Promote Geothermal District Heating Systems in Europe

GeoDH Training

Sessione sulla geotermia
-
Introduzione

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Why renewables?

Current energy consumption is unsustainable - actions are urgently needed!

- growing energy demand
- restricted and uneven distribution of fossil fuels → supply security
- climate change debate: enhanced use of fossil fuels → increased atmospheric CO_2 concentration → global warming, extreme events

Kyoto Protocol

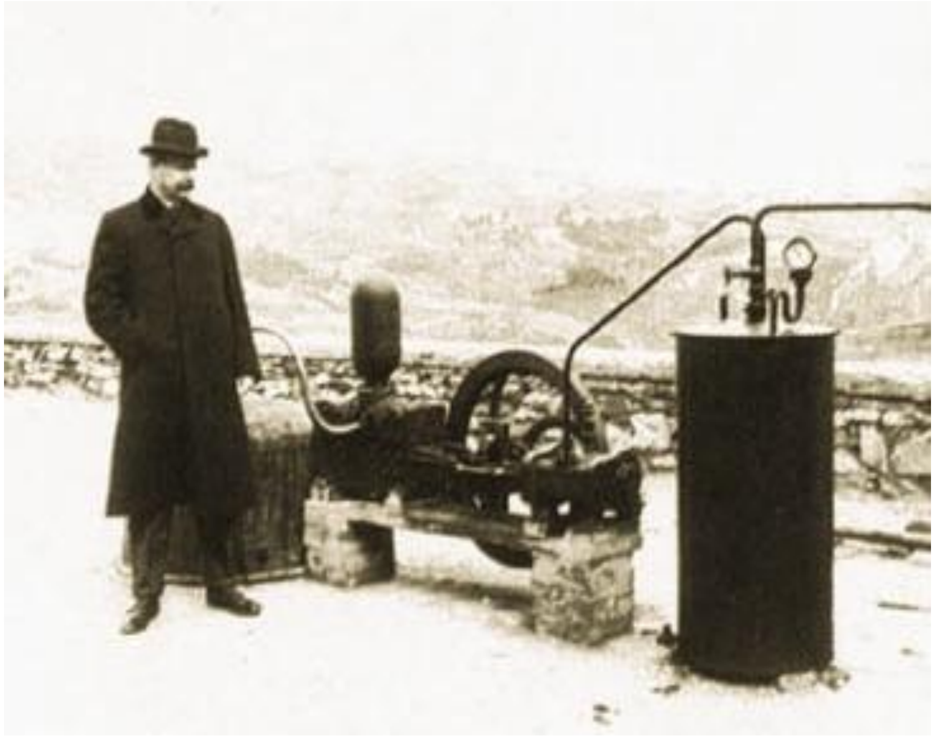
20/20/20 by 2020 COM(2006)848

- cut energy consumption (fossil fuels) and CO_2 emisssions
- increase energy efficiency
- increase renewable energy sources (RES)

increase of renewables in the energy mix: integrated economic development

- ✓ innovative and competitive technologies
- ✓ structural changes in the industry and agriculture
- ✓ new working places
- ✓ decentralized → rural development

History of geothermal



1904: the world's first geothermal power station with a 10kW generator at the Larderello dry steam field, Italy, Tuscany

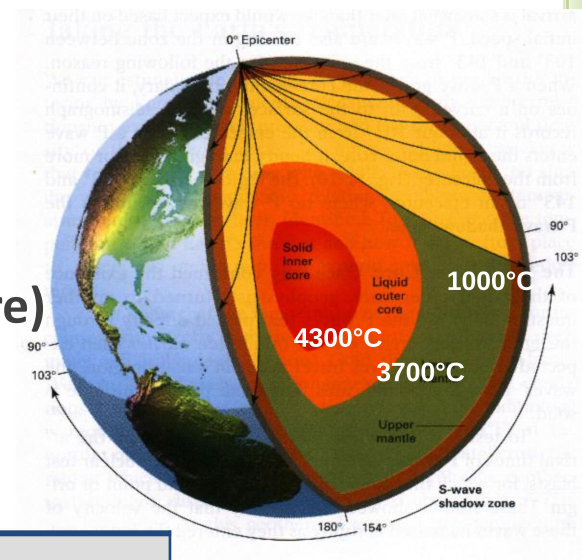
Thermal bath of Caracalla, Thermae Antoninianae

Geothermal energy: definition and basic concepts

Geothermal energy is energy stored in the form of heat below the surface of the solid earth (definition of EU-RES Directive)

99% of Earth's mass is above 1000 °C

Heat content of the Earth: $12{,}6 \cdot 10^{24}$ MJ,



Earth's heat sources:

- „residual" heat of the Earth interior (mantle and core)
- decay of radioactive isotopes: U^{238}, U^{235}, Th^{232}, K^{40}
- solar radiation (limited 5-25 m below the ground)

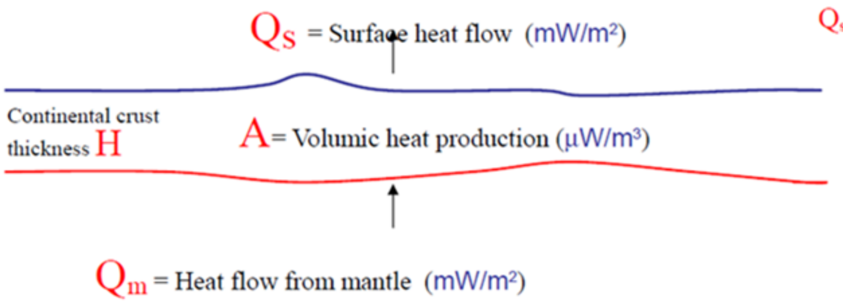
	Total volume of the Earth	Average heat production (μW/m³)
Crust (rich in radioactive isotopes)	2%	1 (continetal) 0,5 (oceanic)
Mantle	82%	0,02
Core (no radioactive isotopes)	16%	

Heat transfer, heat flow

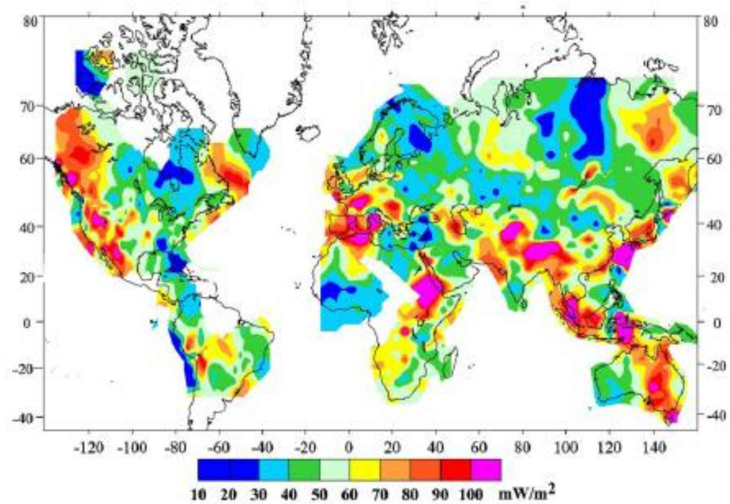
Heat transfer:

- conduction – heat transfer among rock particles
- convection - matter (fluid) movement

Heat-flow:



$Q_s = Q_m + A \,.\, H$



Surface heat flow on the continents

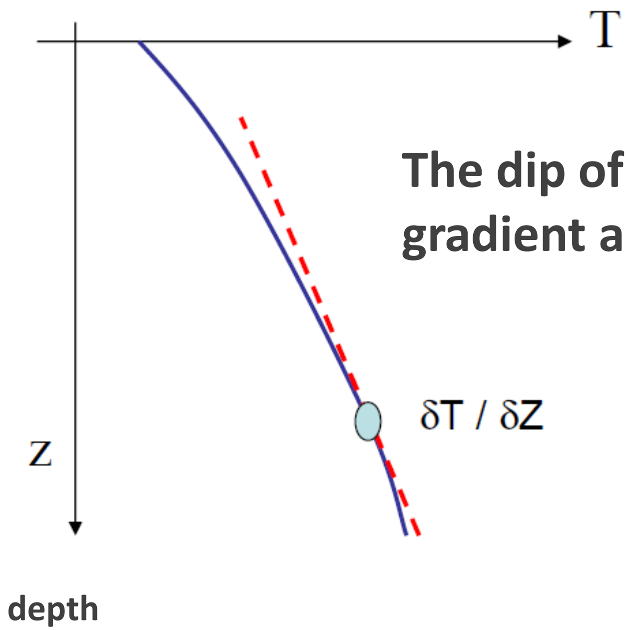
Internal heat production: 20TW

Measured heat flow Q_s = 44TW

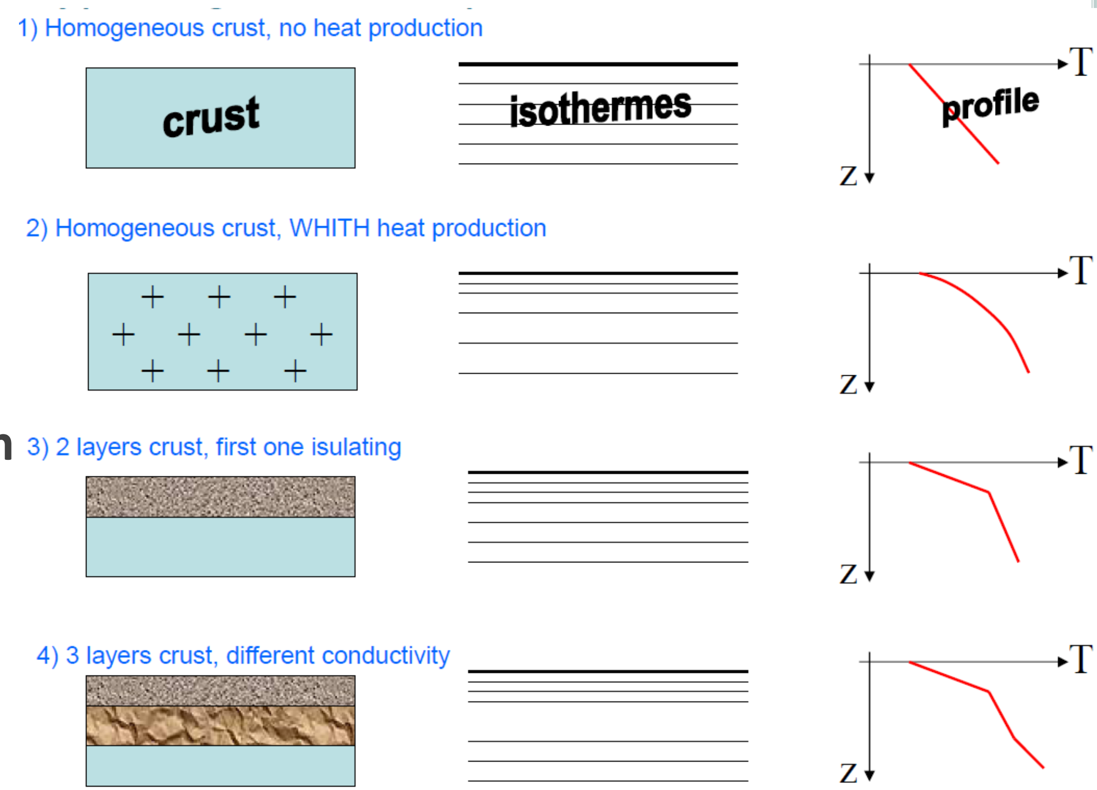
Earth cools down 2X quicker than heat production, however the heat content of the Earth would take over 10^9 years to exhaust via global terrestrial heat flow *(practically inexhaustable on human-scales)*

Geothermal gradient

change of temperature towards the depth

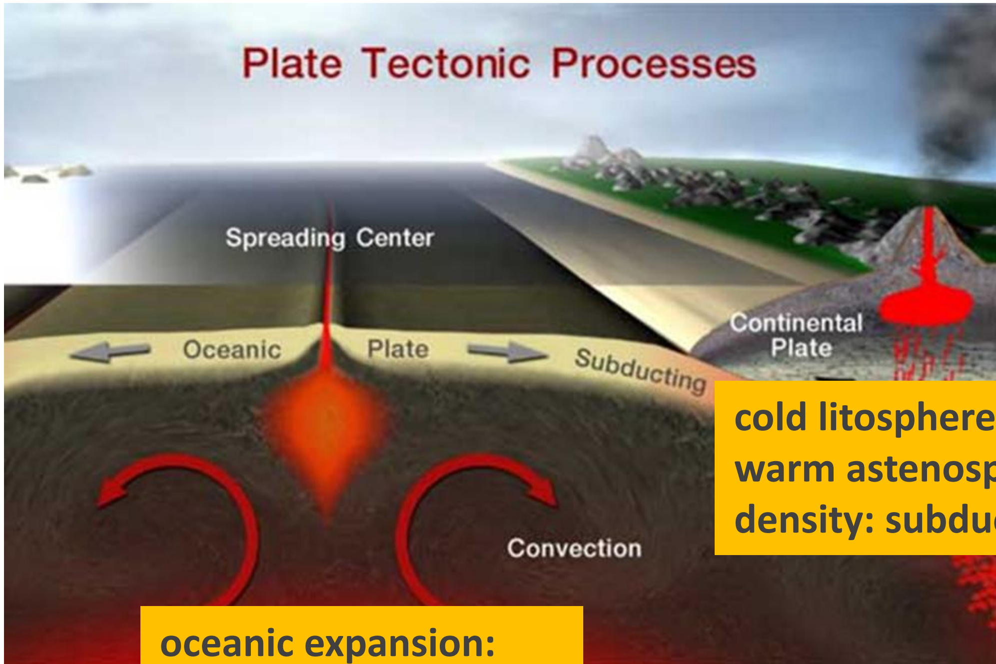


The dip of the thermal profile represents the geothermal gradient and composition of the subsurface



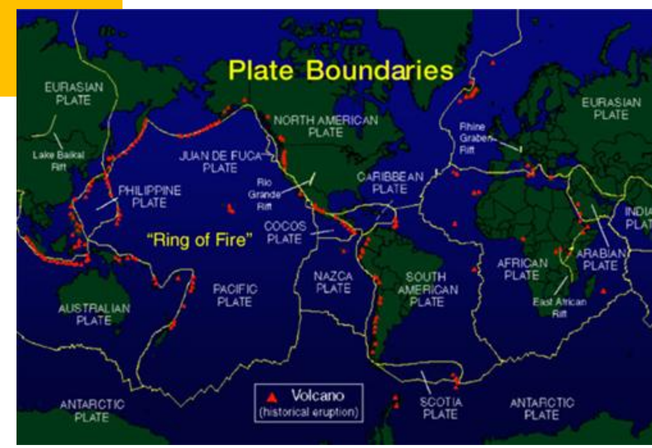
Continental average: 33 °C/km
Active zones: 500°C/km

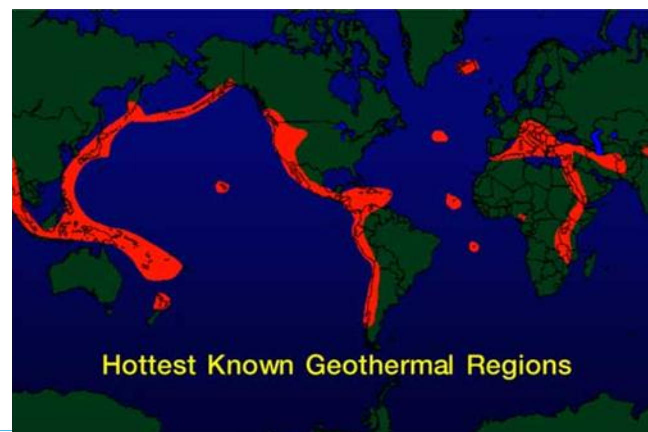
Geodynamics and geothermal



cold litosphere density > warm astenosphere density: subduction

oceanic expansion: uprising astenosphere





Driving force of plate movements: heat from Earth's core generates huge convection cells in the viscous mantle, on which litospheric plates are „floating" and slowly moving

Hottest geothermal regions are related to plate boundaries

Geothermal energy – how to classify?

1) Temperature / enthalpy *

*According to Rowley (1982)

High-temperature (HT): >150°C

geothermal steam reservoirs (dry, wet steam)
Heat source: mainly magma in magma chambers located at shallow depths (reaching the surface as lava during volcanic eruptions)

Low-temperature (LT): < 150°C

hydrogeothermal reservoirs
Heat source: mainly Earth's heat flux
Low-temperature systems and related hydrogeothermal reservoirs occupy much larger areas

Geothermal reservoirs: „a part of the geothermal field that is so hot and permeable that fluid or heat can be economically exploited. Rock that is hot, but impermeable is not part of the reservoir."
(Grant and Bixley, 2011).

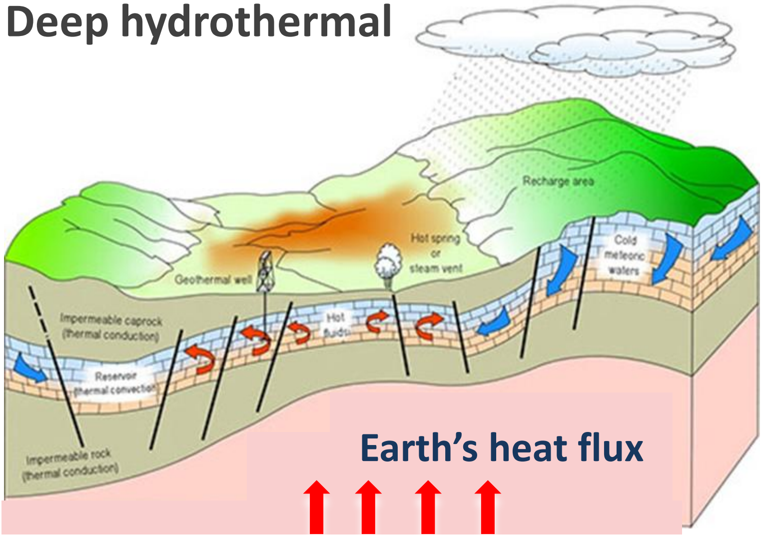
GEODH

Geothermal energy – how to classify?

2) Resource

Shallow

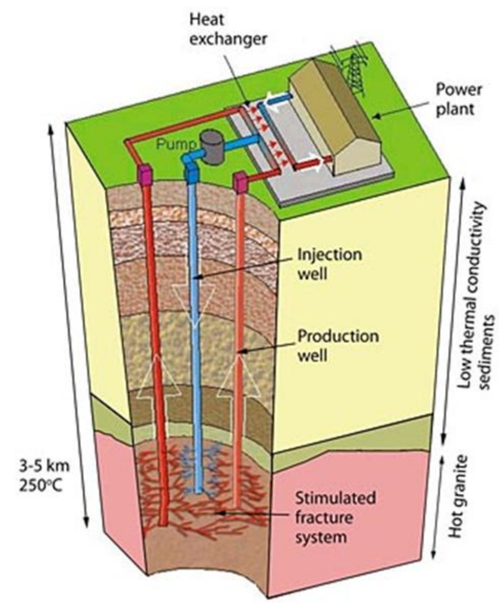
Deep hydrothermal



Elements: heat source, reservoirs, carrying medium (fluid), recharge

Fluid convection: heating → thermal expansion of groundwater → rising and replacement by recharging colder meteoric water

Deep stimulated



artificially created and enlarged fractures as „heat exchangers" in deep lying hot rock bodies

Geothermal energy – how to classify?

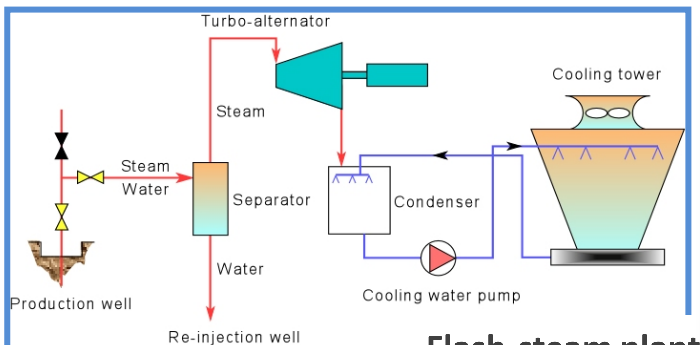
3) Temperature / enthalpy vs. use

Very low: <30°C – requires heat pumps

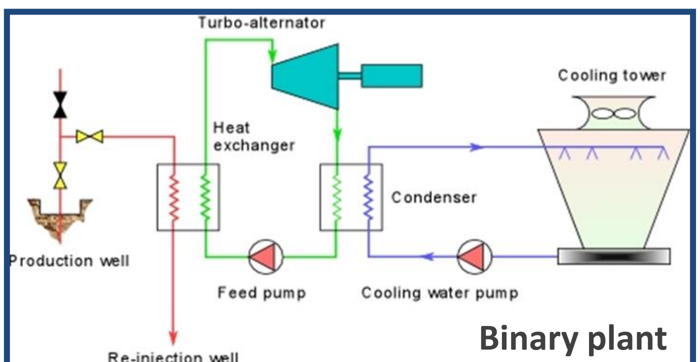
Low: 30-125 °C – direct heat

Medium : 125-150 °C – electricity generation with binary cycles, CHP

High: >150°C – „efficient” electricity production



Flash-steam plant

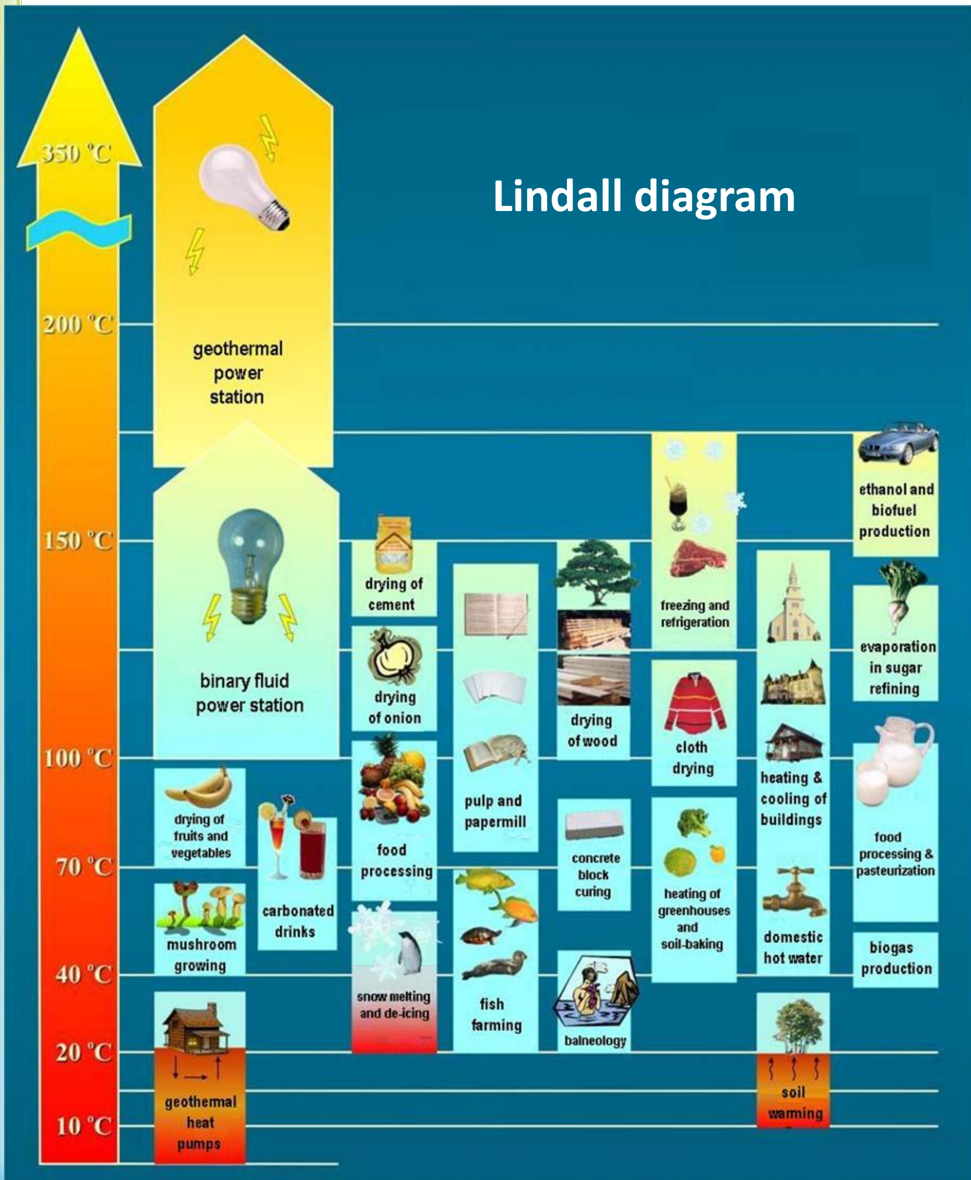


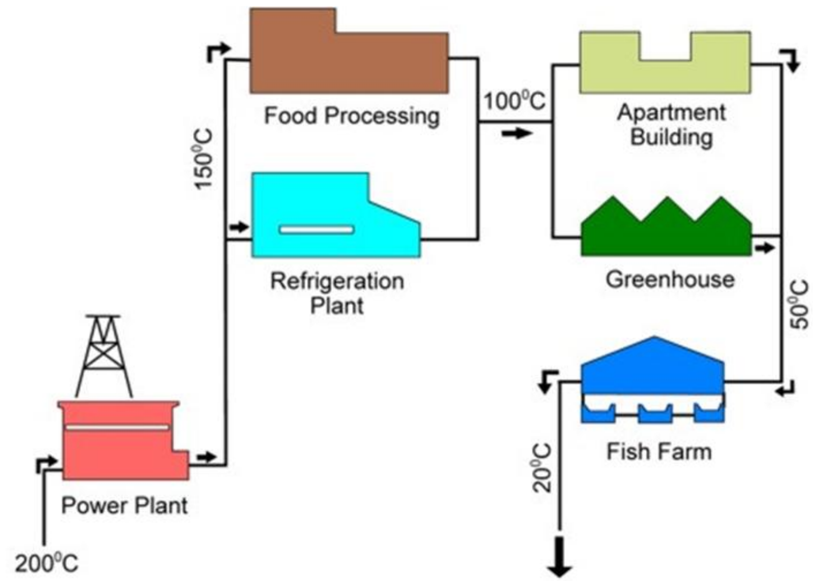
Binary plant

Direct uses

Geothermal energy – how to classify?

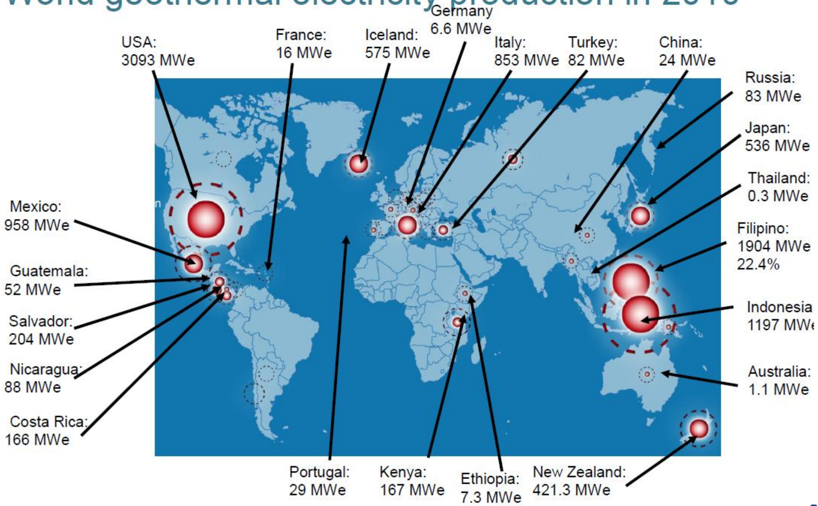
3) Use





Sufficient way: cascade utilization of geothermal energy

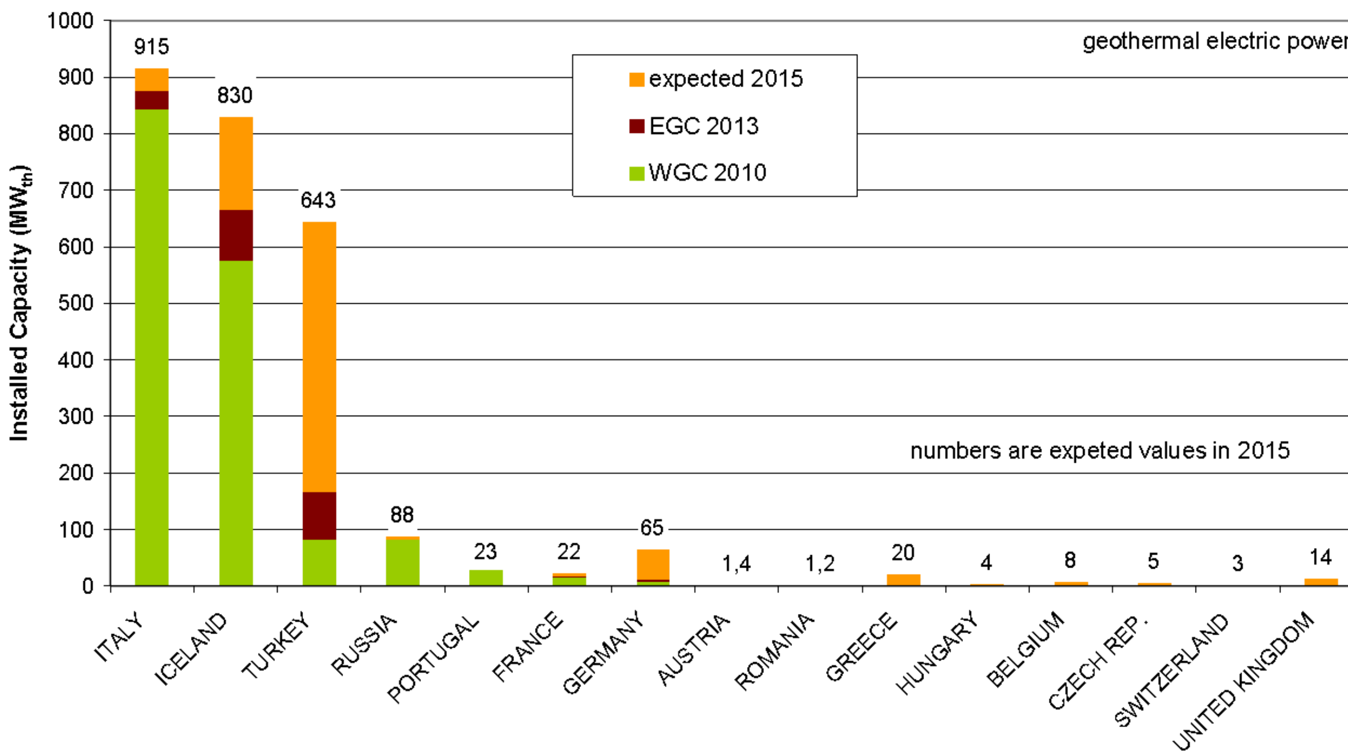
World geothermal electricity production in 2010



Installed power in the 25 producing country : 10.7 GWe (Bertani, 2010).
Prevision at 2015 : 18.5 GWe ; at 2050 : 70 GWe (Bertani, 2010)
(Production EDF in 2008: 97GWe)

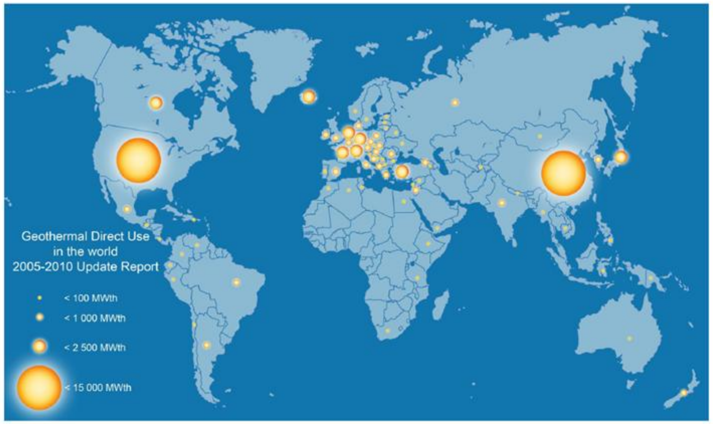
Geothermal electricity production

Installed geothermal power in Europe 2010-2015



Antics et al. 2013

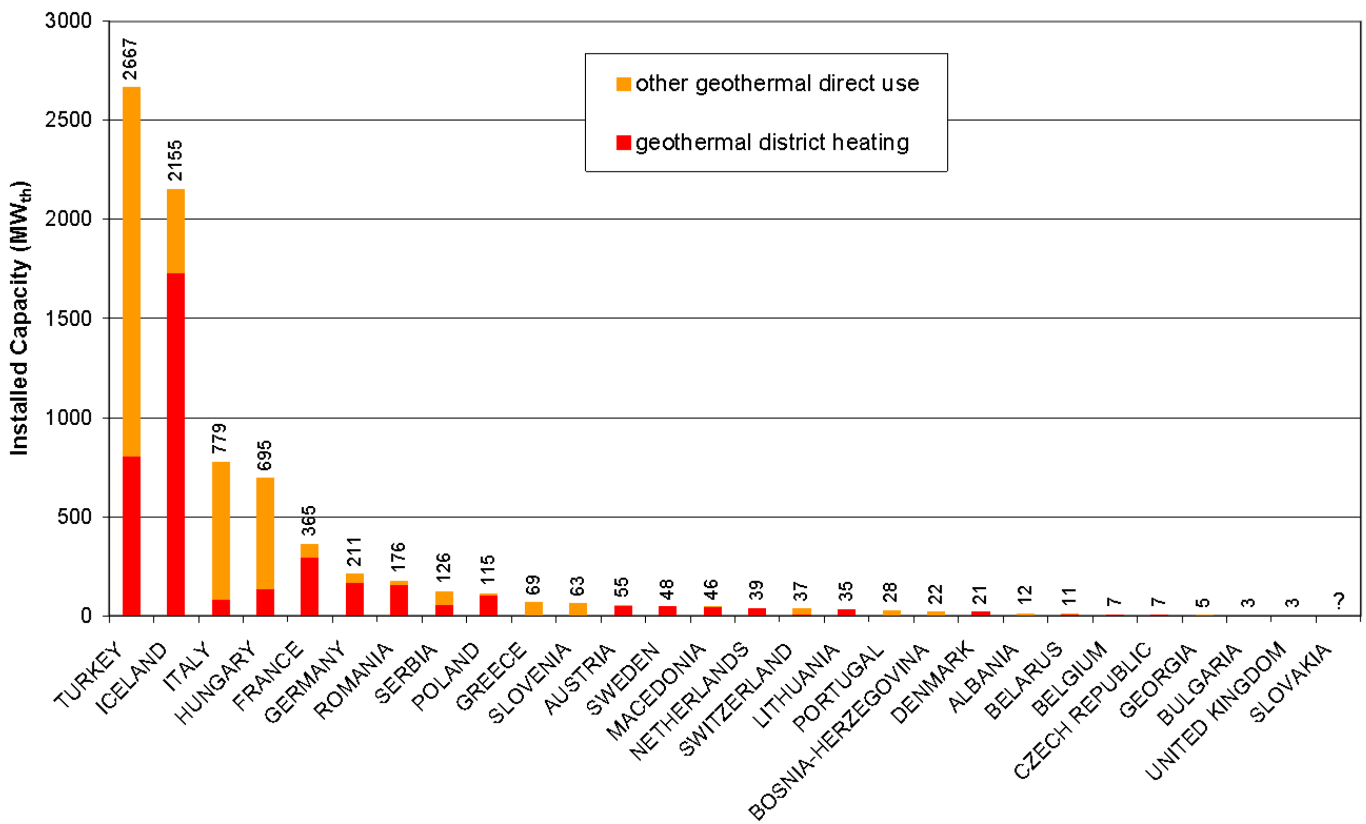
Worldwide heat production in 2010



Installed power in the **79 countries** using geothermal heat was estimated at **43 GWt**

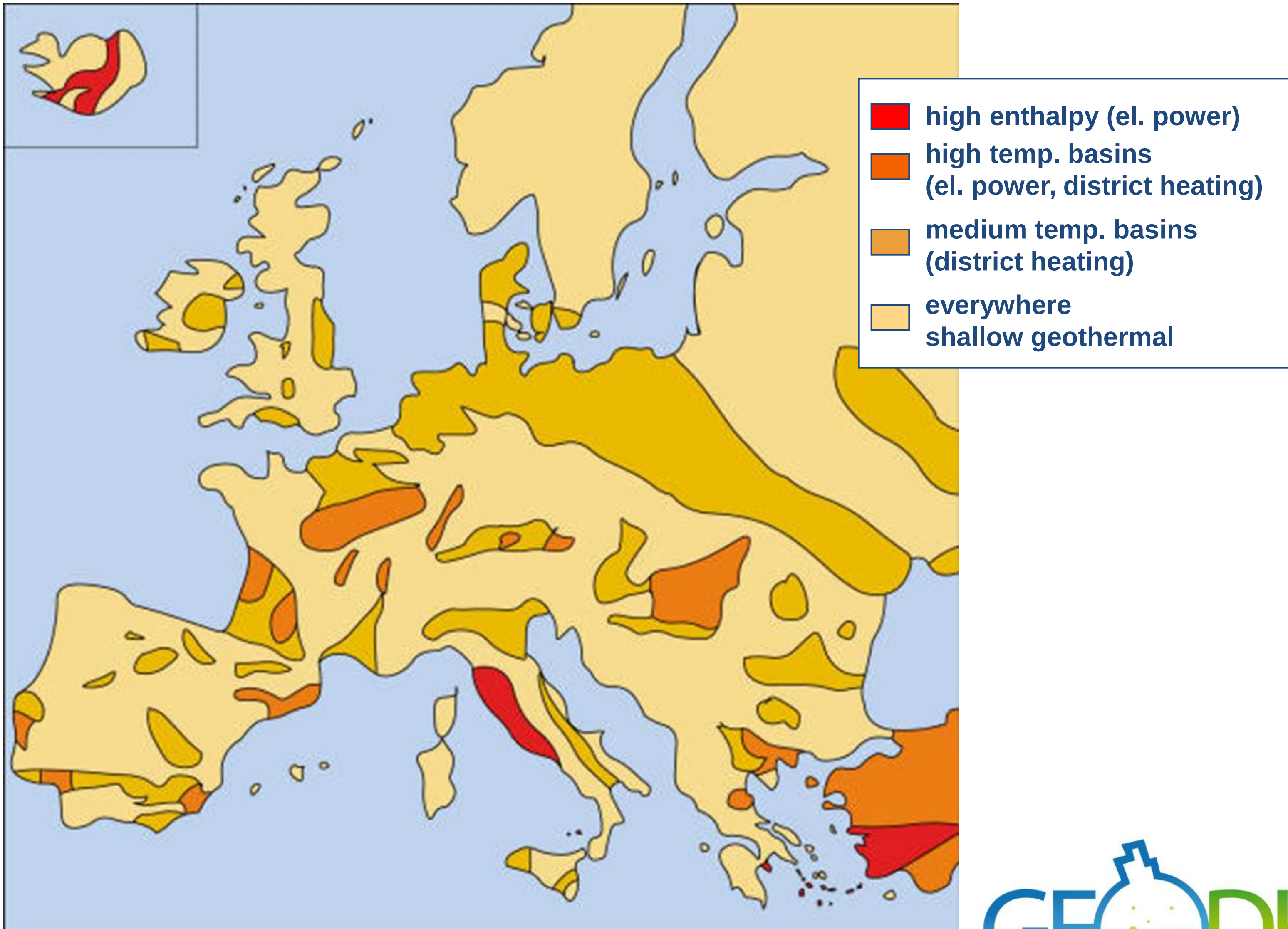
Geothermal direct use

Installed capacity in geothermal direct use in Europe 2012, and share of geotheraml district heating



Antics et al. 2013

Main geothermal provinces of Europe



EGEC

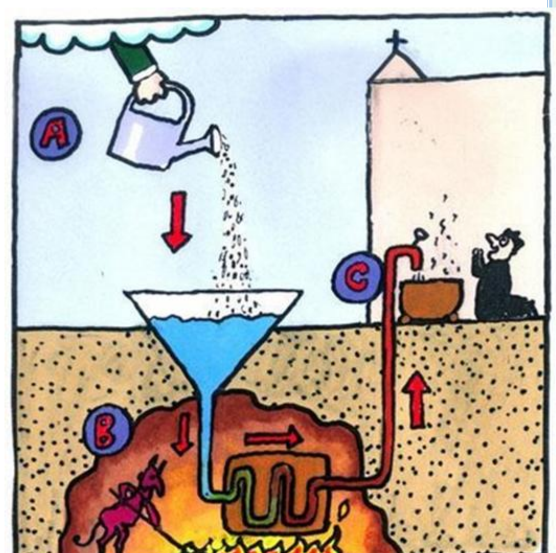
Sustainability of hydrogeothermal systems

the ability of a geothermal heat extraction system to sustain production over long times" (Rybach, 2003)

„... for each geothermal system and for each mode of production there exists a certain level of maximum energy production, below which it will be possible to maintain a constant energy production from the system for a very long time (100 - 300 years)" (Axelsson et al., 2004)
This applies to total extractable energy (heat in the fluid and rock)

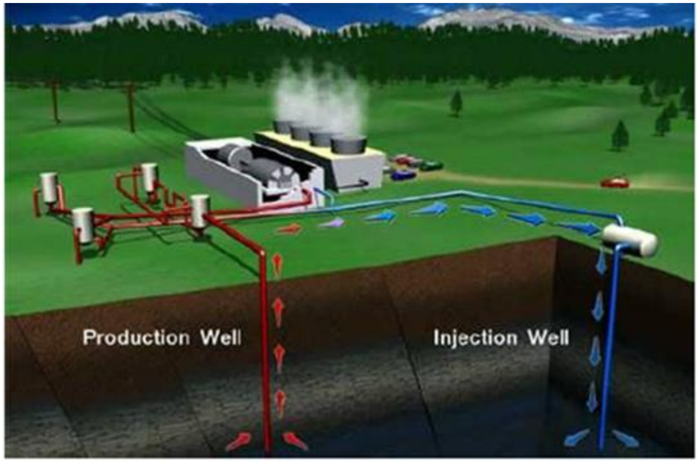
Balanced fluid/heat production (not producing more than the natural recharge re-supplies) is fully sustainable

These rates are limited and often not economical for use



Re-injection

When natural recharge of a hydrothermal system is not sufficient, re-injection is necessary to maintain reservoir pressure and production rates



Benefits

- increased flow rates
- optimum heat recovery
- maintenance of pressure
- land subsidence control
- disposal of the cooled brine

Drawbacks

- „waste water" contamination of the aquifer (e.g. bacteria, gas bubbles, precipitations of chemicals)
- premature cooling (thermal breakthrough) of production wells
- permeability impairment induced by particles

Geothermal energy and the environment

Renewable and reliable energy source (available all year (in contrast to other RES)

Generates a few (or none) of GHG emissions

Impact	Probability of occuring	Severity of consequences
Air quality pollution	low	medium
Pollution of surface and groundwaters (dissolved content	medium	medium to high
Thermal pollution (discharging waste water)	medium	medium
Land subsidence	low	low to medium
High noise level	high	low to medium
Well blow-outs	low	low to medium
Social-economic problems	low	low