# Geothermal energy in private homes

Presentation for
“Energy and the Environment“
Nov. 29th 2011
by
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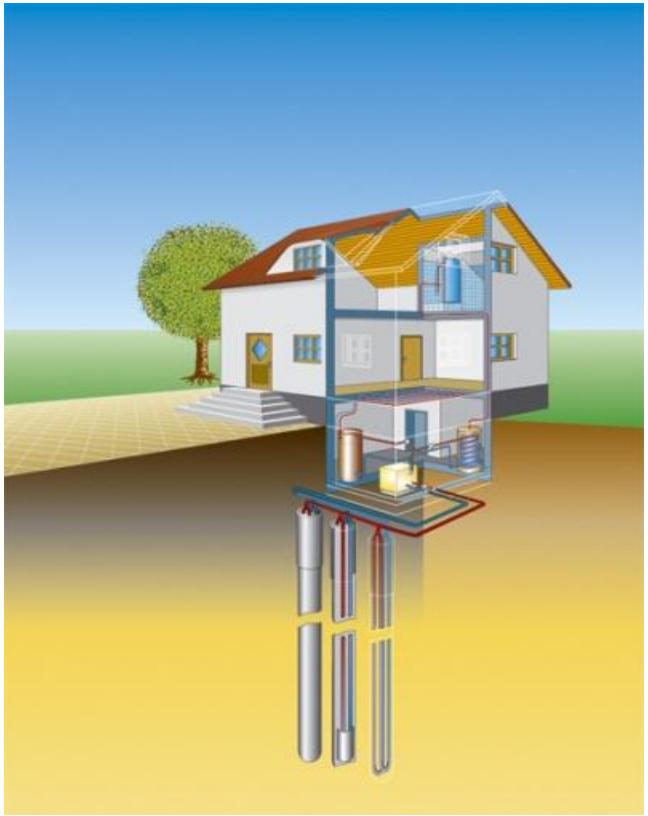


Source: erdwaerme-info.de

# Outline

- Introduction and motivation
- Heat
  - Generation
  - Distribution and mechanisms of transport
- Usage and applications of geothermal energy
  - Accessing geothermal sources
  - Industrial use
- Geothermal energy in private homes
- Risks

# Introduction and motivation

- What is geothermal energy?

Generated by earth itself    Thermal energy in form of heat

- Motivation to use it:
  - Renewable
  - No (to few in total balance) emissions
  - (Nearly) everywhere accessible

# Introduction and motivation (2)

Average heat flux through earth‘s surface: $87 \frac{mW}{m^2}$

result

Total energy for the earth: $4.4 \times 10^{13} W$

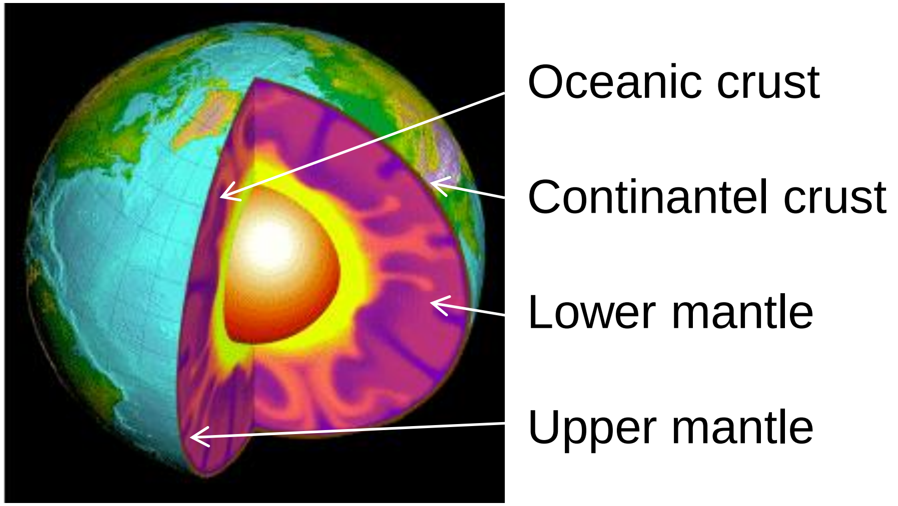
vs.

Total energy consumption estimated for 2006: $1.57 \times 10^{13} W$

Source: all-geo.org

# Heat flow - Generation

- Remnant heat from formation of the core
- heat from decay of long-lived radioactive isotopes
- Plate tectonics (friction)
- Exothermal reactions



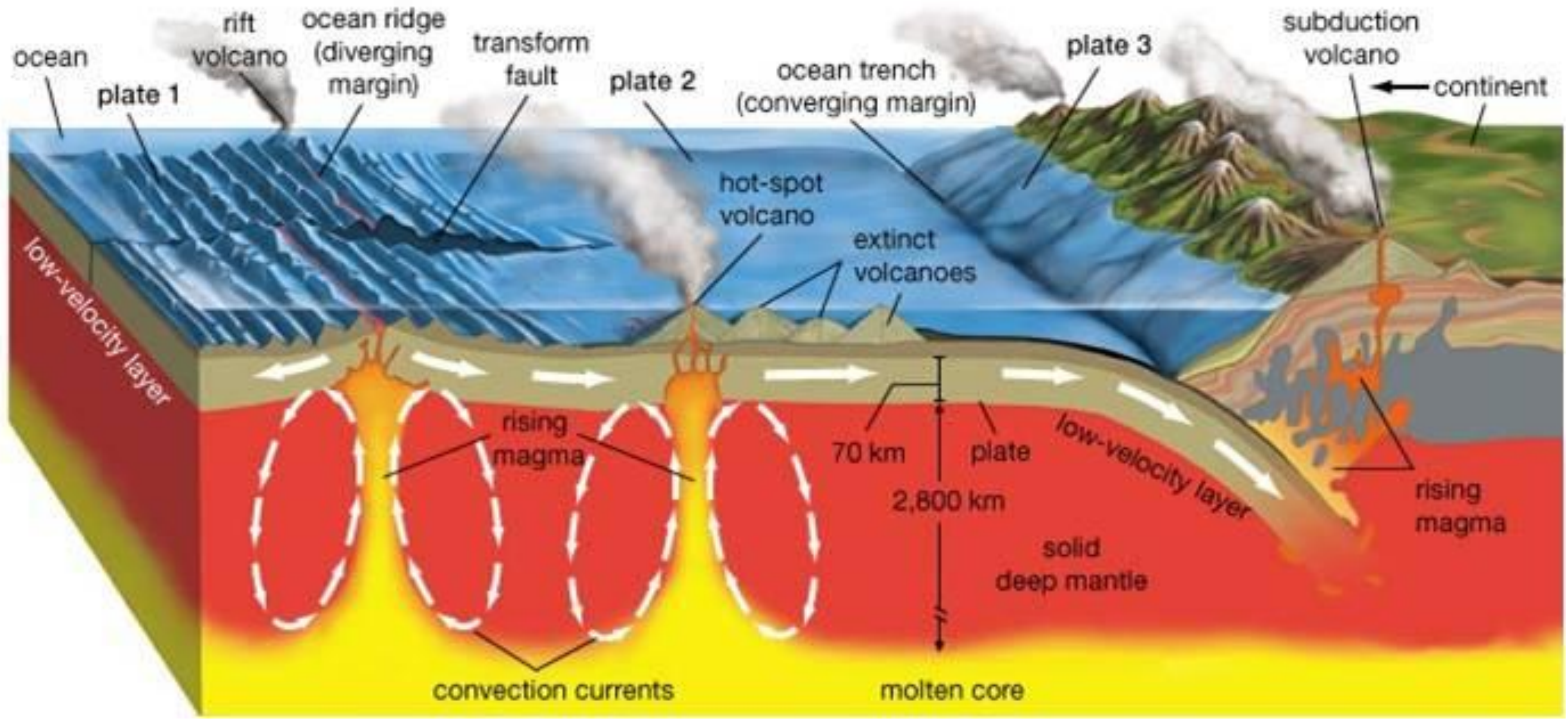

Source: usgs.gov

# Generation of heat – Formation of the core

- Long-lived Radioactive isotopes
  - Decay (e.g. $^{53}Mn_{t1/2} = 3.7 \times 10^{6}\,a$)
  - Collisions of decay products with atoms
- Molten iron migrating to the center
  - forming its liquid core
  - releasing gravitational potential energy
- Core slowly cooling down forming
  - solid inner core
  - liquid outer core

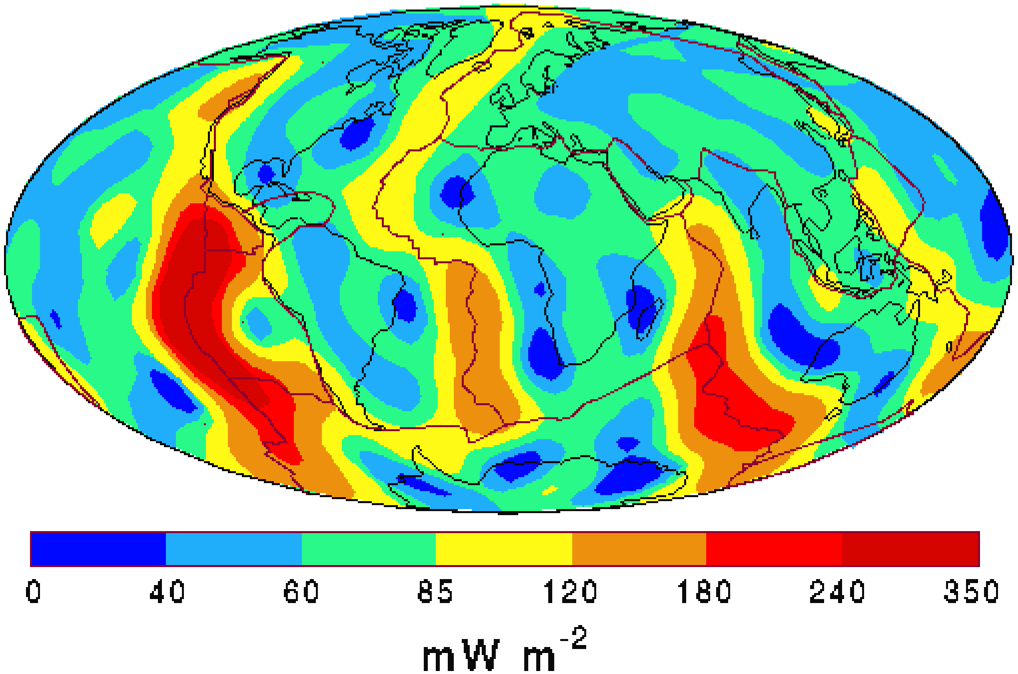
Heat is generated
(ca. 40% of g.e. used heat)

# Generation/distribution of heat – Plate tectonics



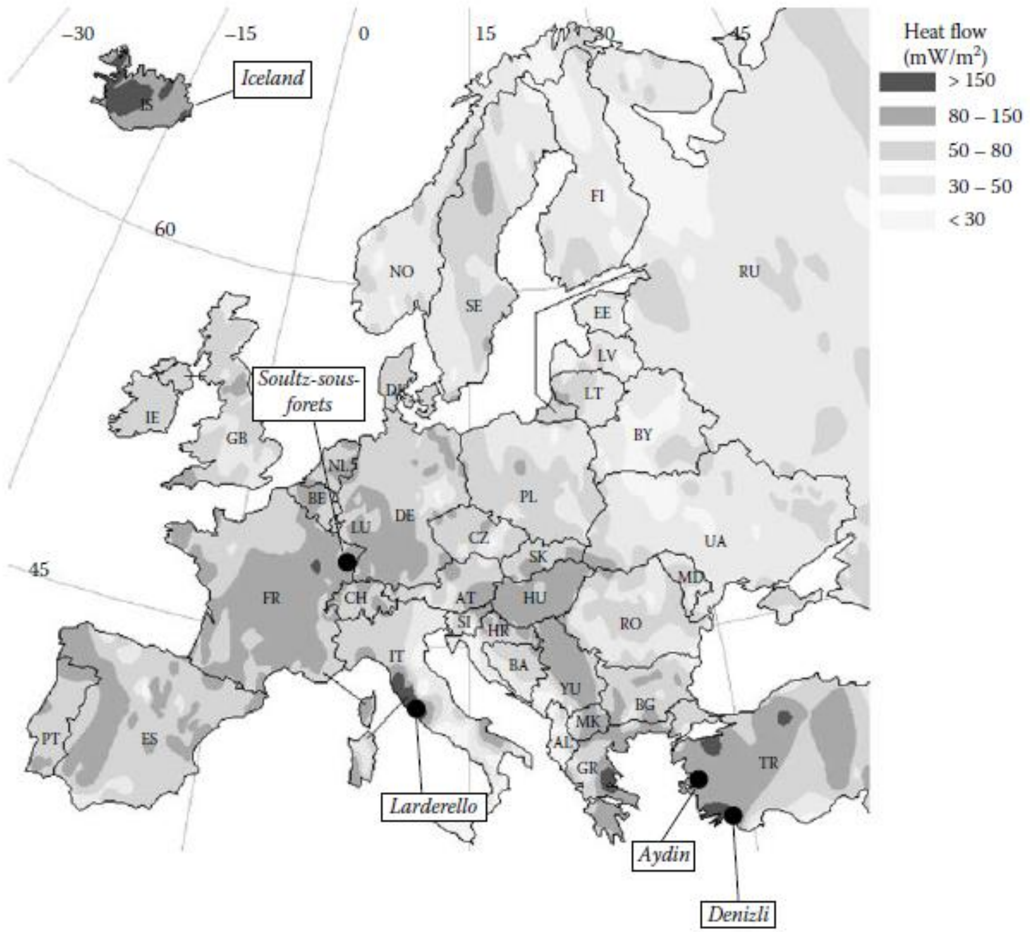

Source: V. Rufus, M. Hansen, N. Strotjohann

# Distribution of heat flow – Global heat flow




Source: lbl.gov

# Distribution of heat flow - Europe




Source: W. E. Glassley, Geothermal Energy, 2010

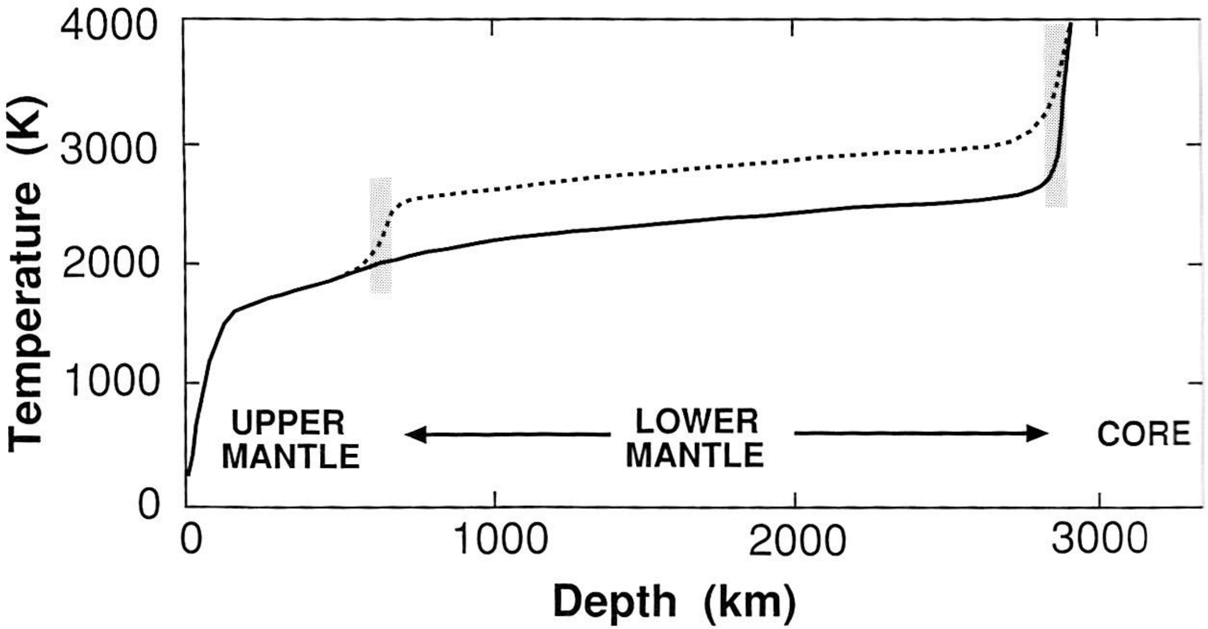
# Transport of heat – Theory

$$\frac{\partial T}{\partial t} = \frac{k}{\rho c_p} \nabla^2 T + \frac{A}{\rho c_p} - \vec{u} \cdot \vec{\nabla} T$$

$$0 = \frac{k}{\rho c_p} \frac{\partial^2 T}{\partial z^2} + \frac{A}{\rho c_p}$$

$$Q = -k \frac{\partial T}{\partial z} = Az + Q_0$$

# Transport of heat - Temperature profile




Source: C.M.R. Fowler, The solid earth, 2005

# Heat Storage inside the earth

**Table 5.4** Estimated U.S. Geothermal Resources[a]

| **Reservoir Type** | **Total Resource (QBtu)** | **Total Potentially Producible (QBtu)** |
|---|---|---|
| Hot water | 12,000 | 6,000 |
| Natural steam | 180 | 45 |
| Geopressured | 73,000 | 2,400 |
| Normal gradient | 1,250,000 | 12,500 |
| Hot dry rock | 160,000 | 1,600 |
| Molten magma | 3,500 | 35 |
| **Total** | 1,500,000 | 22,600 |

[a] To 6,000 meter depth, T ≥ 80°C, national parks excluded.

*Source:* Adapted from CONAES, 1980.

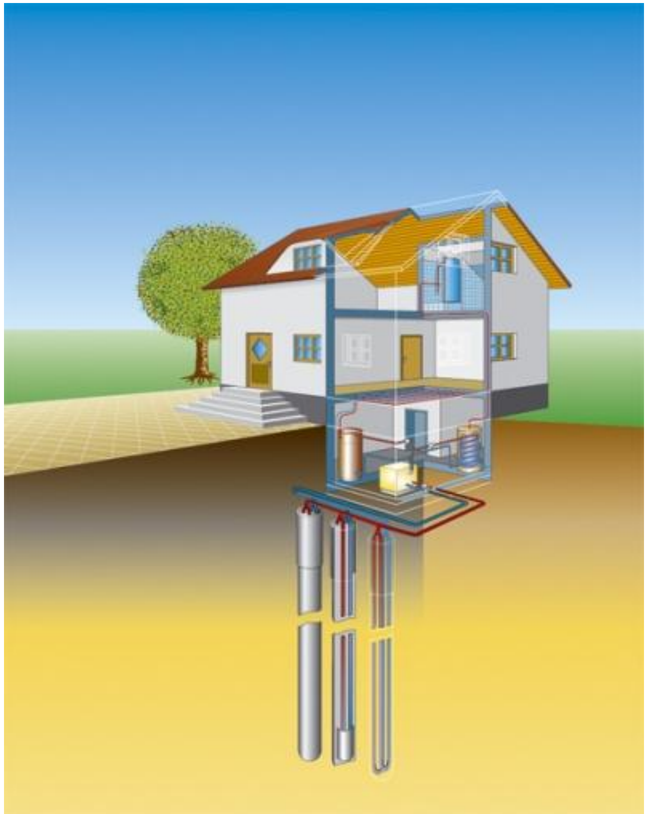
Source: R.A. Ristinen, J.J. Krausharr, Energy and the environment, 1999

$$1 QBtu = 1055 \times 10^{15} J$$

# Exploration of geothermal sites

- Geological information (e.g. concentration of certain silica or certain isotopes)
- Geophysical information (e.g. e/m and seismic surveys) - applied geophysics
- Geothermal information (drilling to measure temp. grad.)
- Private homes: „geologischer Dienst NRW“

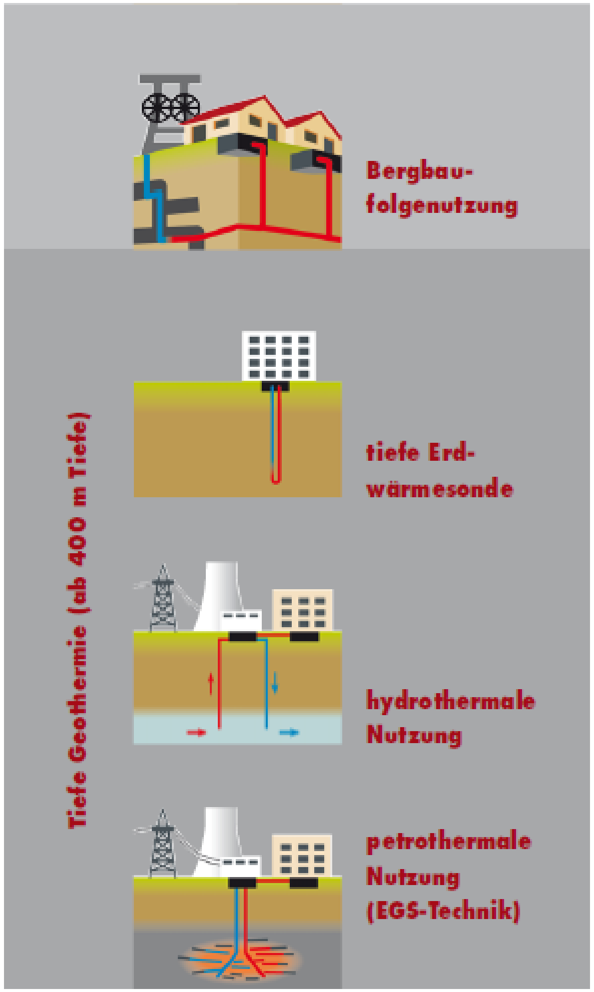
# Application of geothermal energy



Source: erdwaerme-info.de

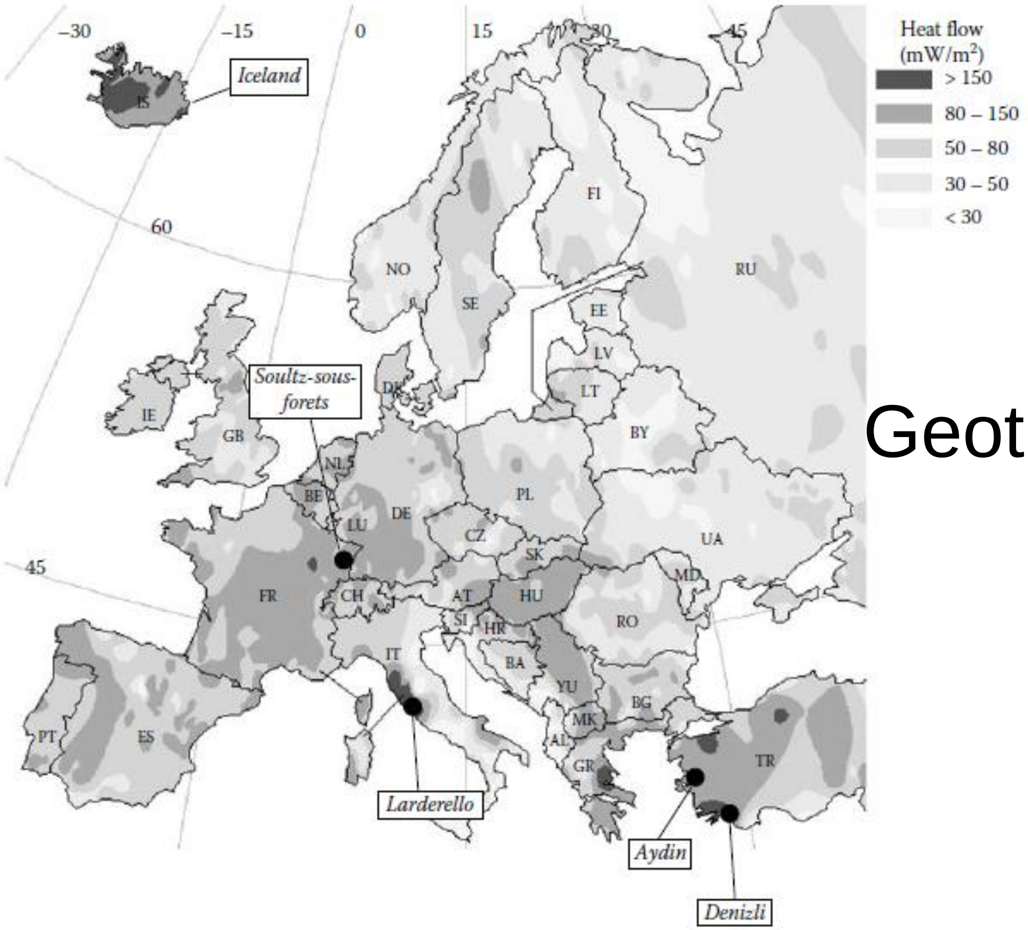
# Usage and application of g.e. - Deep

- Direct application (industrial)
- Generation of electrical power e.g. for the grid




Source: gd.nrw.de

# Usage and application of g.e. - Europe

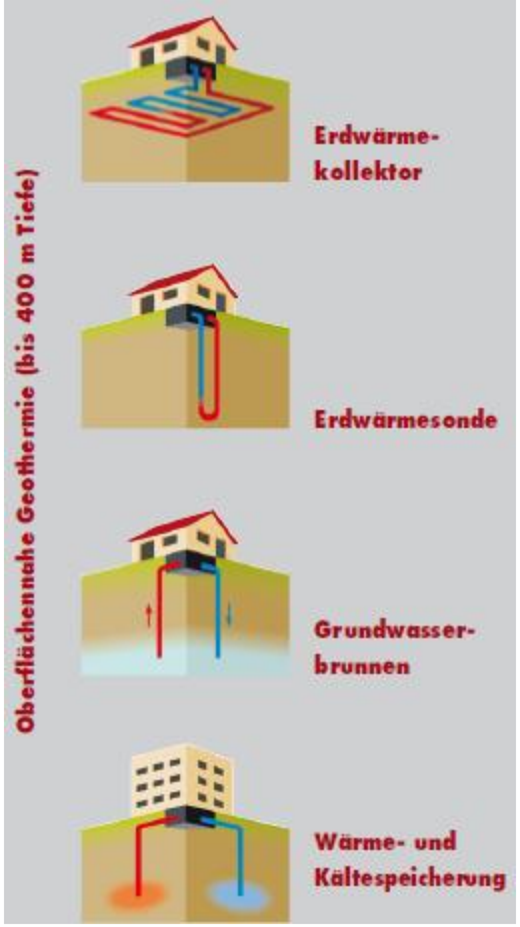



Geothermal power plants

Source: W. E. Glassley, Geothermal Energy, 2010

# Usage and application of g.e. – Close-to-surface

- Heating, ventilation & air conditioning (HVAC)
  - ground source heat pumps
  - open or closed systems
- Storage of heat
  - Variation of temperature on surface
  - Constant temperature in earth

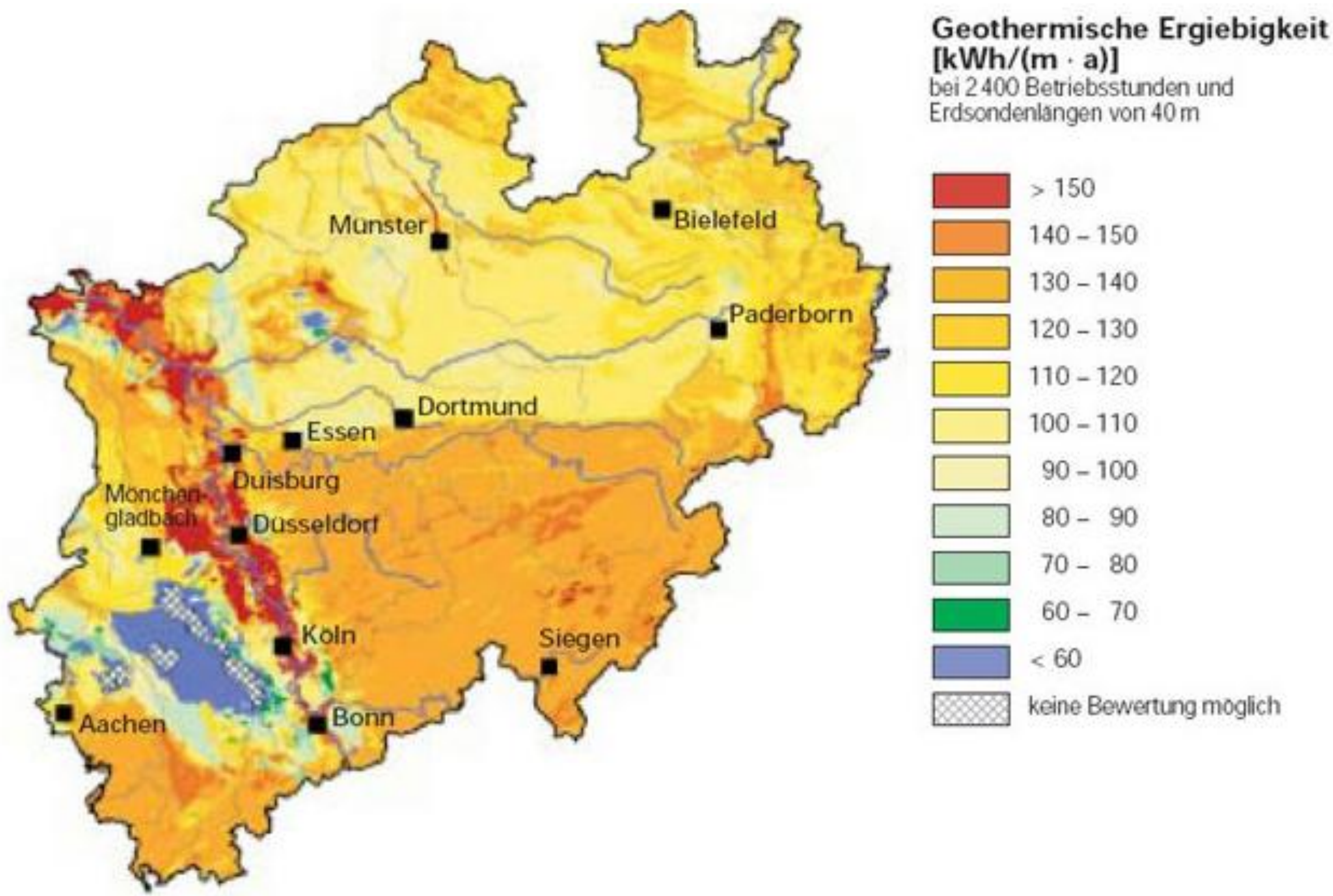



Source: gd.nrw.de

# Usage and application of g.e. – Heating and cooling

- Heating:
  - Cold water is pumped through temperature gradient inside earth to heat up
  - Hot water used for room/floor heating or to supply warm water
- Cooling:
  - Cold water from close-to-surface reservoirs used for air conditioning

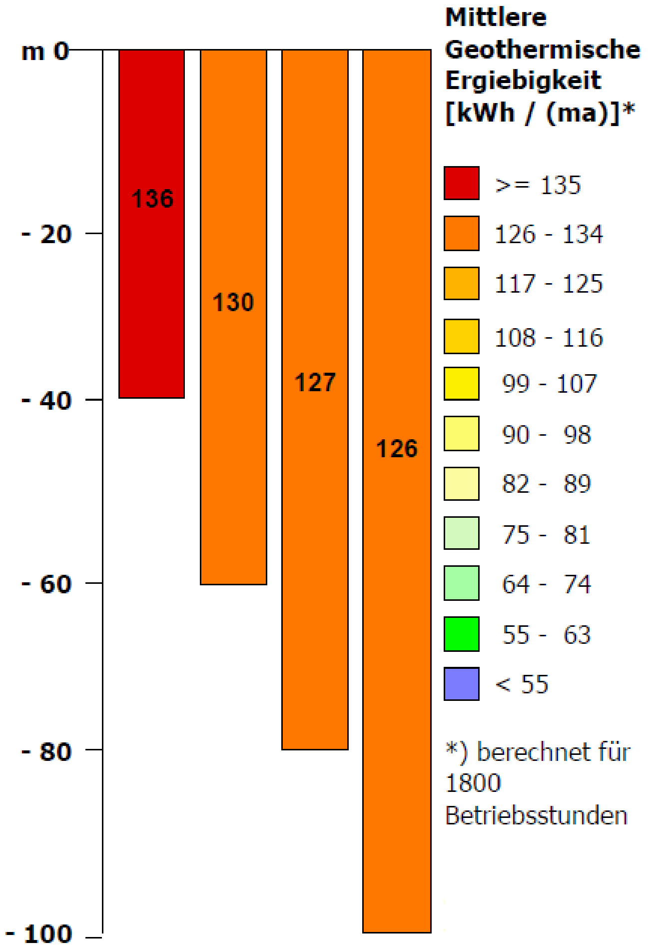
# Geothermal energy in private homes – Exploitation (1)



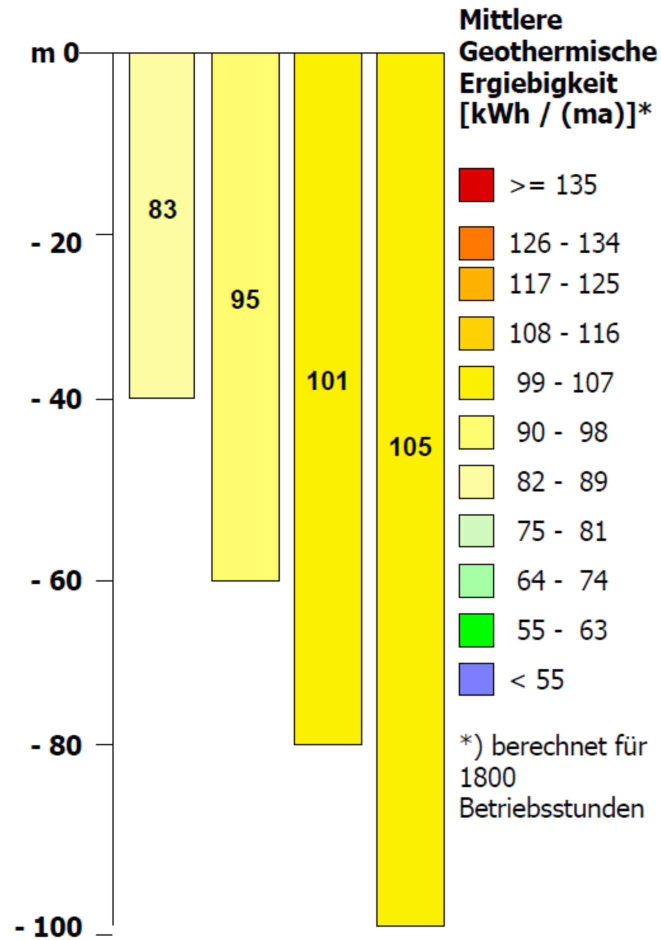

Source: gd.nrw.de

# Geothermal energy in private homes – Exploitation (2)

(i)

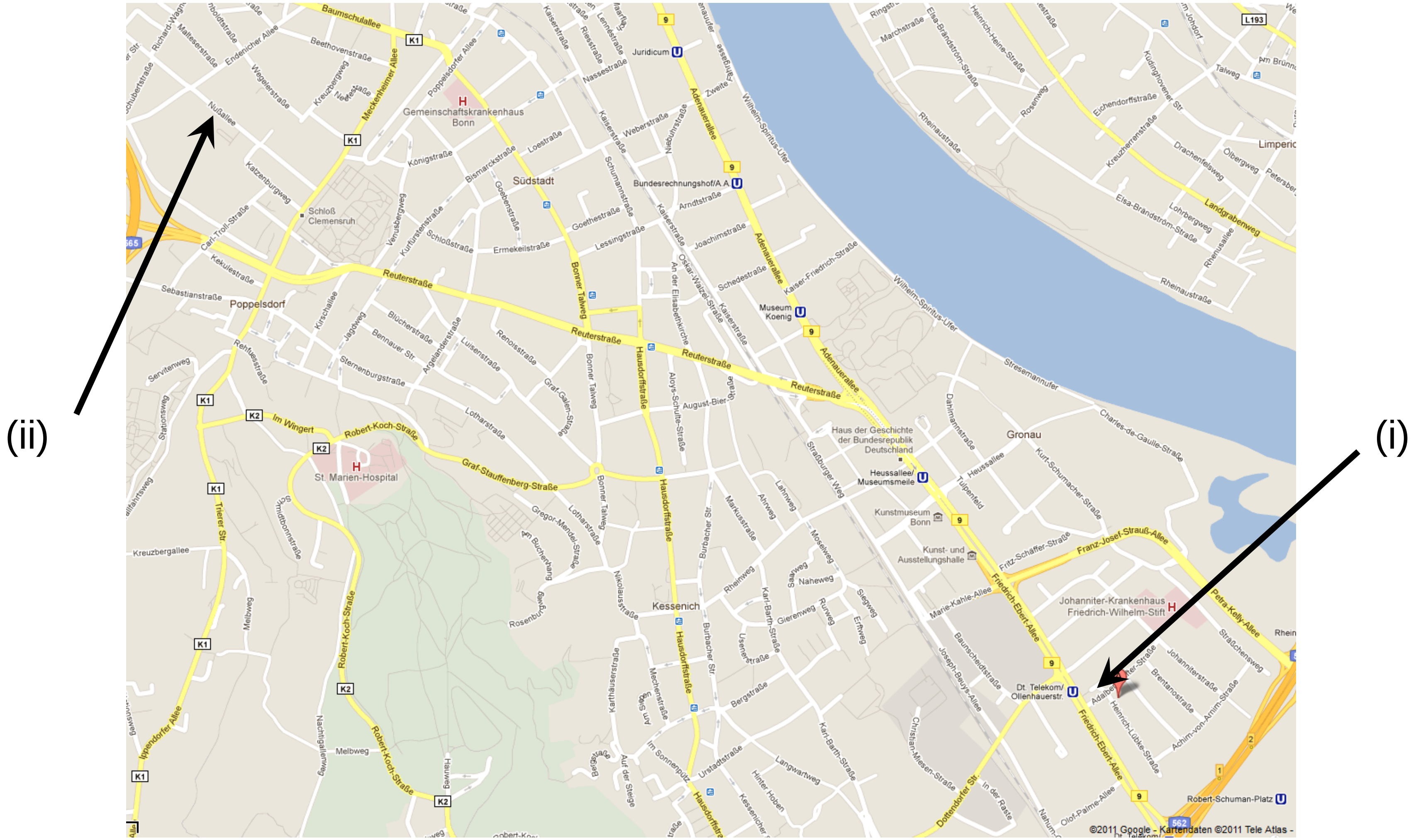



(ii)




Source: gd.nrw.de

# Geothermal energy in private homes – Exploitation (3)



# Geothermal installations (1)

- Collector:
  - Closed system
  - Installed below local ground frost level
  - Sun radiation and rain fall heat up the ground
  - Heat flow per area used to heat/cool water
  - Area of installation twice as large as heated residental property


Source: ipp.mpg.de

# Geothermal installations (2)

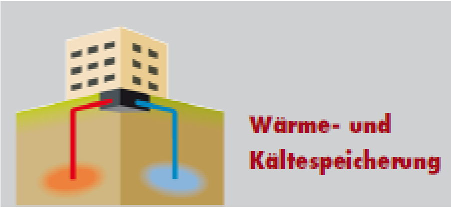
- Probe:
  - Installed in areas where collectors do not suffice
  - Drill hole holds two from each other isolated tubes
  - Circulation of water-chemical mixture (closed system)
  - Expensive
  - To increase efficency many tubes are combined in one hole



Source: hausbauunternehmen.info

# Geothermal installations (3)

- Groundwater well
  - Groundwater is pumped up and down
  - Open system


- Water storage
  - Storage of water in different depths with different temperatures

# Example of a single family home

- Calculation (after 20 years):
  - Installation costs (incl. pump): +19,200 €
  - Annual costs (pump): + 20 x 500 € = +10,000 €
  - Alternative heating System: -6,830 €
  
    with annual operating costs: -20 x 1,200 € = -24,000 €

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-1,630 €

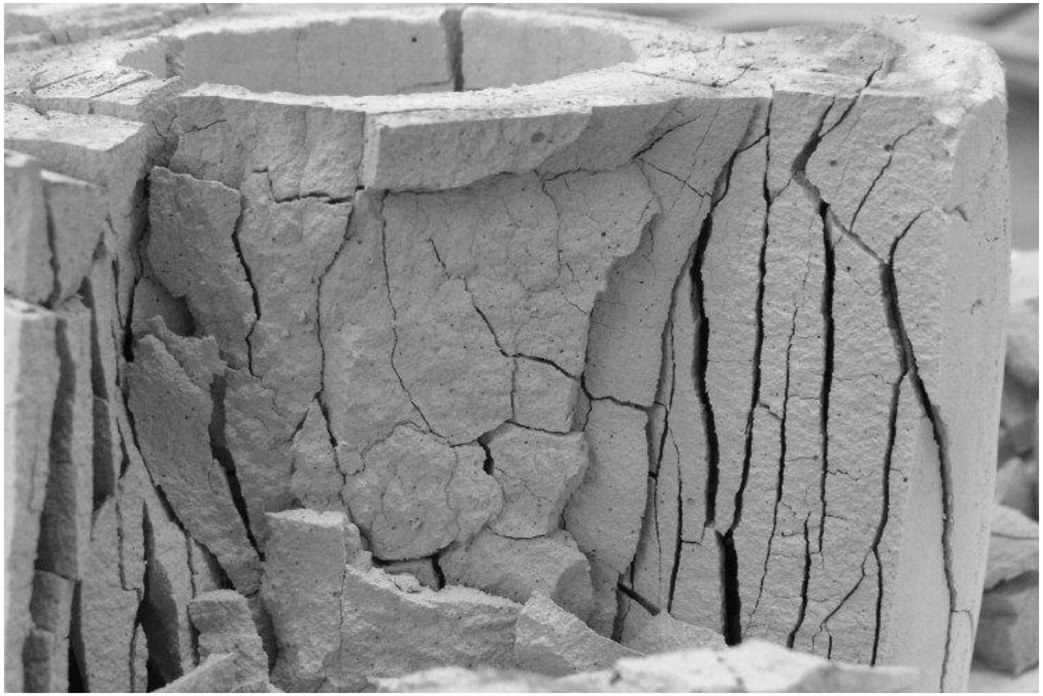
# Risks – General (1)

- Changing integraty of the ground due to drilling
- Changing the flow of groundwater
- M=3.4 earthquake in Basel

Source: welt.de

# Risks – General (2)

- Damage of filling material in drill holes due to change in environmental circumstances



Source: geothermie-nachrichten.de

# Risks – Open systems

- Oaklahoma Earthquake M=5.6 due to Hydraulic Fracturing

Source: nature.com

- Pumping water into the earth to shatter sediment layers containing natural gas
- Open system in geothermal applications = pumpig water into the earth!

# Summary (or Pros and Cons)

## Pros

- Renewable
- Saves money longterm
- No direct effect on the environment
- Versatile in its application
- Almost everywhere accessable

## Cons

- High installation costs
- Might have an effect on the earth‘s integraty
- No substitution for other electricity generating sources
- Strong dependance on the circumstances

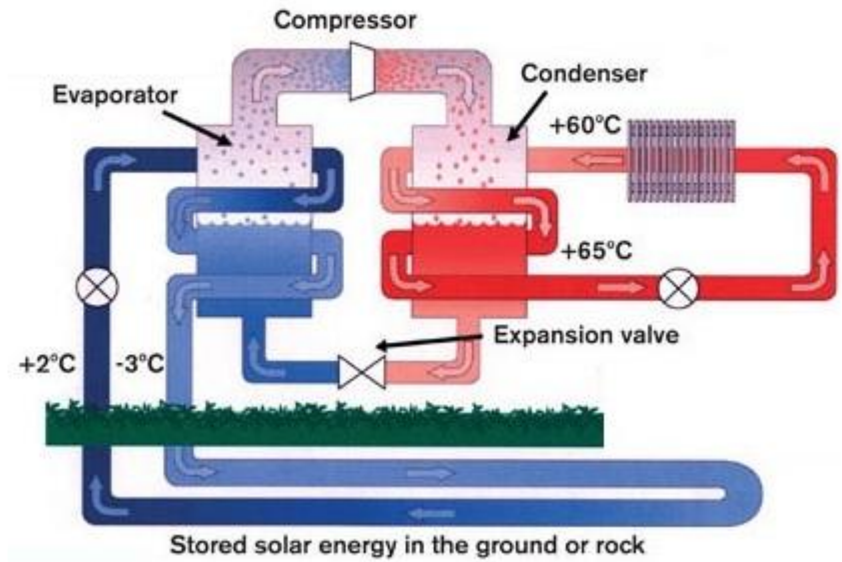
# Geothermal energy in private homes

Thank you for your attention!
Any questions?

See ya!

# Appendix – Principle of a GSHP (1)

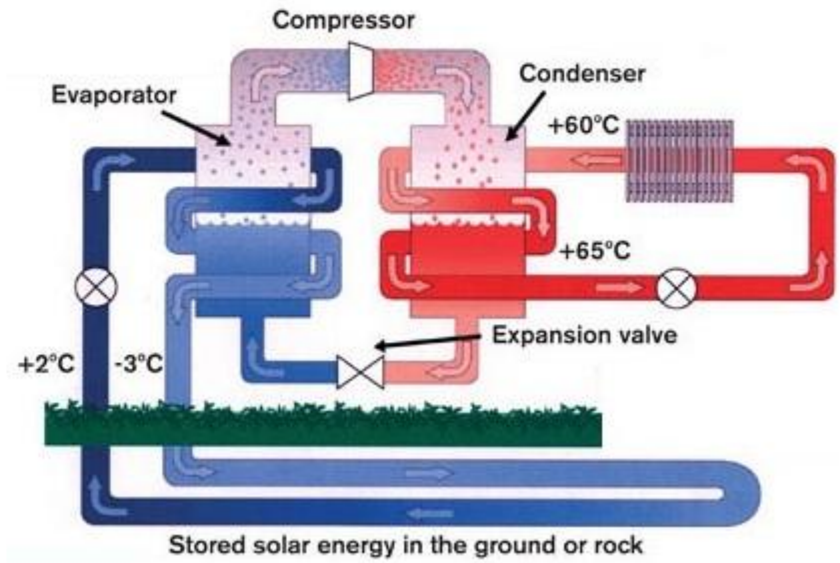
- Basic idea:
  - Inverse Carnot cycle
  - Mech. work is used to transfer heat from lower T to higher T reservoir (e.g. 2°C to 60°C)
- Requirement
  - Fluid with low temp. of ebullition (e.g. propane)




Source: rjsheating.co.uk

# Appendix – Principle of a GSHP (2)

- Fluid at high *p*, low *T* is pumped through warmer ground → heat intake, evaporation (-3°C→ +2°C)
- Gaseous fluid is compressed → condensation, heat output to heating system
- *T* in heating cycle increases




Source: rjsheating.co.uk

# Appendix – Geothermal energy in Germany

- G.e. relative to other renewable energies(July 2011)
  - 0.027% in electricity
  - 4.1% in heating

| | | Endenergie 2010 | Anteil am Endenergie-verbrauch | | vermiedene THG-Emissionen | Endenergie 2009 |
|---|---|---|---|---|---|---|
| | | [GWh] | [%] | | [1.000 t] | [GWh] |
| Stromerzeugung | Wasserkraft [1] | 20.630 | Anteil am Stromverbrauch [9] | 3,4 | 16.390 | 19.059 |
| | Windenergie | 37.793 | | 6,2 | 27.800 | 38.639 |
| | an Land | 37.619 | | 6,2 | 26.672 | 38.602 |
| | auf See (Offshore) | 174 | | 0,03 | 128 | 38 |
| | Photovoltaik | 11.683 | | 1,9 | 7.934 | 6.583 |
| | biogene Festbrennstoffe | 11.800 | | 1,9 | 9.185 | 11.356 |
| | biogene flüssige Brennstoffe | 1.800 | | 0,3 | 1.084 | 2.009 |
| | Biogas | 13.300 | | 2,2 | 7.517 | 10.757 |
| | Klärgas | 1.101 | | 0,2 | 824 | 1.057 |
| | Deponiegas | 680 | | 0,1 | 509 | 810 |
| | biogener Anteil des Abfalls [2] | 4.651 | | 0,8 | 3.594 | 4.352 |
| | Geothermie | 27,7 | | 0,005 | 14 | 19 |
| | **Summe** | **103.466** | | **17,0** | **74.850** | **94.641** |
| Wärmeerzeugung | biogene Festbrennstoffe (Haushalte) [3] | 72.700 | Anteil am EEV für Wärme [10] | 5,1 | 21.928 | 62.016 |
| | biogene Festbrennstoffe (Industrie) [4] | 20.400 | | 1,4 | 6.192 | 19.818 |
| | biogene Festbrennstoffe (HW/HKW) [5] | 7.200 | | 0,5 | 2.062 | 6.222 |
| | biogene flüssige Brennstoffe [6] | 4.100 | | 0,3 | 1.135 | 4.583 |
| | Biogas | 7.600 | | 0,5 | 1.192 | 6.507 |
| | Klärgas [7] | 1.086 | | 0,1 | 289 | 1.076 |
| | Deponiegas | 360 | | 0,03 | 96 | 419 |
| | biogener Anteil des Abfalls [2] | 11.850 | | 0,8 | 3.460 | 10.863 |
| | Solarthermie | 5.200 | | 0,4 | 1.168 | 4.733 |
| | tiefe Geothermie | 285 | | 0,02 | 18 | 291 |
| | oberflächennahe Geothermie [8] | 5.300 | | 0,4 | 443 | 4.640 |
| | **Summe** | **136.081** | | **9,5** | **37.982** | **121.168** |
| Kraftstoff | Biodiesel | 26.520 | Anteil am Kraftstoffverbrauch [11] | 4,3 | 3.639 | 25.972 |
| | Pflanzenöl | 636 | | 0,1 | 112 | 1.043 |
| | Bioethanol | 8.541 | | 1,4 | 1.236 | 6.748 |
| | **Summe** | **35.697** | | **5,8** | **4.987** | **33.763** |
| | **gesamt** | **275.244** | **EEV [12]** | **10,9** | **117.819** | **249.572** |

Source: bmu.de