# Powered by Rock

## Earth's Energy Systems

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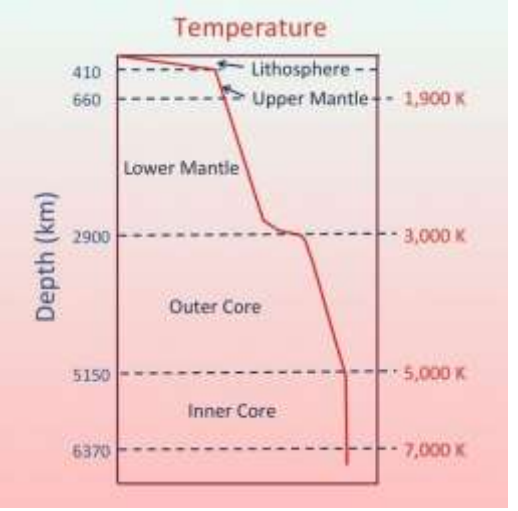
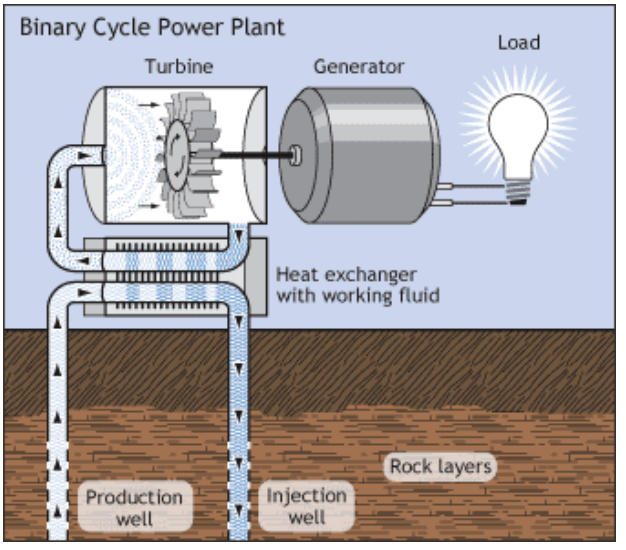
## Geothermal Energy

# Geothermal Gradient

- Driven by heat from radioactive decay in Earth's core
- Rate at which temperature increases with depth
- Average global value around 25°C/km




# Geothermal power



# Role of Geothermal

- Non-intermittent energy resource
- Low Carbon
- Low visual impact
- Potential for heat and power
- Improved technology has renewed interest

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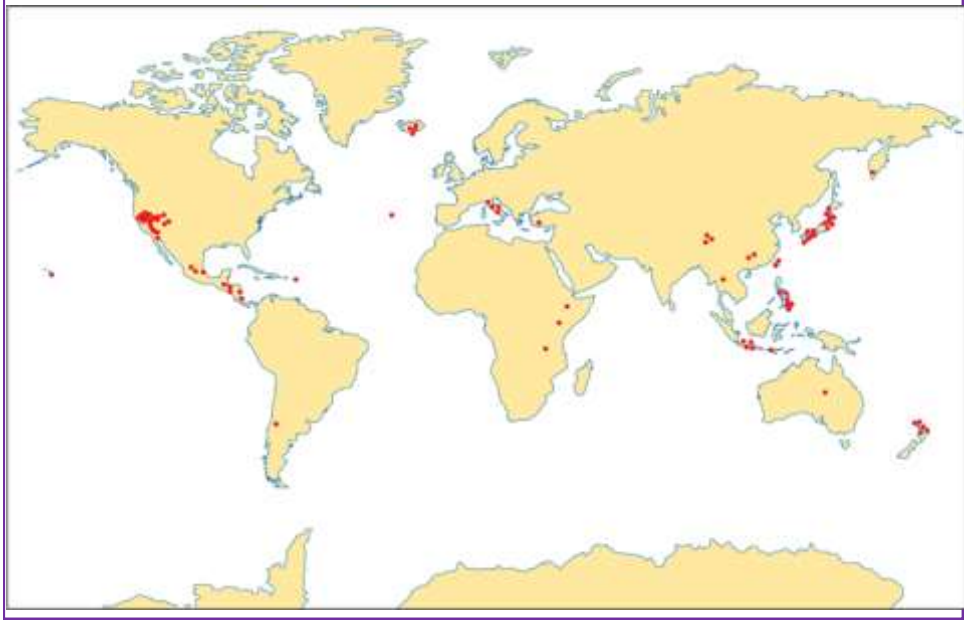
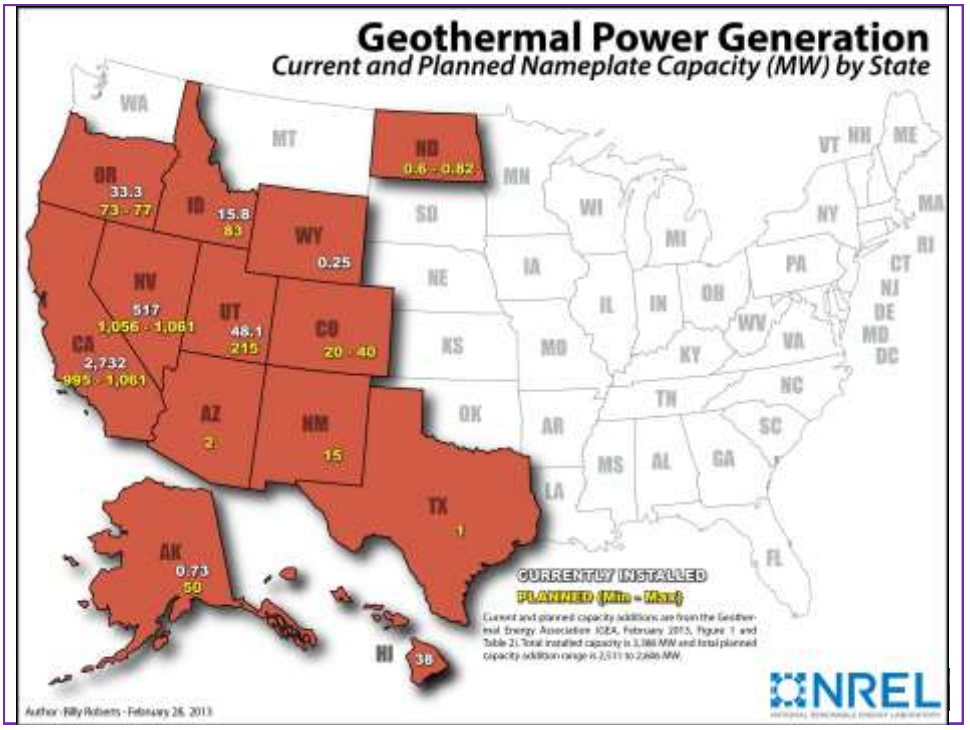
# Global geothermal






## Types of Geothermal System

### Temperature

- High Enthalpy >150°C
  (e.g. Iceland, other volcanic areas)
- Low Enthalpy <150°C
  (e.g. intraplate settings)

### Geological Setting

- Hydrothermal Systems
- Engineered Geothermal Systems
- Hot Aquifer Systems

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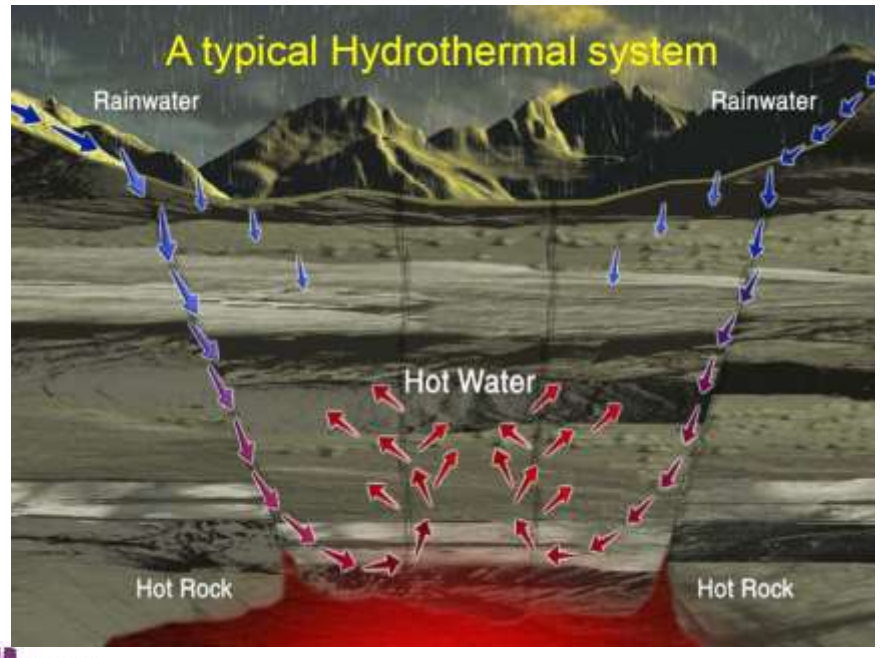
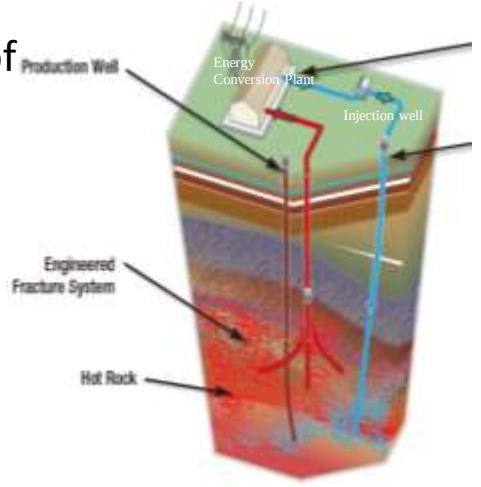
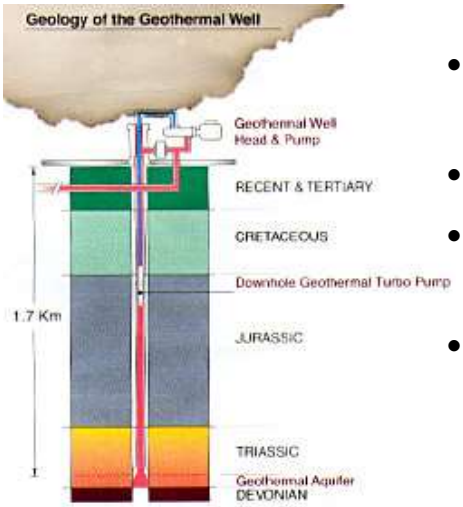



## Engineered Geothermal Systems

- Fracture stimulation of hot, dry rock
- 5km depth; source temperature: 200° C
- Germany/France
- 3024m$^3$/day gives 1.5MW$^e$



# Hot Aquifer Systems




- Aquifer Depths 2-5km – convective flow
- Heat only
- Temperature typically >60$^{o}$C
- Southampton: 860m$^{3}$/day @ 74$^{o}$C provides 1.4MW$^{th}$

# The Costs of Geothermal Energy

- Equalized costs (2011) £/MWh
  - Solar PV £89.3
  - Wind £53.6
  - Geothermal £55.4
  - Gas £41.5

*converted from USD at 1 USD = 0.62 GBP

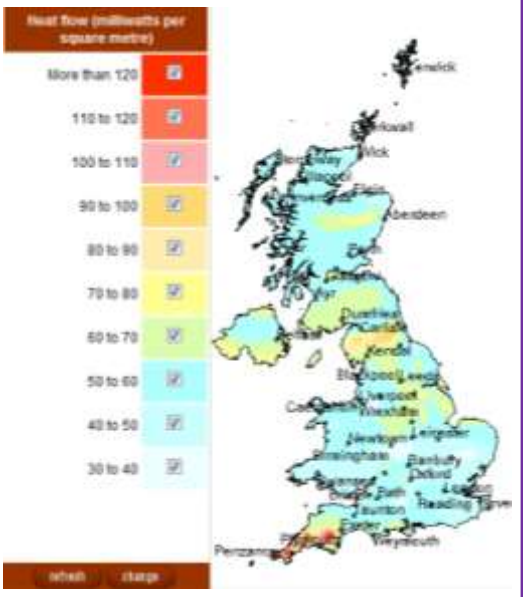
Source: U.S. Energy Information Administration

For or against?

Your geothermal arguments

# UK Geothermal Potential

- Modest heat flow
- Average thermal gradients ~26° C/km; peak of 35° C /km
- Areas of high heat flow = granites with high Th content

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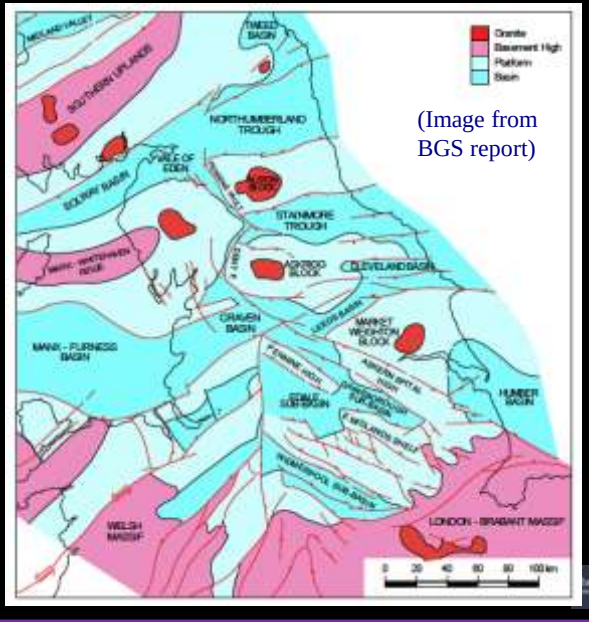
# Granitic blocks and sedimentary basins




(Image from BGS report)

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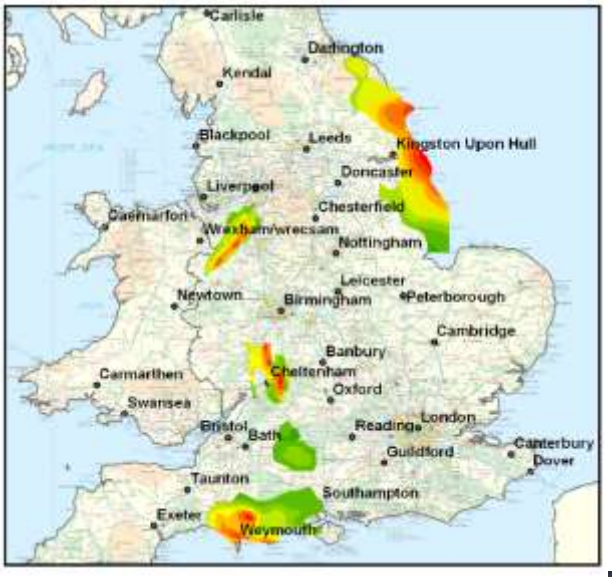
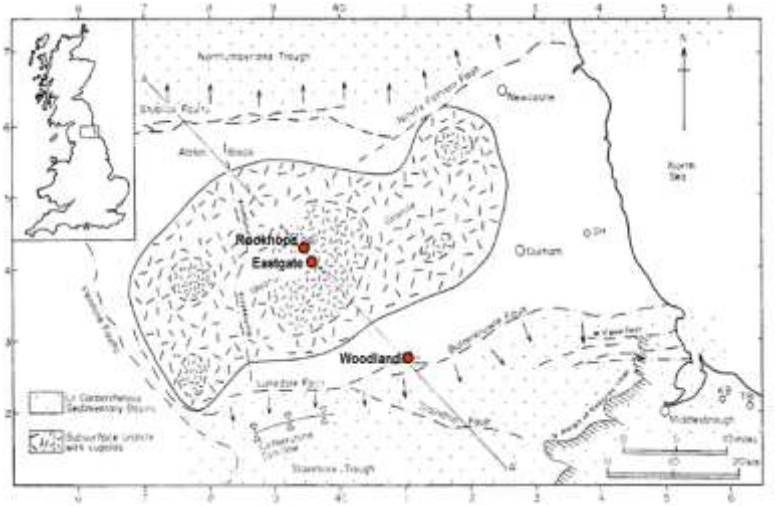
# Geothermal Basins in England



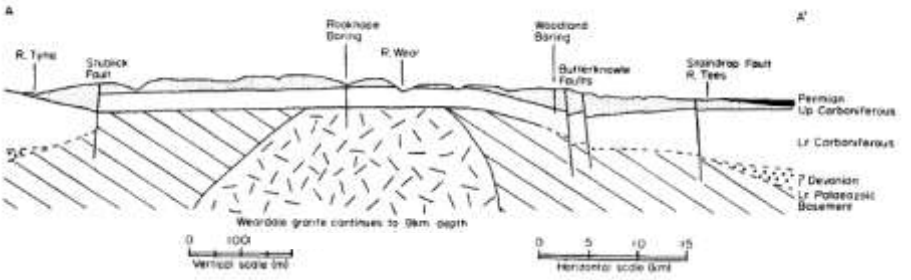

From Busby, 2010

# Geothermal Potential of the North Pennines




From Bott *et al.*, 1972

# North Pennines Cross-section




From Bott *et al.* 1972

# Evidence for fluid flow

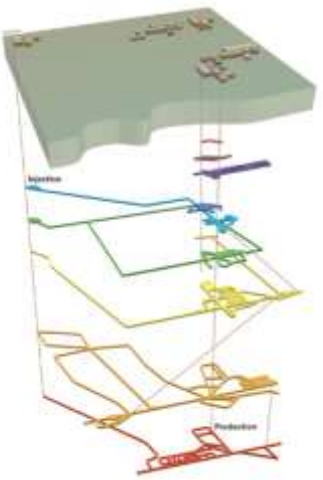
Fractured, mineralized granite

# Depth and Temperature studies

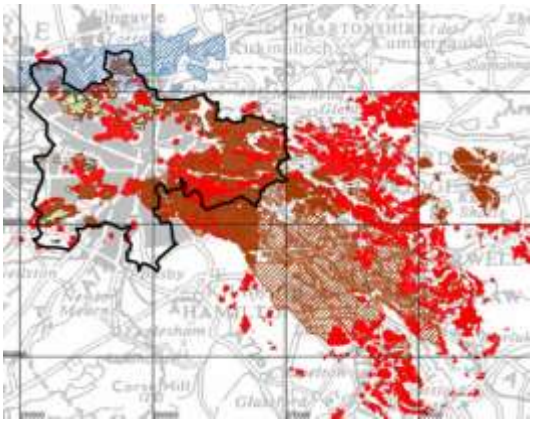
| | Temp (°C) | Depth (m) |
|---|---|---|
| Rookhope | 40 | 808 |
| Woodland | 29.3 | 499 |
| Eastgate | 46.7 | 995 |
| Science Central | 72 | 1900 |

Drilling rig, Science Central site, Newcastle

# Geothermal Glasgow?



Dutch minewater geothermal



Mines beneath Glasgow
= 20 Gwh / km2 / yr
= 40% of city heating

From BGS / CUSP project

Geothermal – for or against?

VOTE!

Prof. David MacKay

In the UK, “geothermal will only ever play a tiny part”


Next week: Water power
Hydroelectric & Tidal