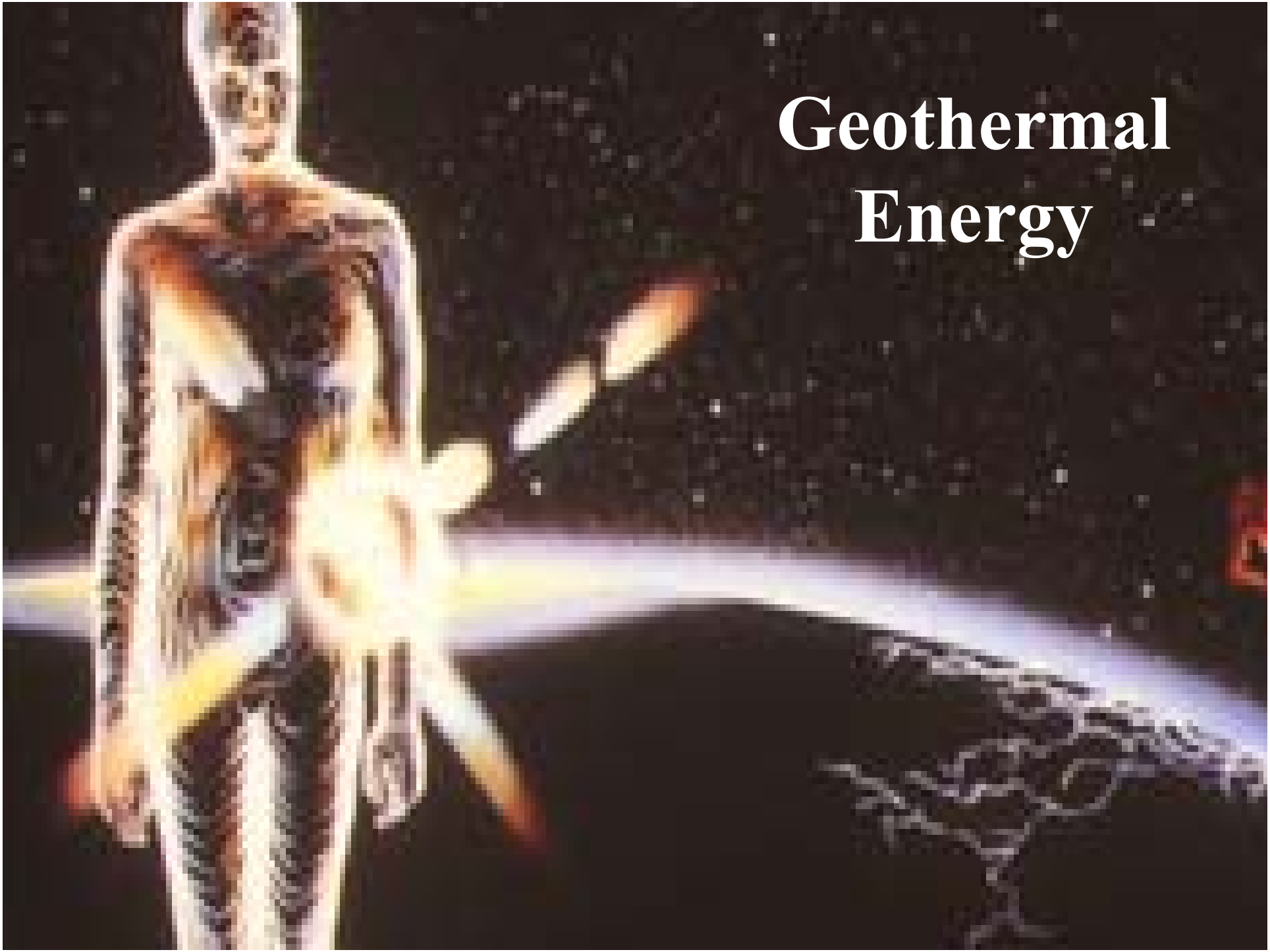
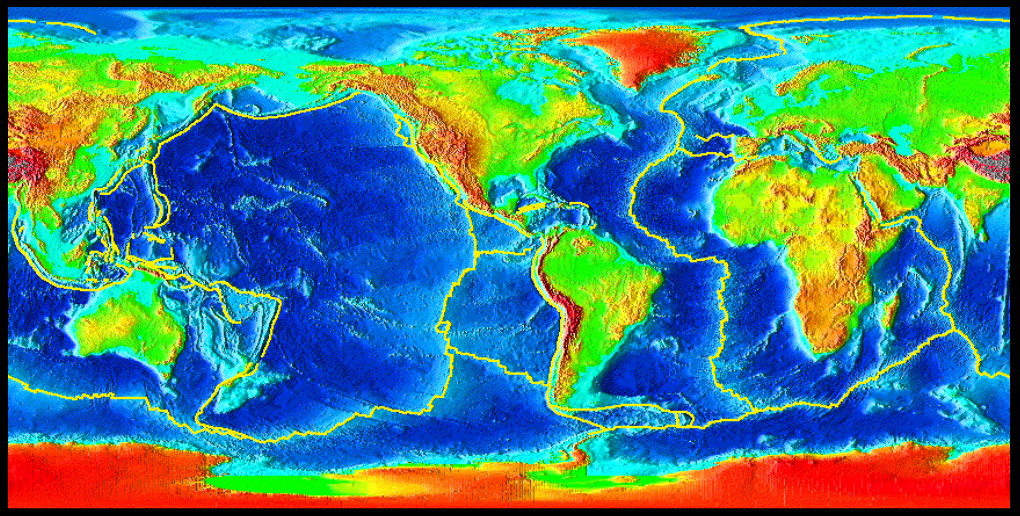

Geothermal
Energy

Volcanic activity

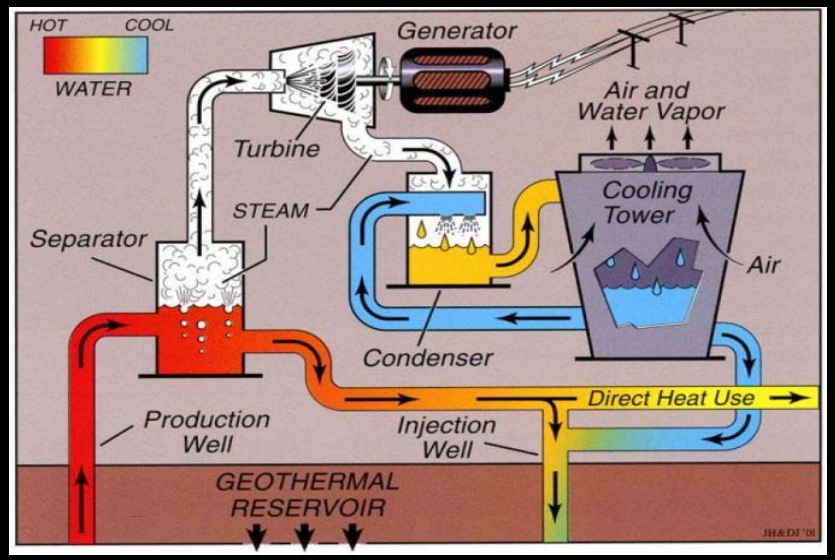
- The most violent manifestation of geothermal energy.
- The most promising regions for geothermal exploitation are found close to the boundaries between the tectonic plates of the earth's crust.



Crustal Plate Boundaries

High Enthalpy Sites

- Geysers: indicate hot water and steam close to the surface.
- T~200^{o}C
- Extraction of electrical energy from such a high enthalpy site is then relatively straightforward; the excess heat may be exploited as well.



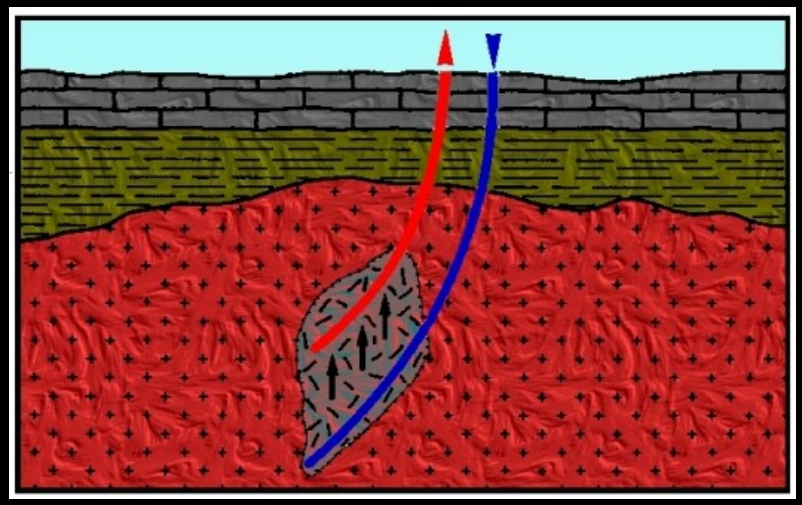
High enthalpy sites

- Lardarello, Northern Italy established in 1904.
- Produce 500 MW of electrical power.

- Krafla geothermal power station Iceland.
- 2 x 30MW steam turbines

Hot, dry rock

- Basic idea is to drill injection and recovery bore-holes into impermeable rock, and then fracture it deep underground. Cold water is injected and hot water is recovered.
- Experimental bore-holes have been drilled in a number of locations, including Switzerland and Australia.



Low enthalpy sites for district heating

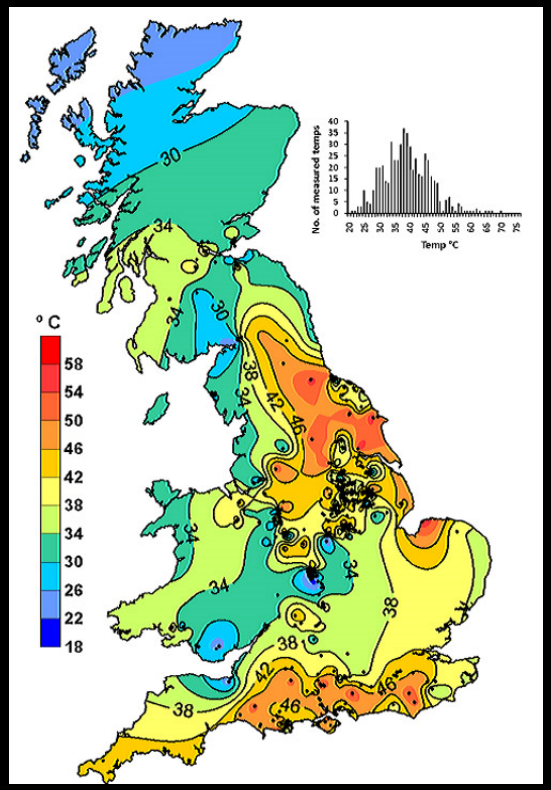
- ~80-150°C
- Used for district heat.
- Reykjavik, Iceland benefits from geothermal district heating schemes with a total capacity exceeding 660 MW.

- Possible to use organic Rankine cycle (ORC) to generate electricity at low temperature ~100°C

The 4MW Akça ORC geothermal plant in Turkey. Credit: Exergy.

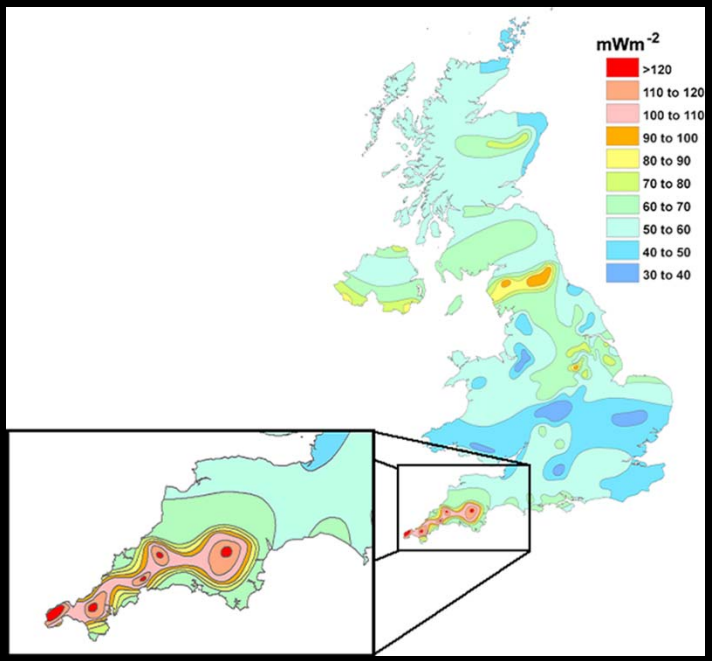
UK Low enthalpy sites for district heating

- Southampton, England has a 2 MW district heating plant, and plans further expansion.



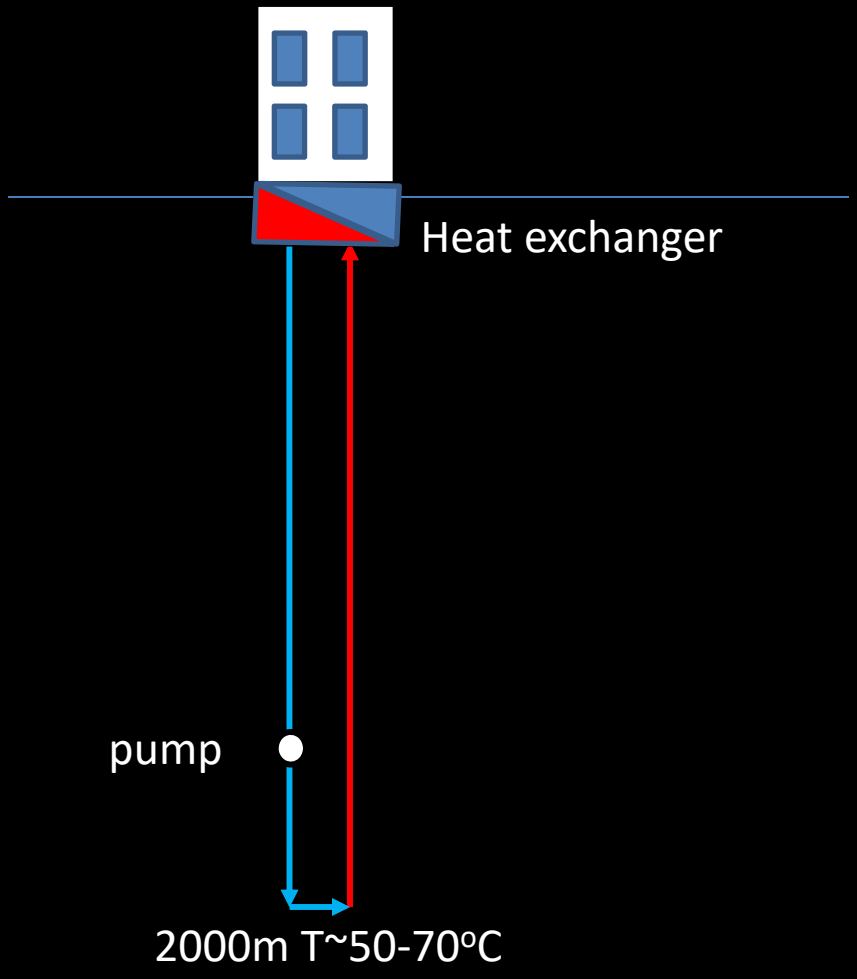
Temperatures at 1000m – source: BGS

Geothermal heat flux mW/m² source: BGS



Halo Kilmarnock

- 2km borehole as part of a district heating scheme.



Scotland to get its first deep geothermal heating system providing cheap renewable energy

Developers say the heat 'beneath our feet' will help reduce fuel poverty

Ian Johnston | @montaukian | Tuesday 19 September 2017 15:27 | 6 comments

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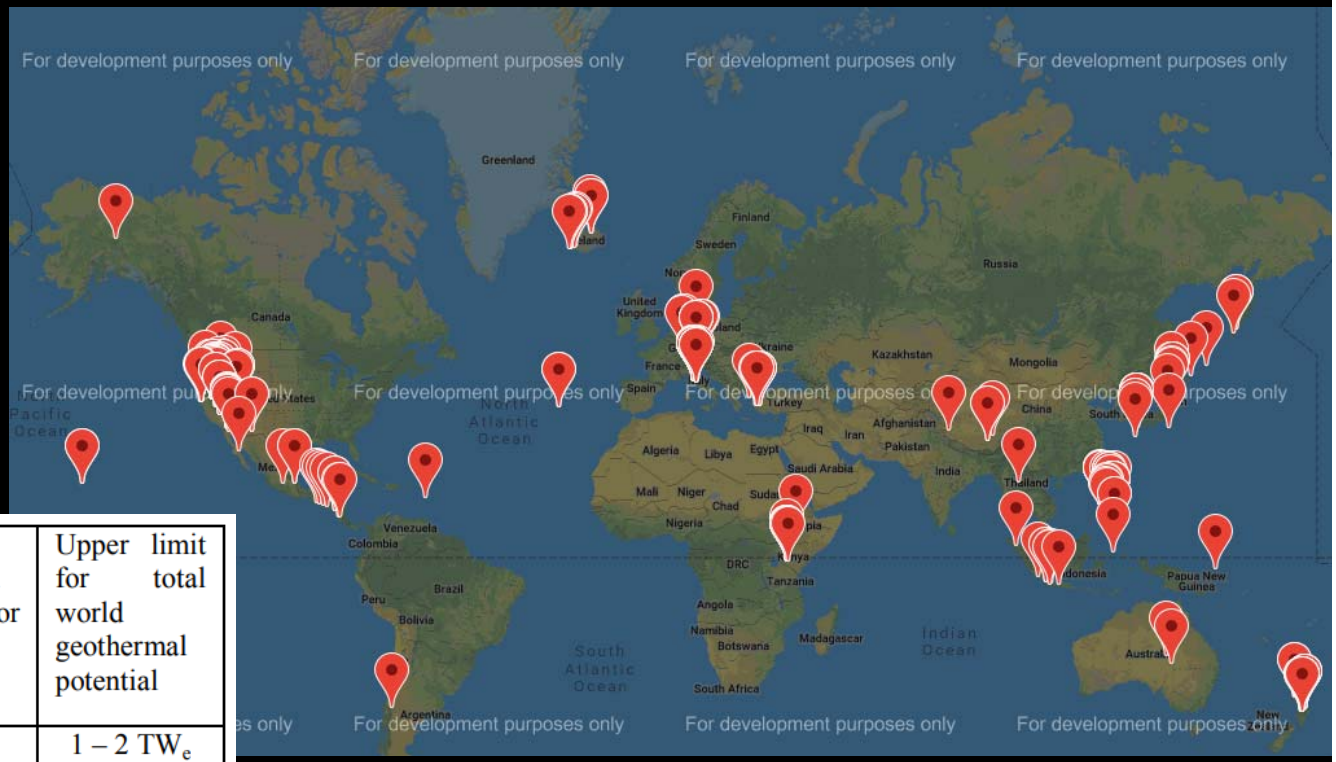
Source: The Independent

Global geothermal potential and exploitation

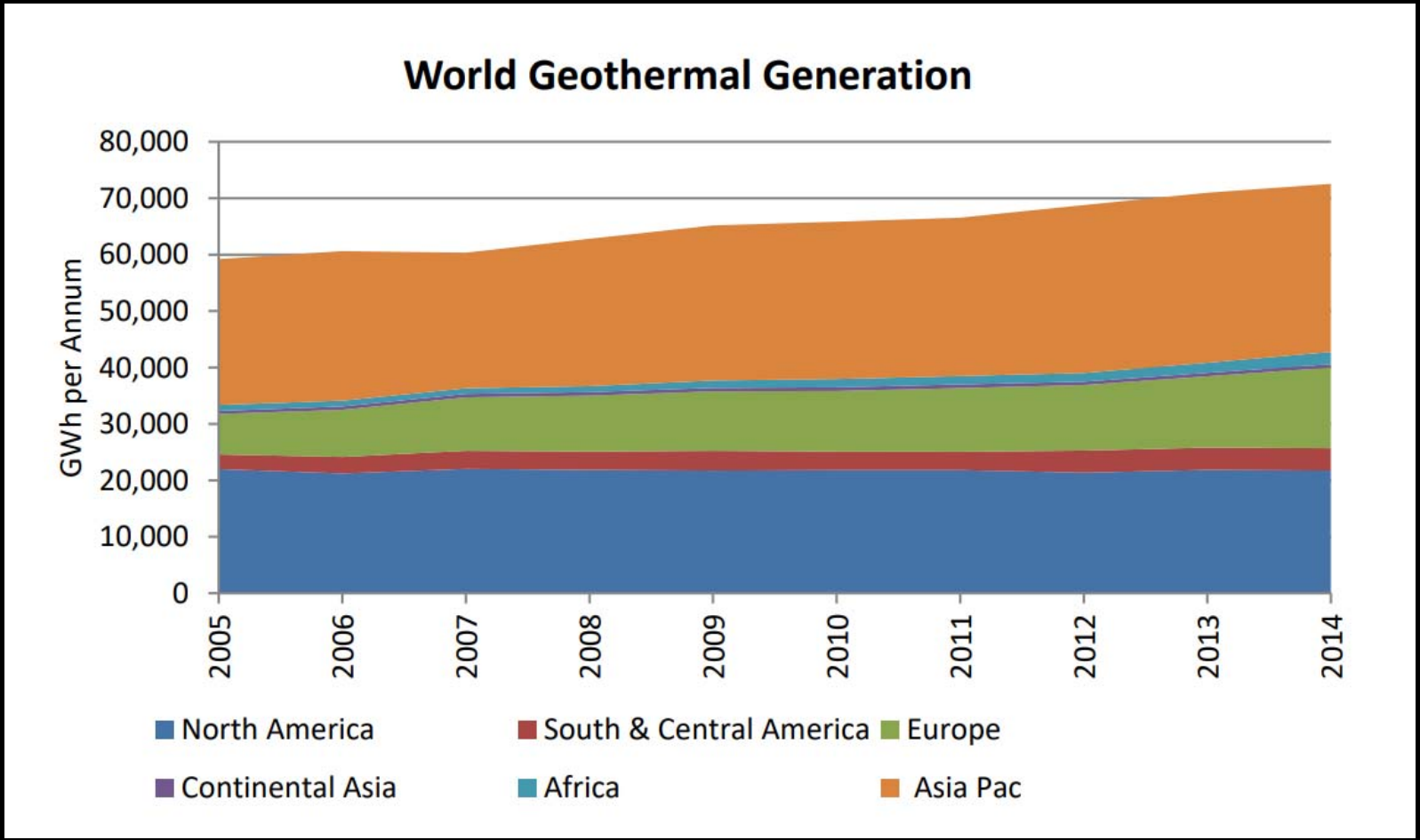


http://map.thinkgeoenergy.com/map/

	Lower limit for the potential of geothermal resources	World geothermal potential for identified resources	Upper limit for total world geothermal potential
Resources suitable for electricity generation	0.05 TW_e	0.2 TW_e	1 – 2 TW_e
Resources only suitable for direct use	1 TW_{th}	4.4 TW_{th}	22 – 44 TW_{th}
Total potential	1.5 TW_{th}	6 TW_{th}	30 – 60 TW_{th}

https://orkustofnun.is/gogn/Greinargerdir/Jardhitavettvangur/World-geothermal-assessment-VS.pdf

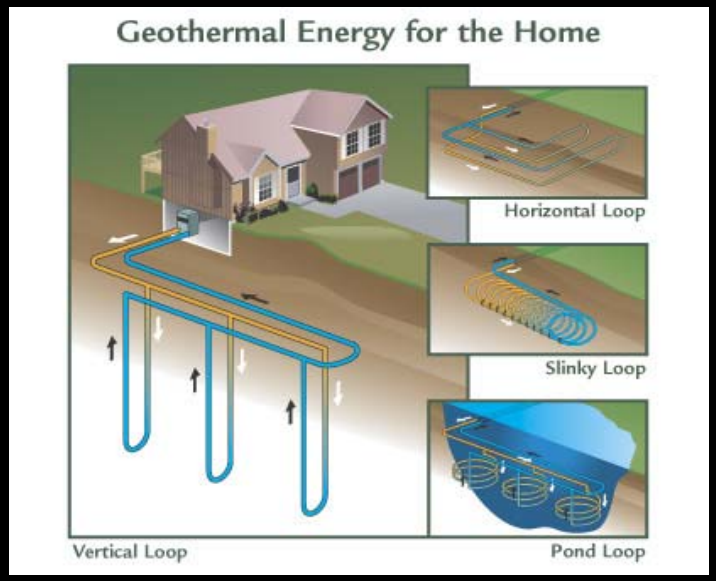
Global geothermal electricity generation



https://www.worldenergy.org

Heat Pumps

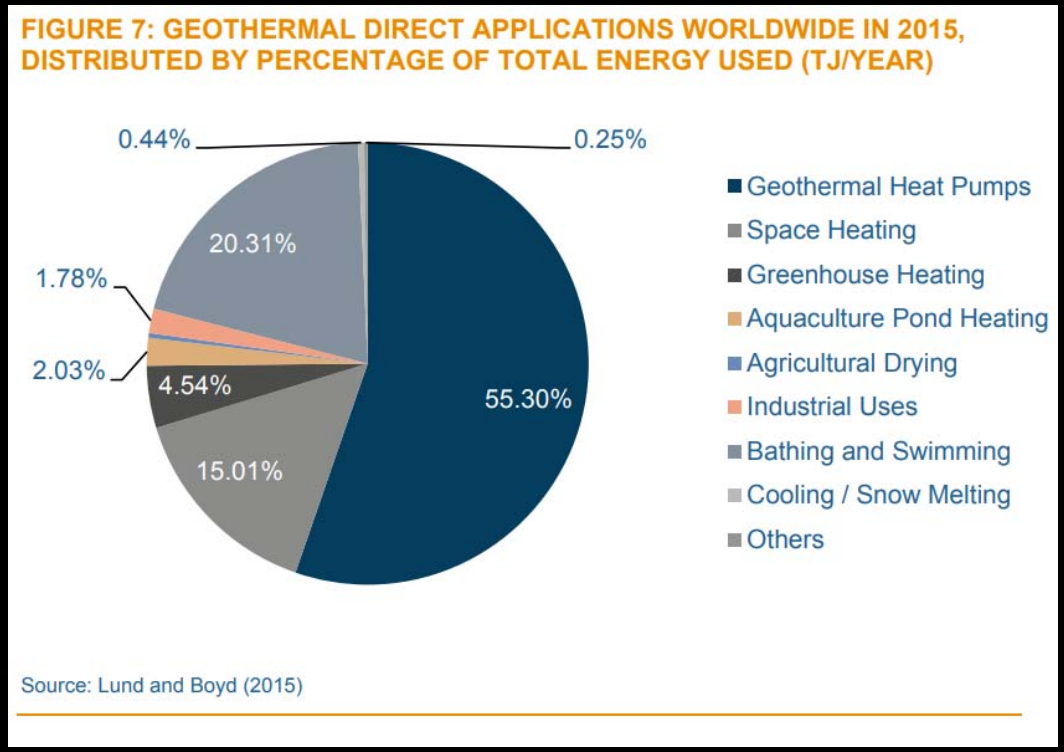
- Heat pumps transfer heat from low-quality heat sources.
- Often referred to as a geothermal technology
- Sources can include ground (1-200m) or water (GSHP, WSHP).
- An alternative is the air-source heat pump (ASHP), which uses the atmosphere as the primary source.

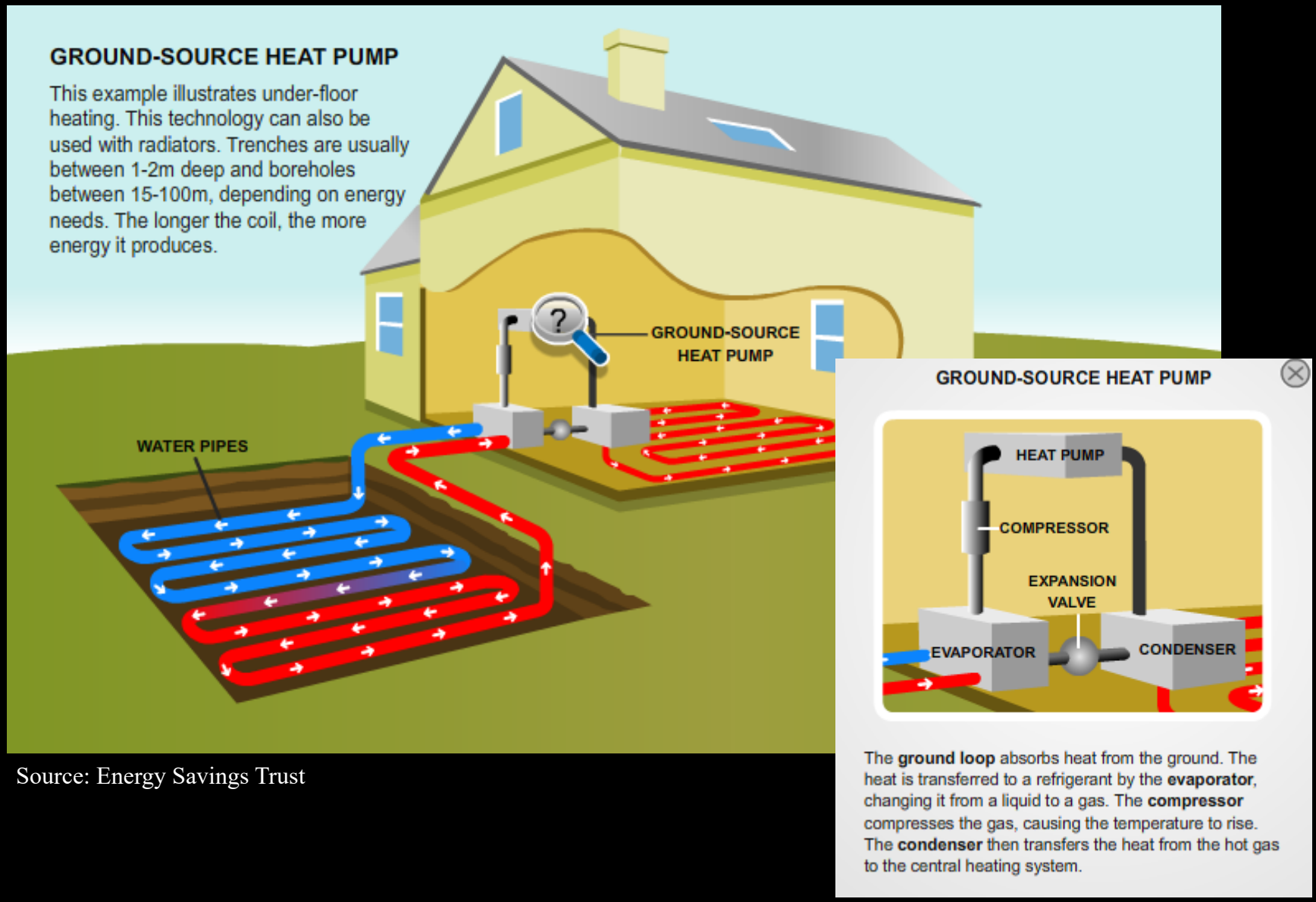


Source: Heat King

GSHP – Geothermal?

- Average geothermal heat flux ~90 mW/m^2
- Average solar flux ~240W/m^2
- At GSHP depths (~100m) the main heat source is really solar energy not geothermal energy.





Source: Energy Savings Trust

Heat Pumps

- With a low carbon electricity supply heat pumps are often viewed as a low-carbon means to provide space heating and hot water to buildings.
- However there are potential problems:
  - increased strain on the electricity network with significant take-up;
  - poor performance if incorrectly installed;
  - failure of GSHP installations (over time) if incorrectly sized;
  - poor performance of ASHP in low temperatures and humid climates (need to defrost evaporator coils).

Image: Mitsubishi