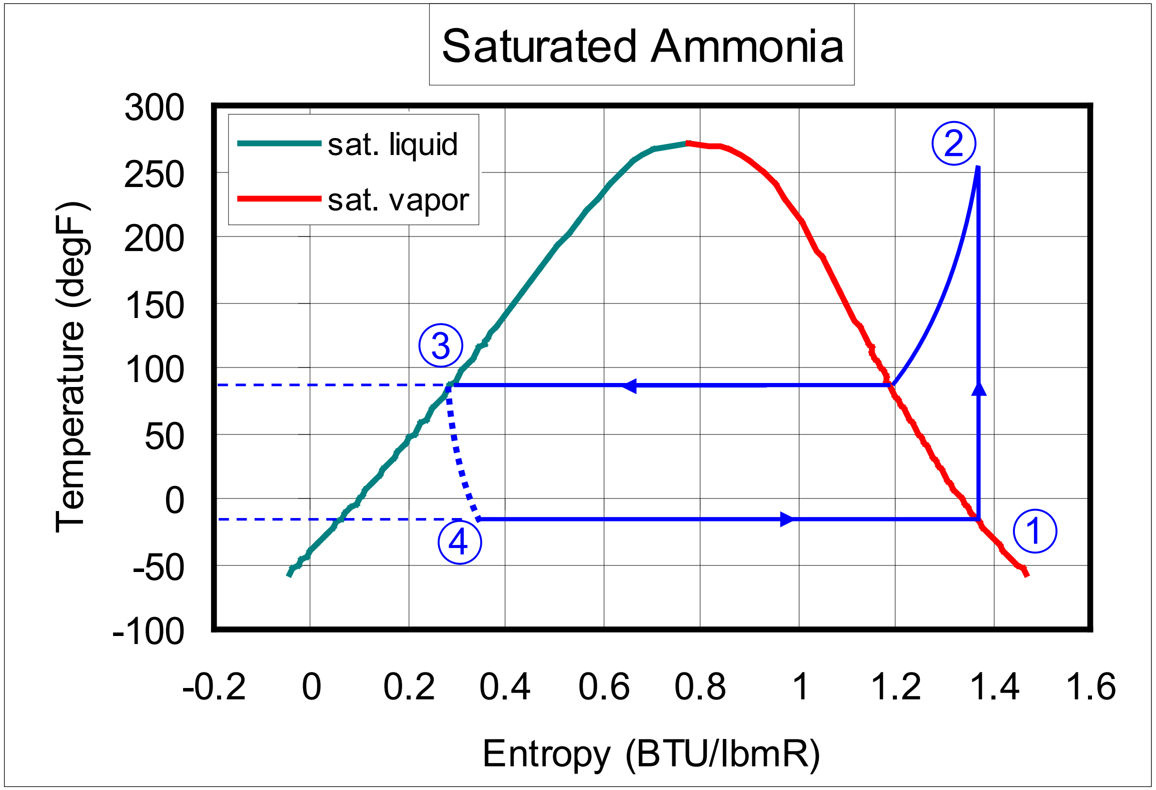
Vapor Compression Cycle:

- Recall 2nd Law of thermodynamics: It takes energy to get heat to move from a cold region to a hot region



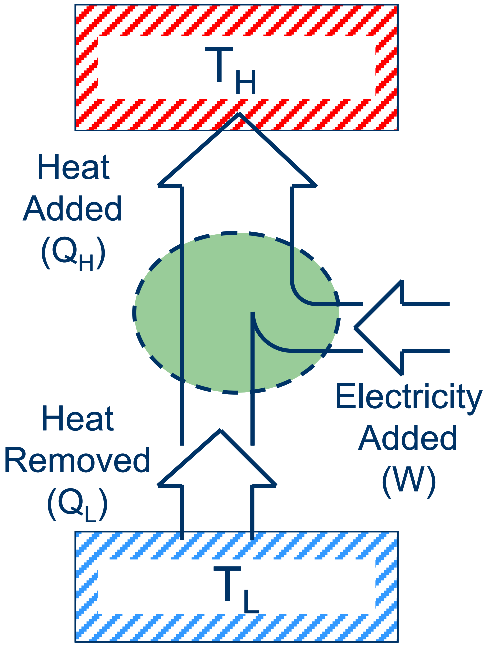


Vapor Compression Cycle



- 1 to 2 Compression from Low to High Pressure
- 2 to 3 Heat Rejection at T_H (Condensation)
- 3 to 4 Throttling from High to Low Pressure
- 4 to 1 Heat Addition at T_L (Evaporation)

Coefficient of Performance



1st Law: $Q_H = W + Q_L$

$$COP = \frac{\text{Heating (or Cooling) Benefit}}{\text{Power Supplied}}$$

$$COP_{Heating} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_L}$$

Carnot Limit:

$$COP_H)_{Carnot} = \frac{T_H}{T_H - T_L}$$

A Comparison of Air and Ground Source Heat Pumps

- Heat Delivered at 45°C

	COP	Carnot Limit
Air Source Heat Pump		
at -20C	2.0	5.6
at 0C	2.8	7.1
Ground Source Heat Pump		
at 0C	3.7	7.1
at 10C	5.0	9.1

<u>Commercial Earth Energy Networks</u>, The Canadian Renewable Energy Network

Example: Ground Source Heat Pump

A ground source heat pump system with a COP = 3.2 provides 18 kW of heat to a radiator/ DHW system at 65°C from a source at 10°C.

- Determine the power required (in kW)
- Compare the performance of this system with the theoretical Carnot limit

GLHP Example, Cont'd

Power Required:

$$W = \frac{Q_H}{COP} = \frac{18\text{kW}}{3.2} = 5.63\text{kW}$$

Theoretical Carnot Limit:

$$COP)_{Carnot} = \frac{T_H}{T_H - T_L} = \frac{338\text{K}}{338\text{K} - 283\text{K}} = 6.15$$

Exercise: Heat Pump System

A heat pump requires 12 kW of power to deliver 64 kW of heat from at well at 20°C to a heating system which operates at 70°C.

- Calculate the coefficient of performance for this heat pump system.
- How much heat (in kW) is removed from the well?
- Assuming the power input remains the same (12 kW), estimate the maximum possible amount of heat that could be delivered by a heat pump operating between 20°C and 70°C.