Geothermal energy

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Geothermal Energy

1. What is
2. How is used
3. Pros
4. Cons
5. Research frontiers

Status and perspectives

1

What is the source of geothermal energy? What part is used?

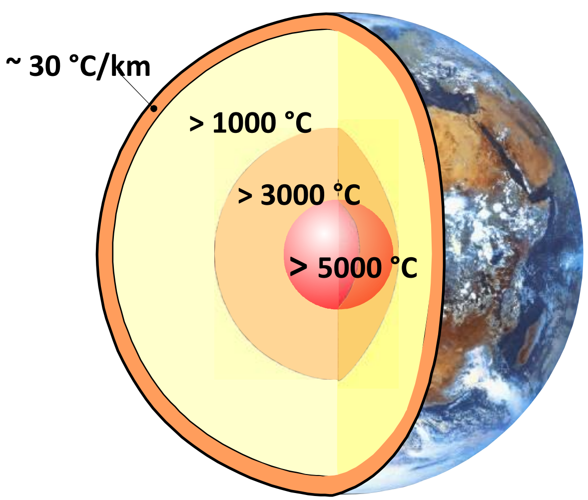
What is Geothermal Energy

IGG – Institute of Geosciences and Earth Resources
National Research Council of Italy

WHAT is Geothermal energy

Geothermal Energy
From Greek ***gêo*** (earth) e ***thermòs*** (heat)

Heat inside the Earth

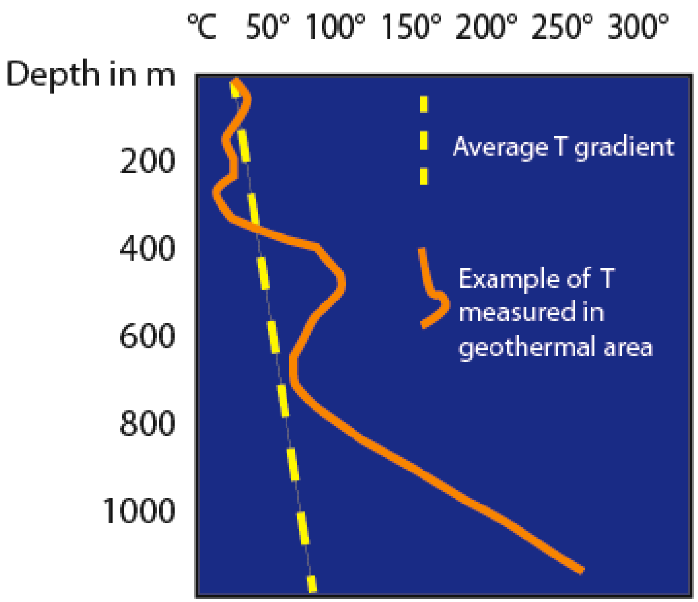


The basis of geothermal energy is the immense heat content of the earth's interior: the Earth is slowly cooling down. Since billions of years the heat in the Earth Crust is constantly supplied by the decay of natural radioactive isotopes or the cooling of hot, shallow magmatic bodies.

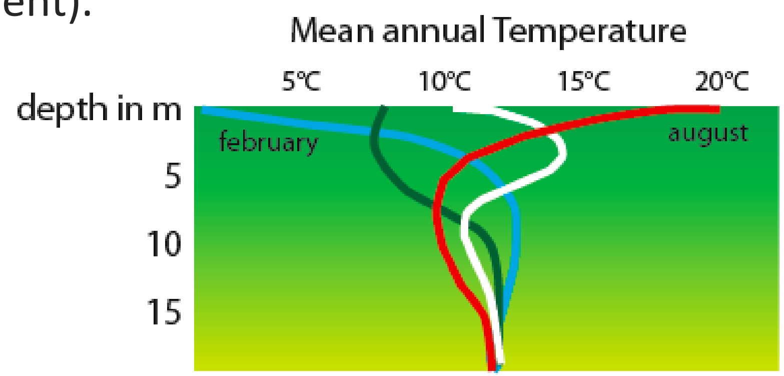
The resource is vast and ubiquitous and has a corresponding **large potential for utilization**.

WHAT is Geothermal energy

Temperature in the ground has a daily (few cm) and seasonal (few meters) fluctuations, becoming essentially constant and equal to the average air temperature at about 18-20 m depth. Below this depth, it essentially increases with depth (geothermal gradient).



Deep geothermal: exploits the underground heat at T>> air T

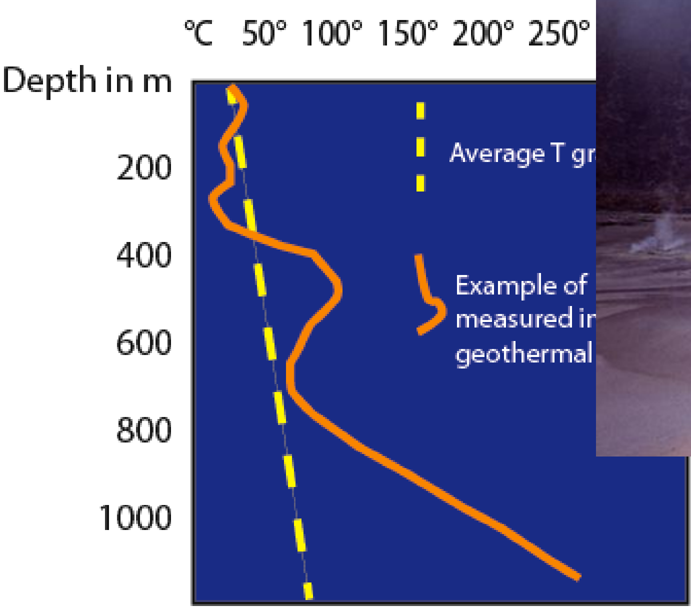


Shallow geothermal: exploits the underground constant T= average air T

The resource is vast and ubiquitous and has a corresponding large potential for utilization.

WHAT is Geothermal energy

The temperature increase with depth, as well as volcanoes, geysers, hot springs etc., are in a sense the visible or tangible expression of the heat in the interior of the Earth, but this heat also engenders other phenomena that are less discernable by man, but of such magnitude that the Earth has been compared to an immense "thermal engine”.



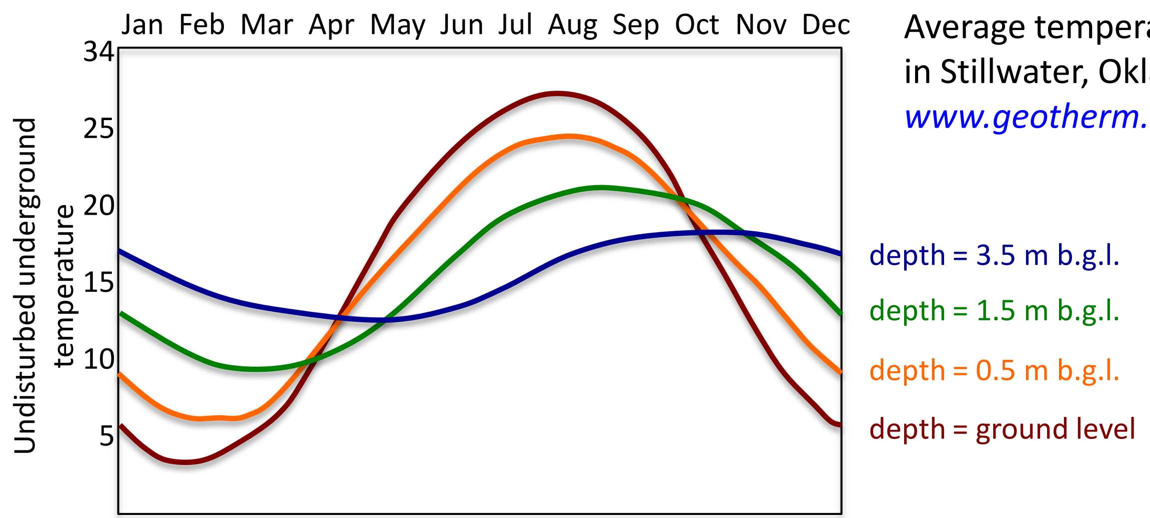
WHAT is Geothermal energy

The Earth's heat flow at the surface is the amount of heat that is released into space from the interior though a unit area in a unit of time. It is measured in milliwatt per square meter (mWm^{-2})
The heat flow is the product of the geothermal gradient and the thermal conductivity of rocks. On average, heat flow is 40-90 mW/m^2

The total global output is over 4×10^{13}W, four times more than the present world energy consumption, which is 10^{13}W.

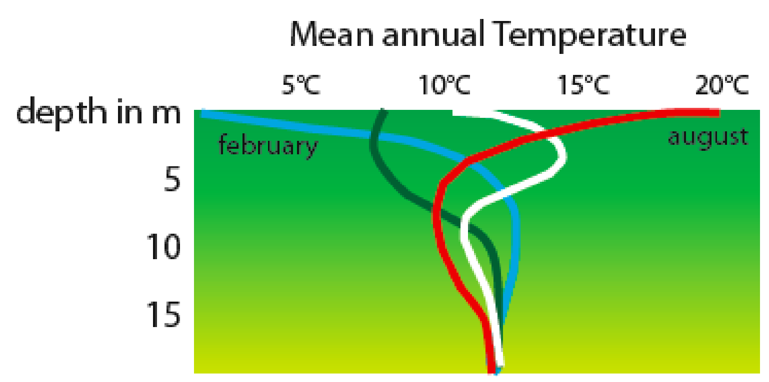
The thermal energy of the Earth is, therefore immense, but only a fraction can be utilized by man.

WHAT is Geothermal energy

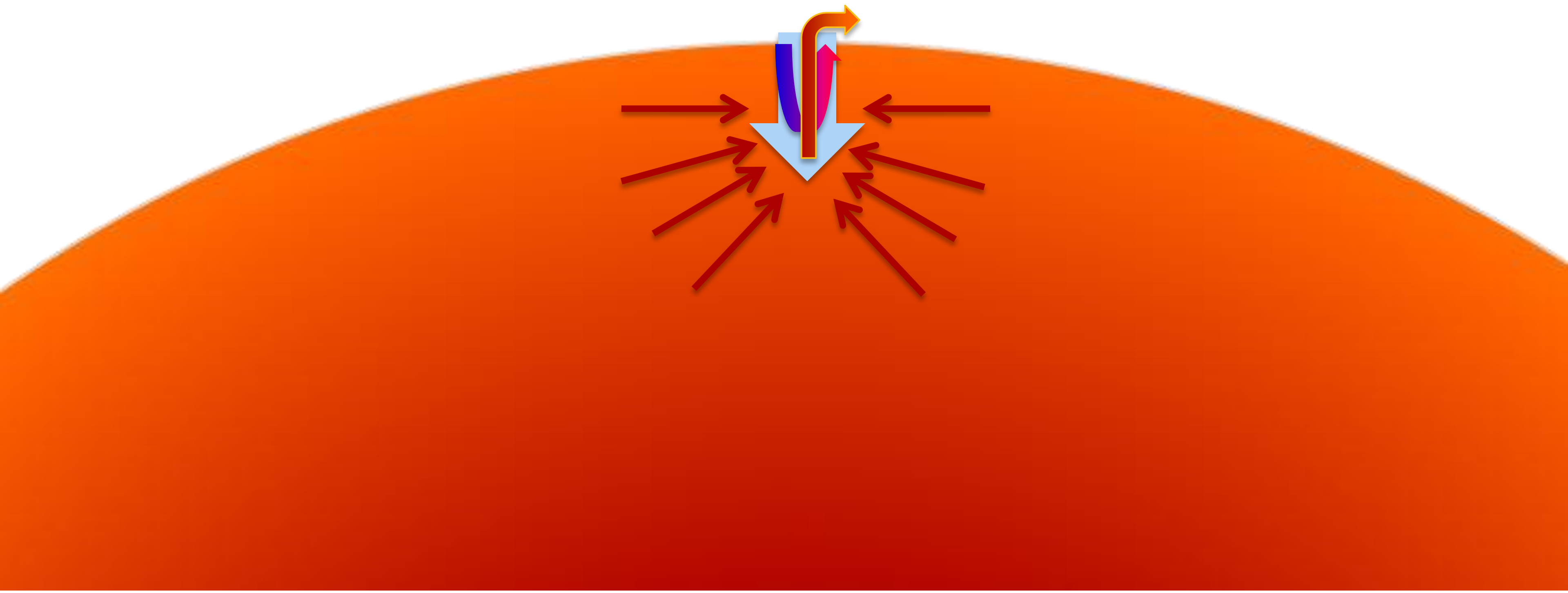


Average temperature variation in Stillwater, Oklahome, USA
www.geotherm.it

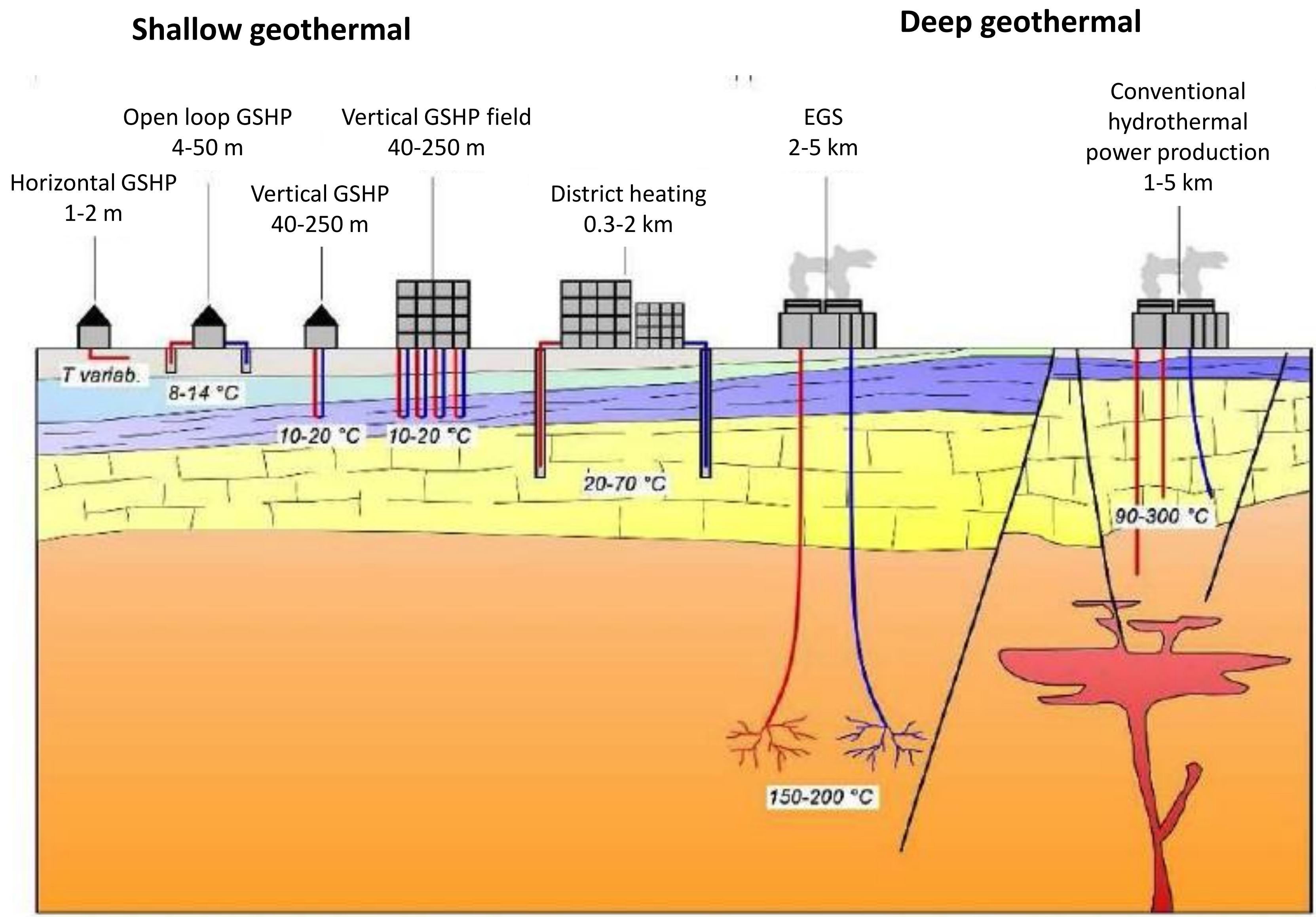
Another way to take advantage of the underground thermal state is to use the thermal stability at depth of few meters.



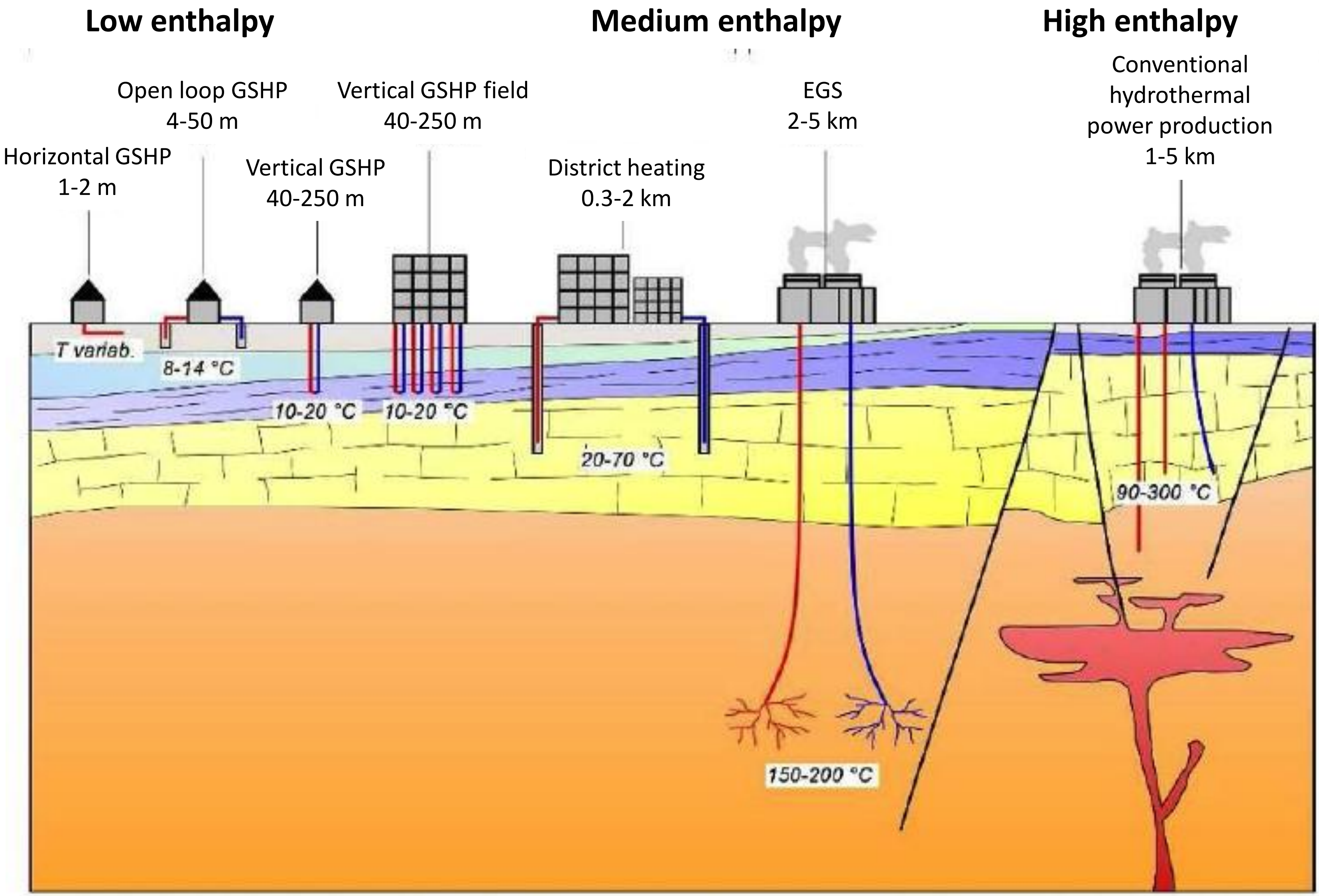
WHAT is Geothermal energy



WHAT is Geothermal energy



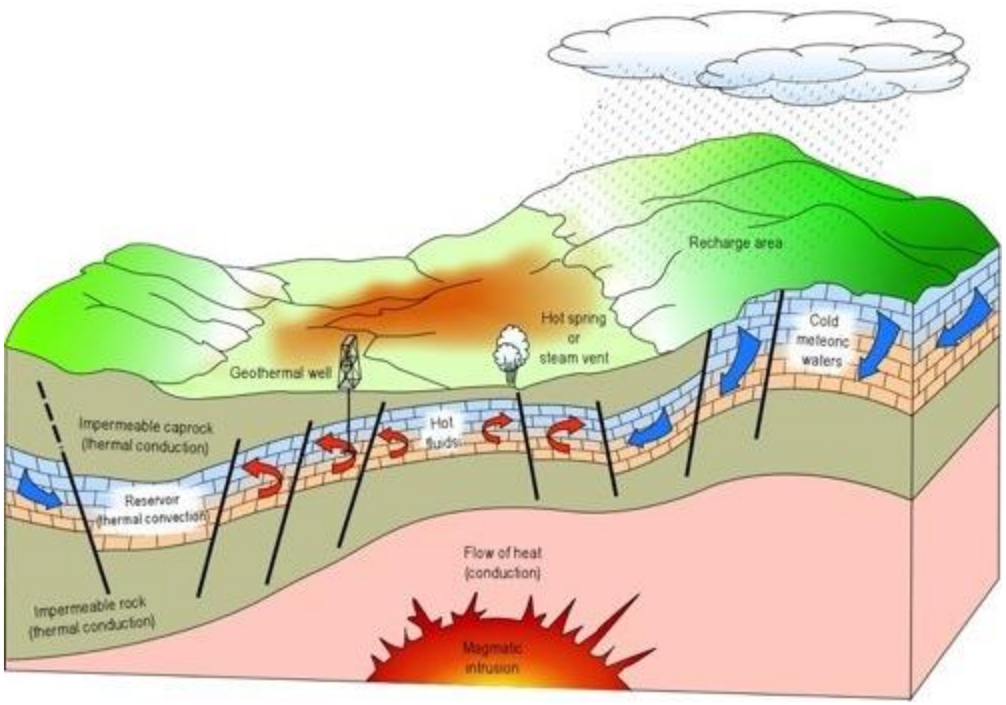
WHAT is Geothermal energy



WHAT is Geothermal energy

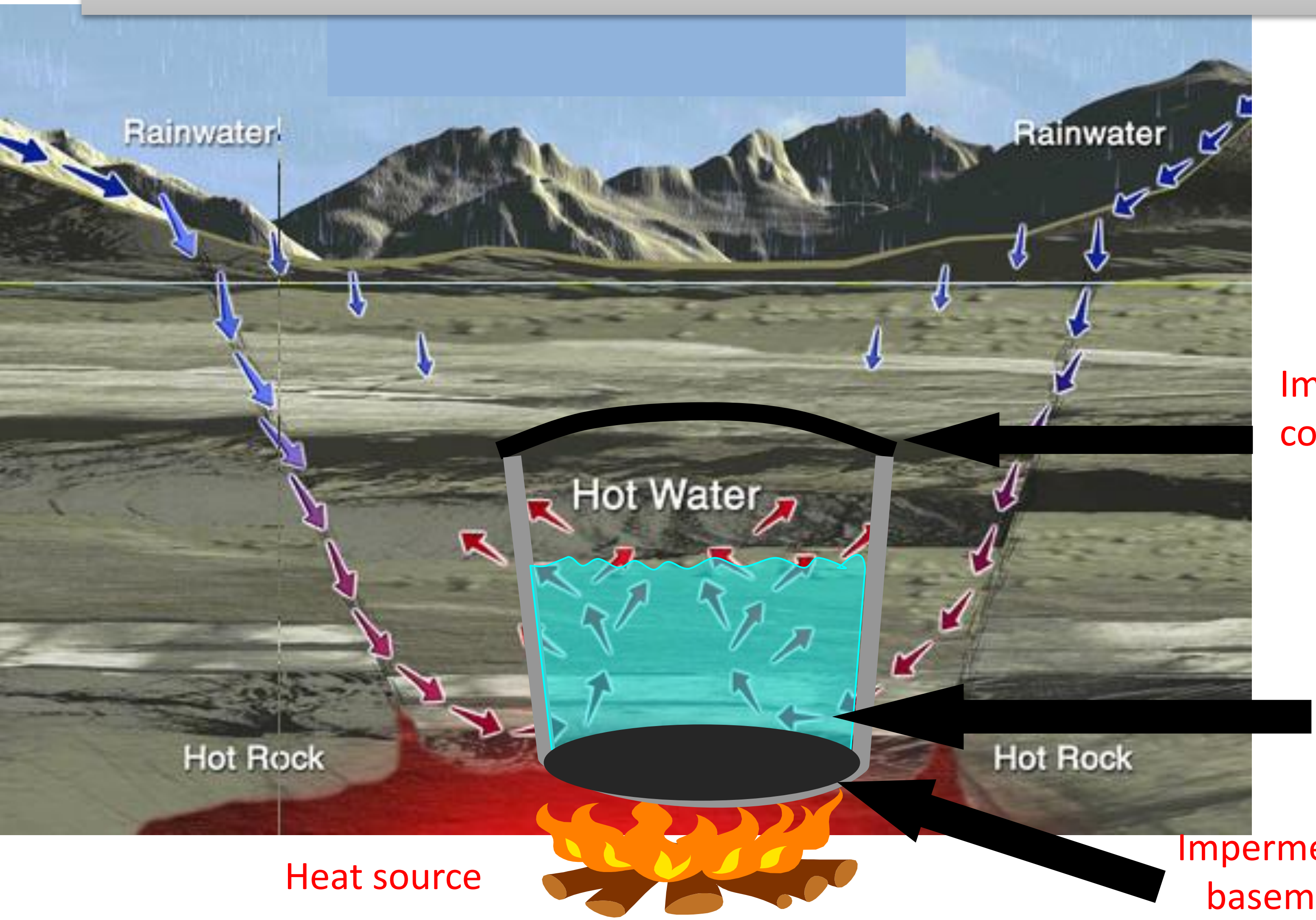
A heat source alone is not enough for creating a geothermal resource.

A ***geothermal system*** can be described schematically as "convecting water in the upper crust of the Earth, which, in a confined space, transfers heat from a heat source to a heat sink, usually the free surface".

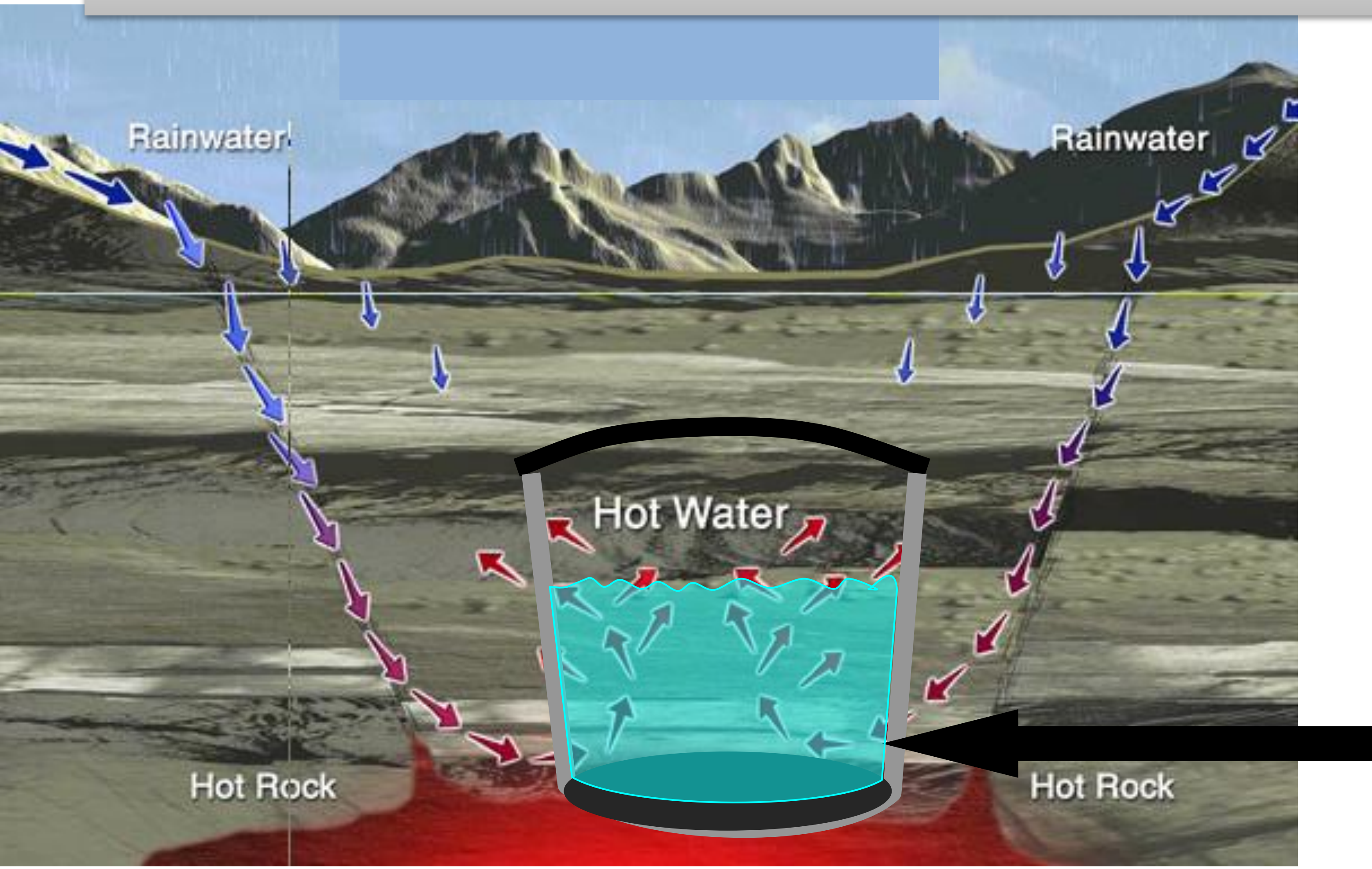


In a geothermal system the meteoric waters are trapped in the reservoir, are heated and a natural convective circulation is activated, driving the heat up to the surface.

WHAT is Geothermal energy

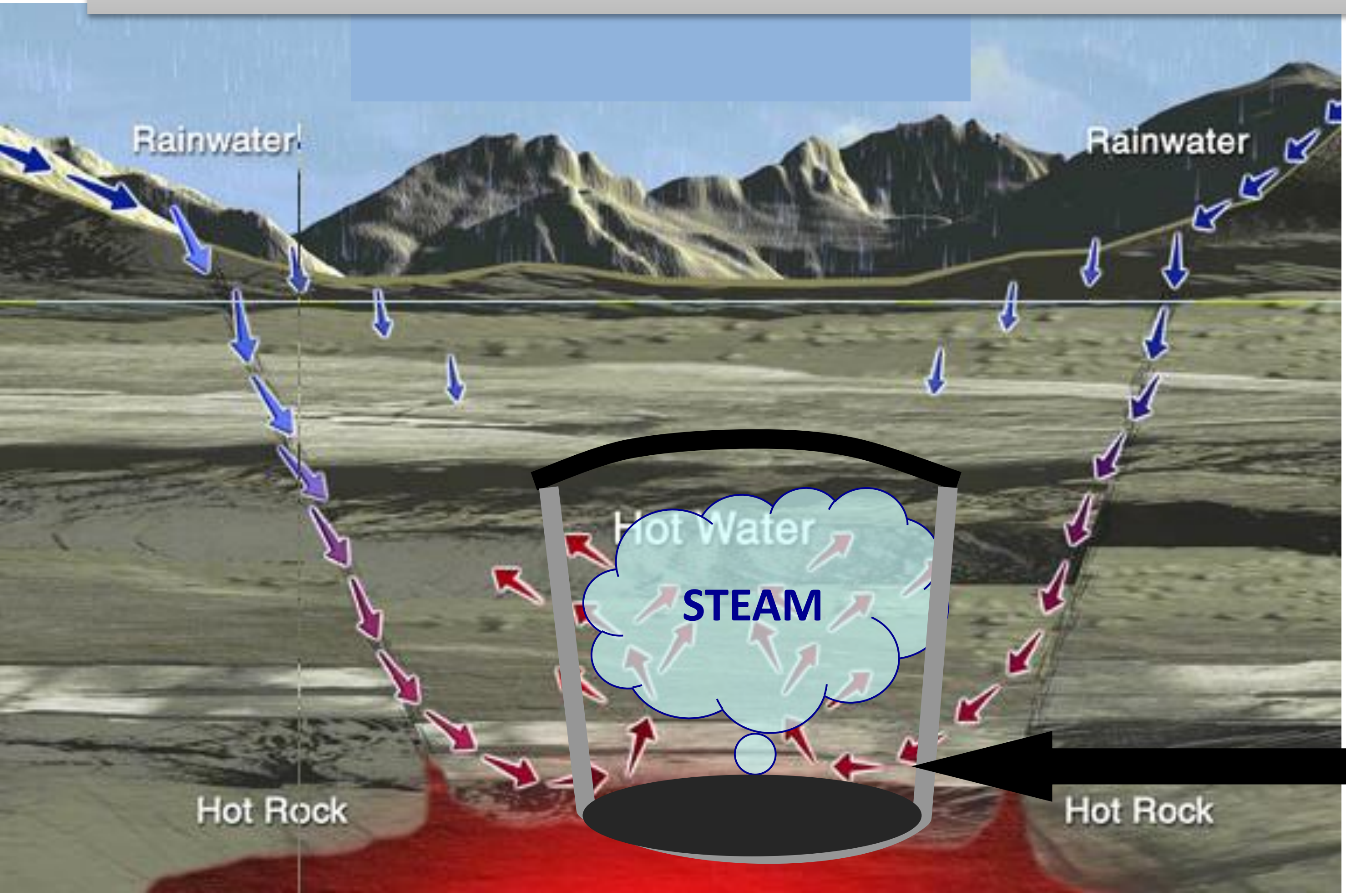


WHAT is Geothermal energy



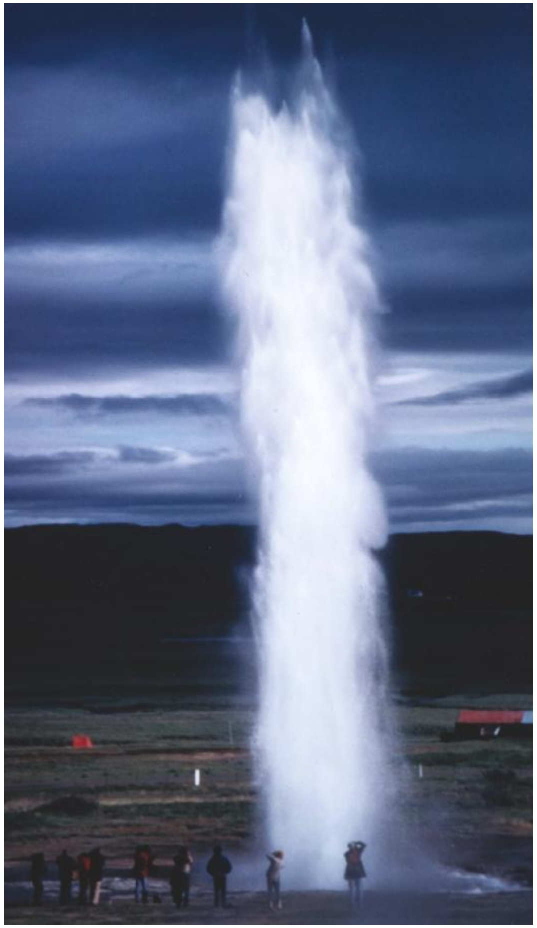
Hydrostatic pressure in the reservoir: Water dominated systems.

WHAT is Geothermal energy



In some situations, the pressure is relatively low and the temperature is regulated by the steam phase: Steam dominated systems

WHAT is Geothermal energy



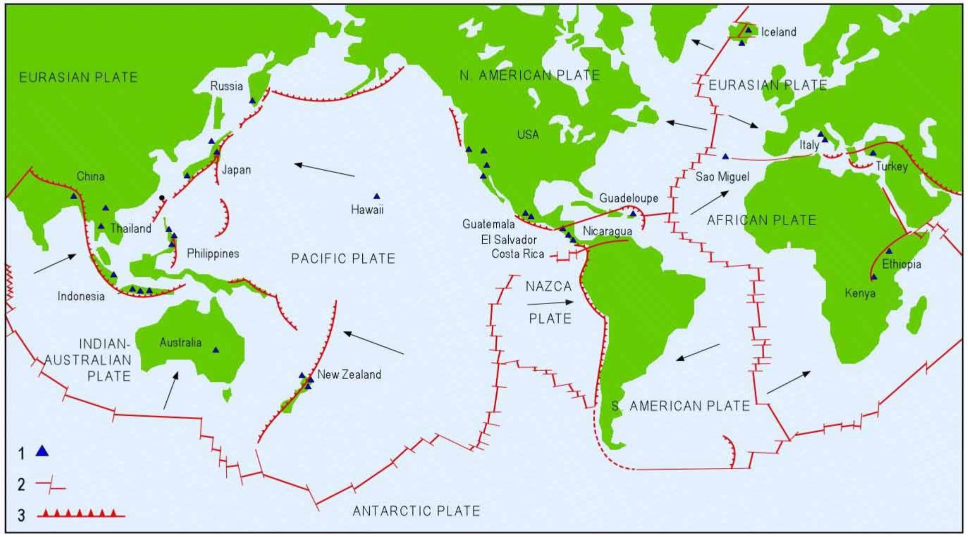
Geyser - Iceland

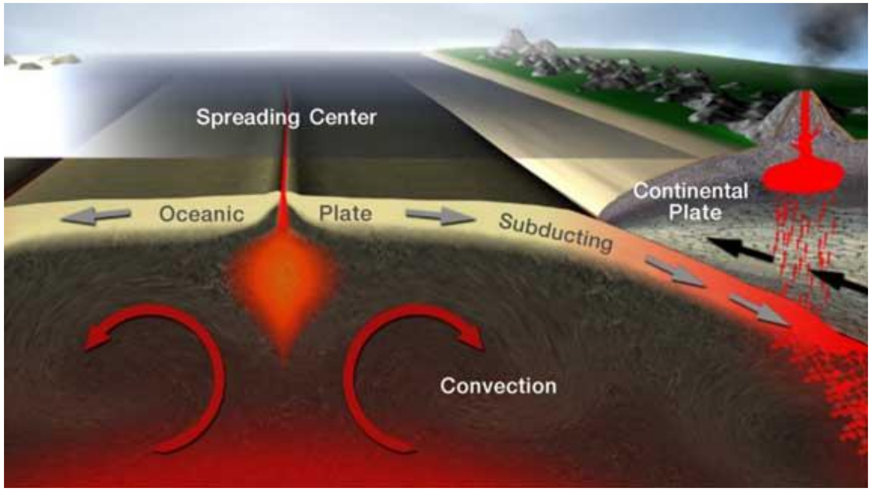
Boiling spring - USA

WHAT is Geothermal energy

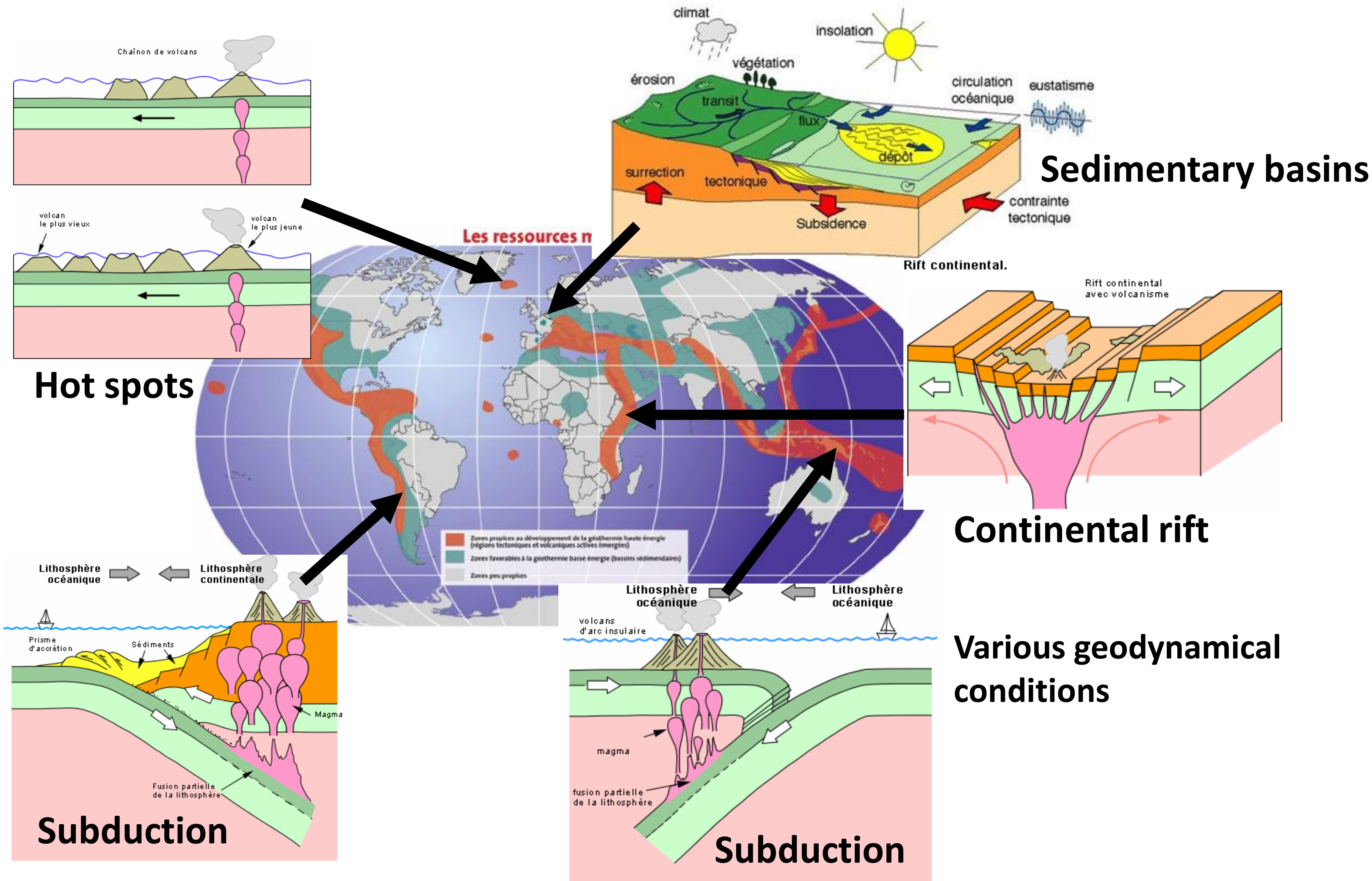
The most "precious" geothermal resources are confined to areas of the Earth's crust where heat flow is higher than in surrounding areas and heats the water contained in permeable rocks (reservoirs) at depth.

The resources with the highest energy potential are mainly concentrated on the boundaries between plates where geothermal activity frequently exists.





WHAT is Geothermal energy

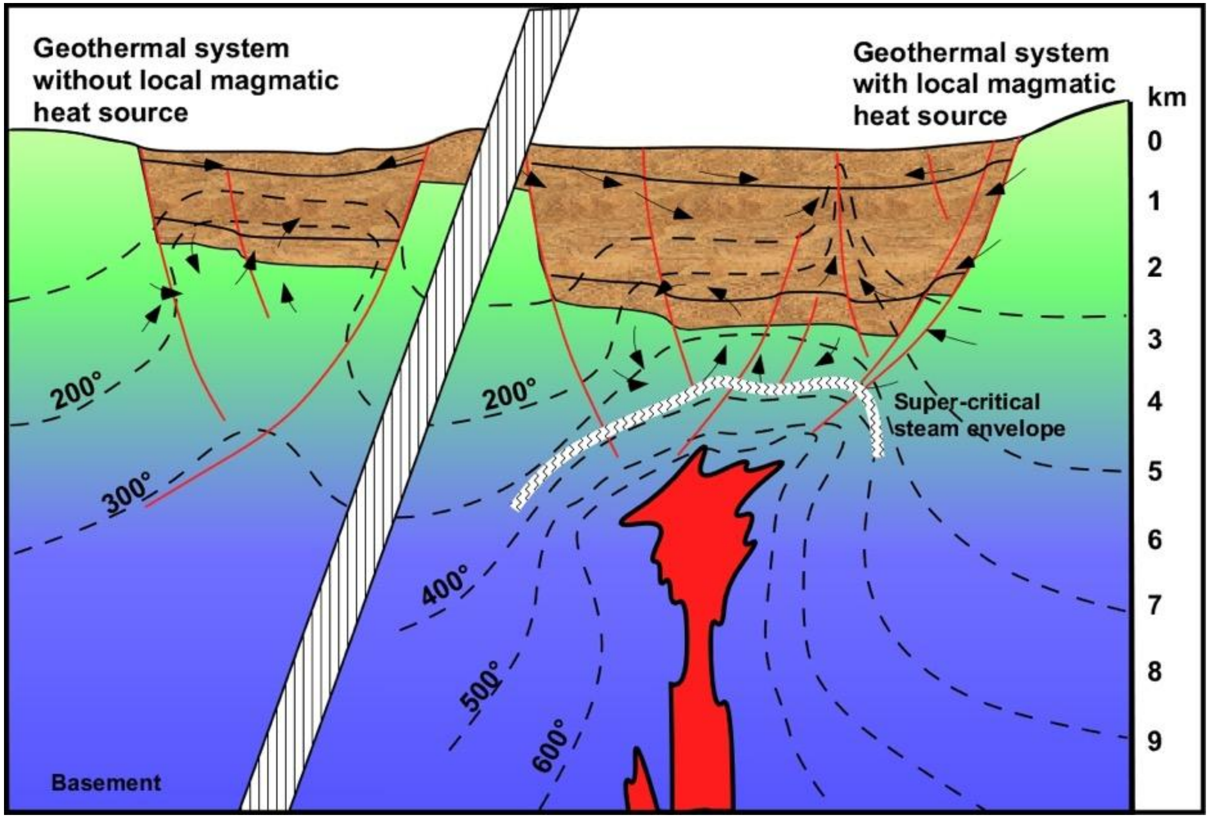


High heat flow conditions ➡ rift zones, subduction zones and mantle plumes.

Thick blankets of thermally insulating sediment covering a basement rock that has a relatively normal heat flow ➡ lower grade

Other sources of thermal anomaly:

- Large granitic rocks rich in radioisotopes
- Very rapid uplift of meteoric water heated by normal gradient



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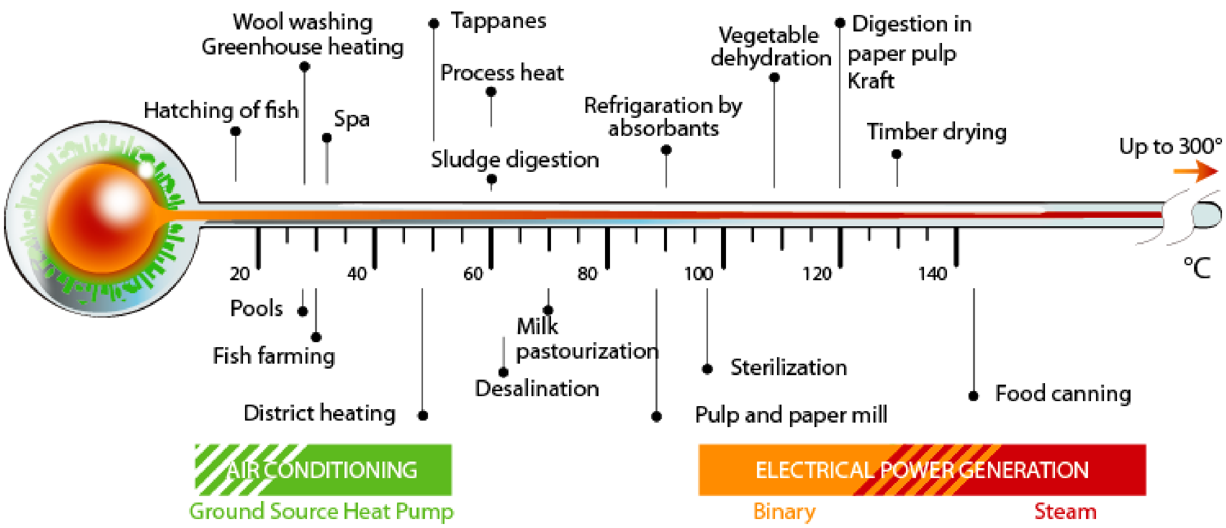
Heat? Power? Depending on what?

How Geothermal Energy is used

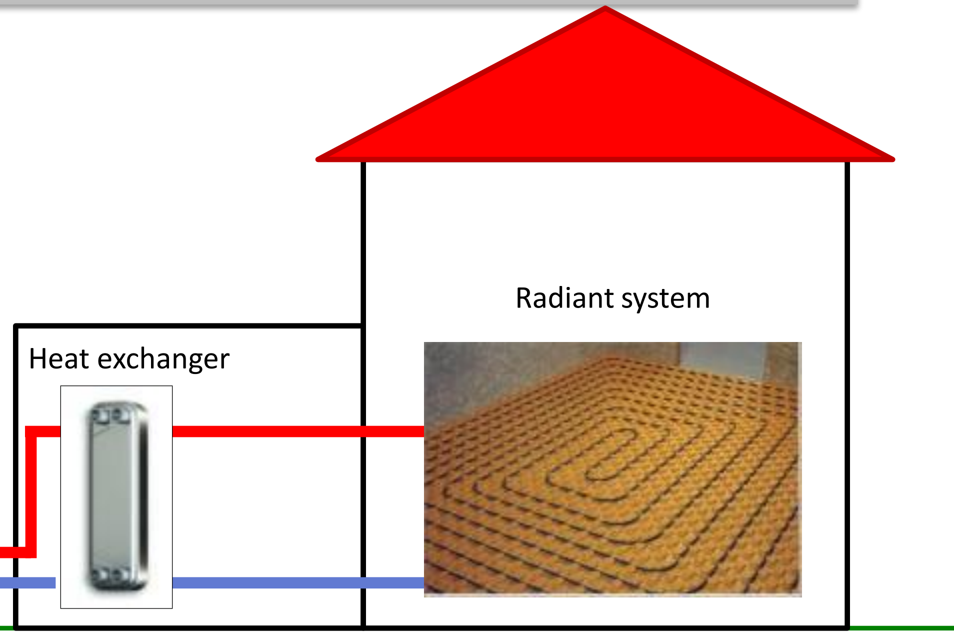
How Geothermal Energy is used

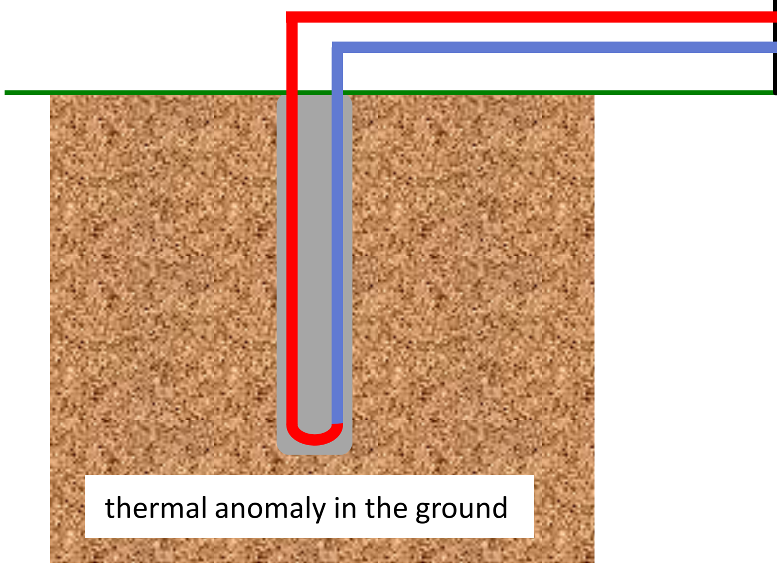


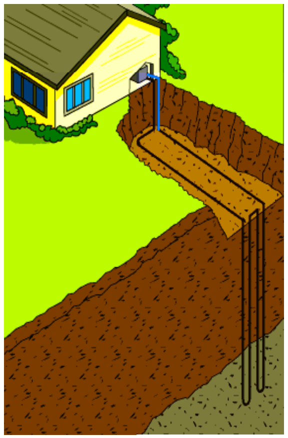
Warm and hot fluids can be extracted from the underground in a wide range of temperature and discharge rate, and used **directly for their heat content or to produce electric power**. Even the modest temperatures found at shallower depths can be used to extract or store heat by means of ground source heat pumps, that are nowadays a widespread application for geothermal energy.

How Geothermal Energy is used

When the ground and aquifer has a temperature similar to what we need at surface we may use the “free cooling” and “free heating” systems.
Energy efficiency is guaranteed.







How Geothermal Energy is used

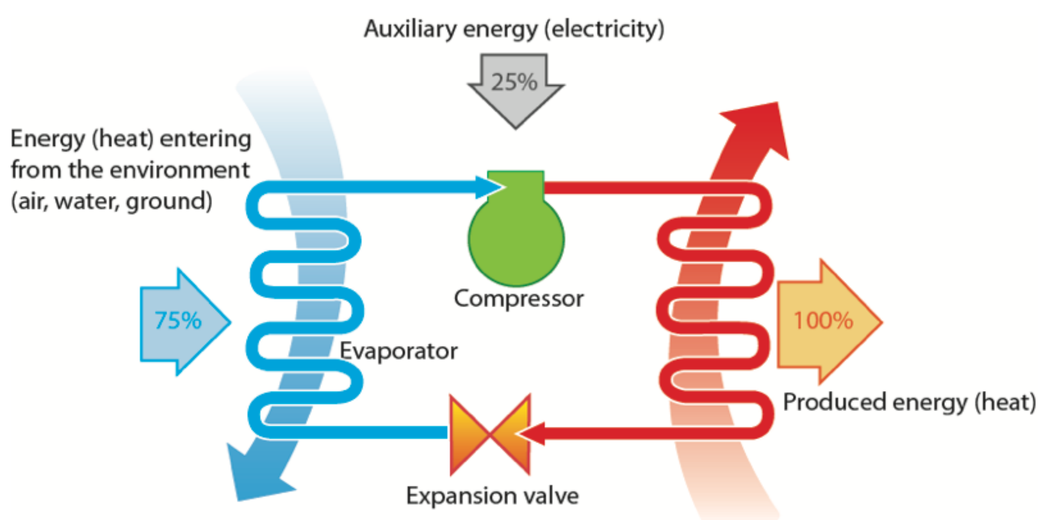
Geothermal heat pump (GHP) or Ground Source Heat Pump (GSHP)

The heat pump systems exploit the physical property of fluids to absorb and release heat when they vaporize or condense, respectively, and move heat from a space (to keep it cool) discharging heat at higher temperature (heating mode).

compressor
(power consumption)
to compress the vapour

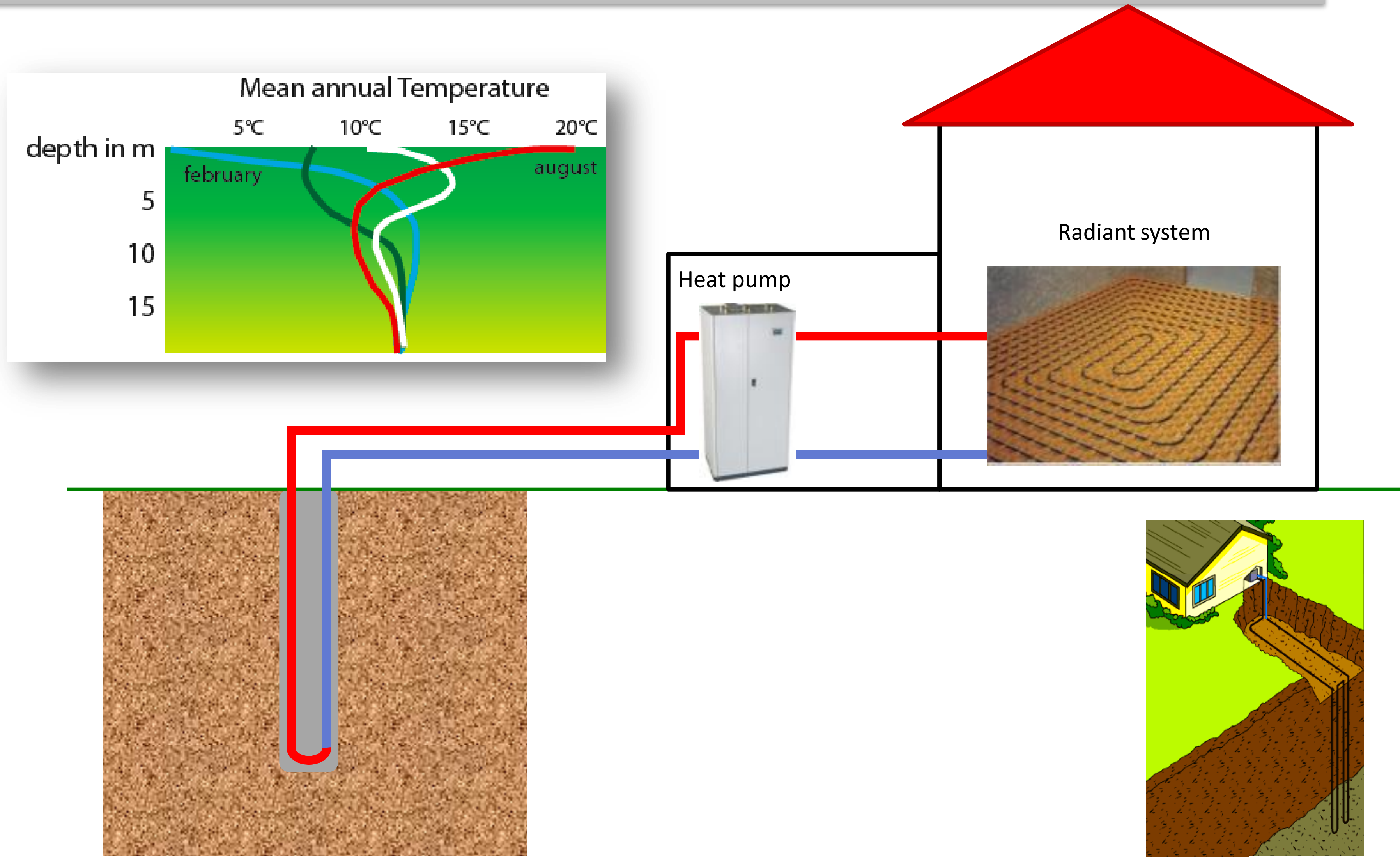
cold source
(ground)

In the evaporator the fluid absorbs heat and evaporates

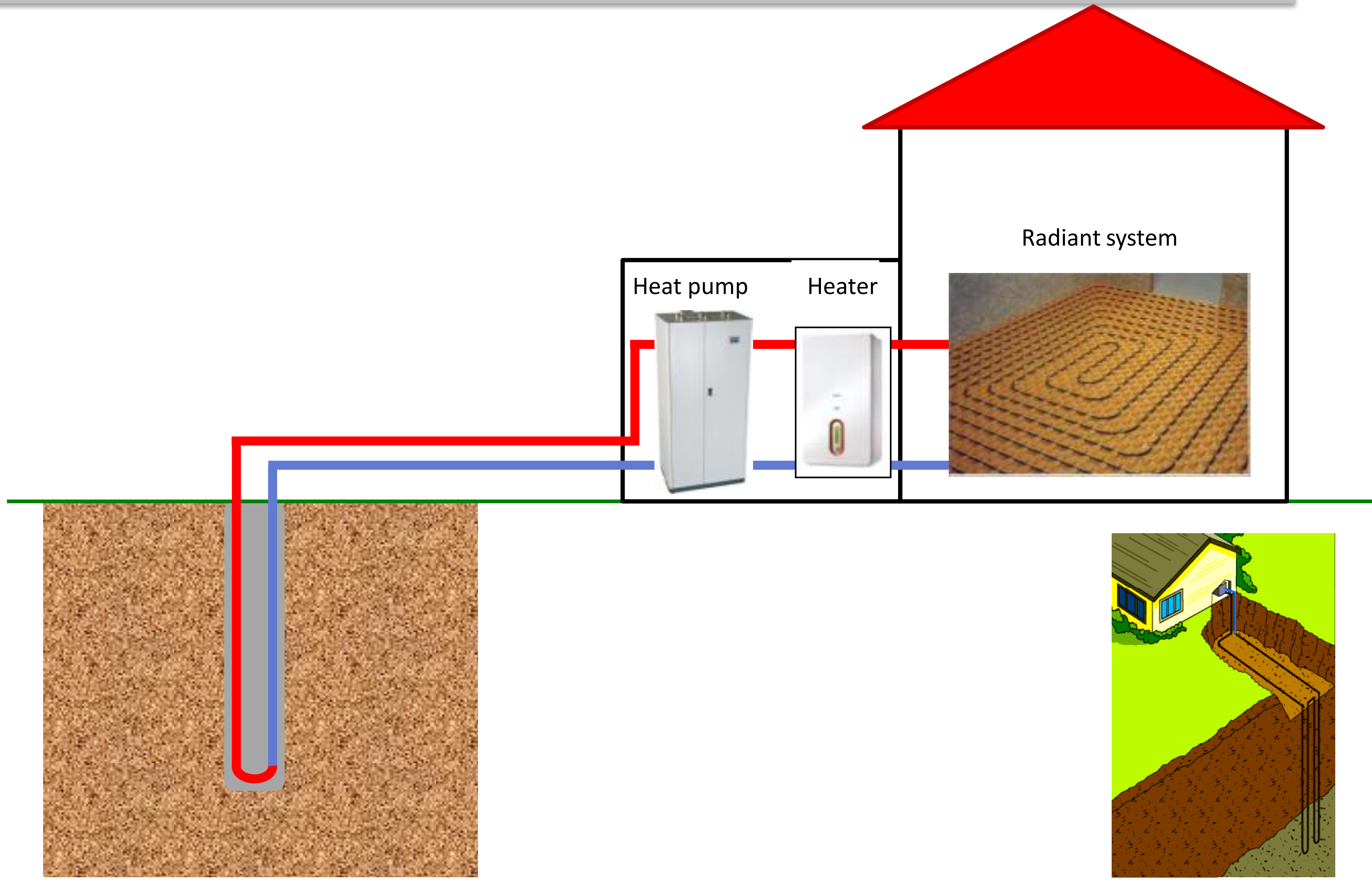


condenser where the warm vapour releases heat and becomes liquid
while heating

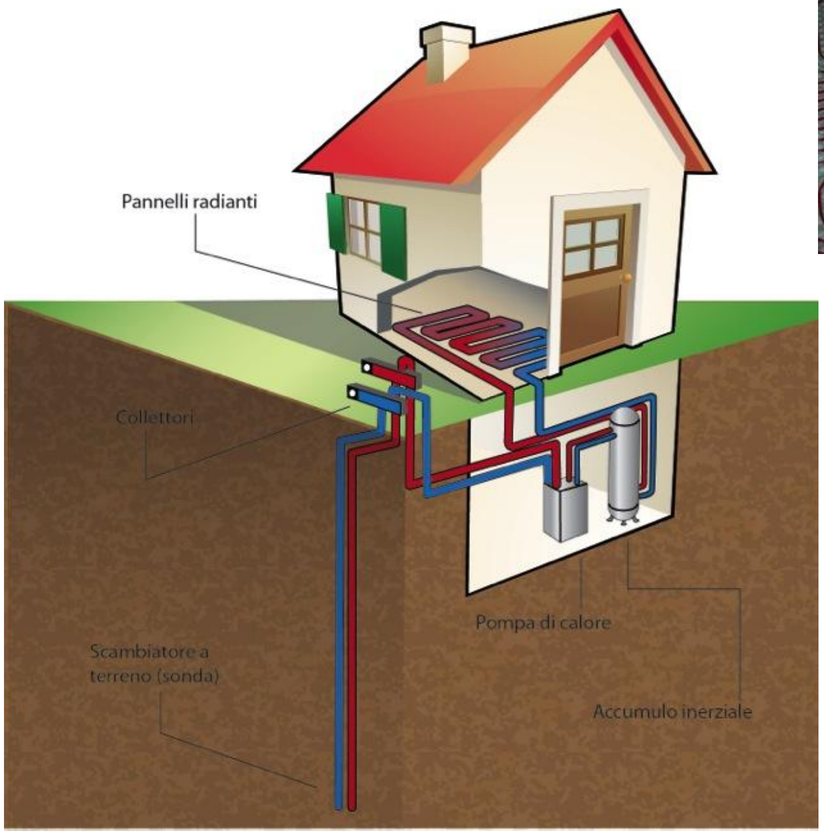
How Geothermal Energy is used



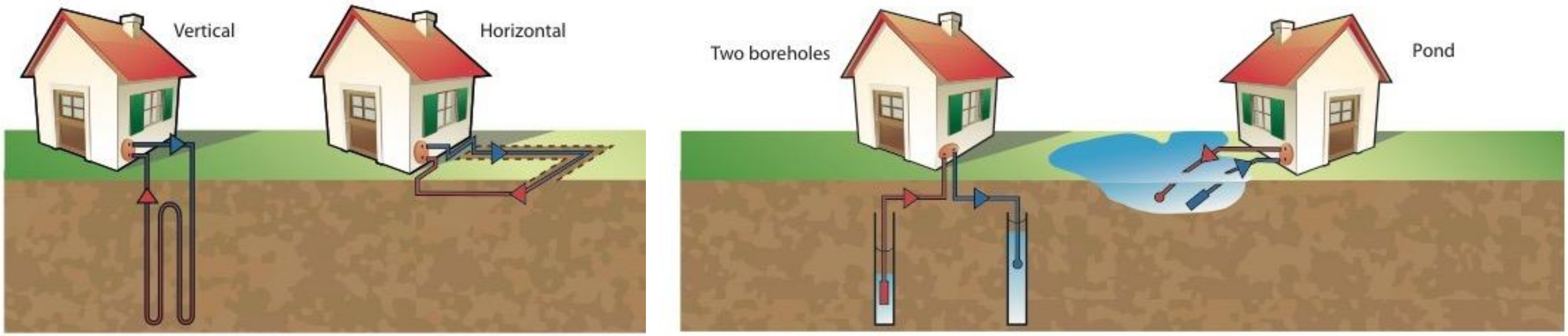
How Geothermal Energy is used



How Geothermal Energy is used



How Geothermal Energy is used



Closed loop systems

A ground-coupled systems where a plastic pipe is placed in the ground, either horizontally at 1-2 m depth or vertically in a borehole down to 50-250 m depth. A water-antifreeze solution is circulated through the pipe collecting heat from the ground in the winter and optionally rejecting heat to the ground in the summer.

Open loop systems

It uses groundwater or lake water as a heat source in a heat exchanger and then discharges it into another well, a stream or lake or even on the ground.

How Geothermal Energy is used

For single units requiring a thermal capacity within 35 kW one heat pump is enough. The energy efficiency may reach 150% (it is 80% for a gas heater, and energy consumption is almost halved).
For larger volumes the units are installed in parallel.

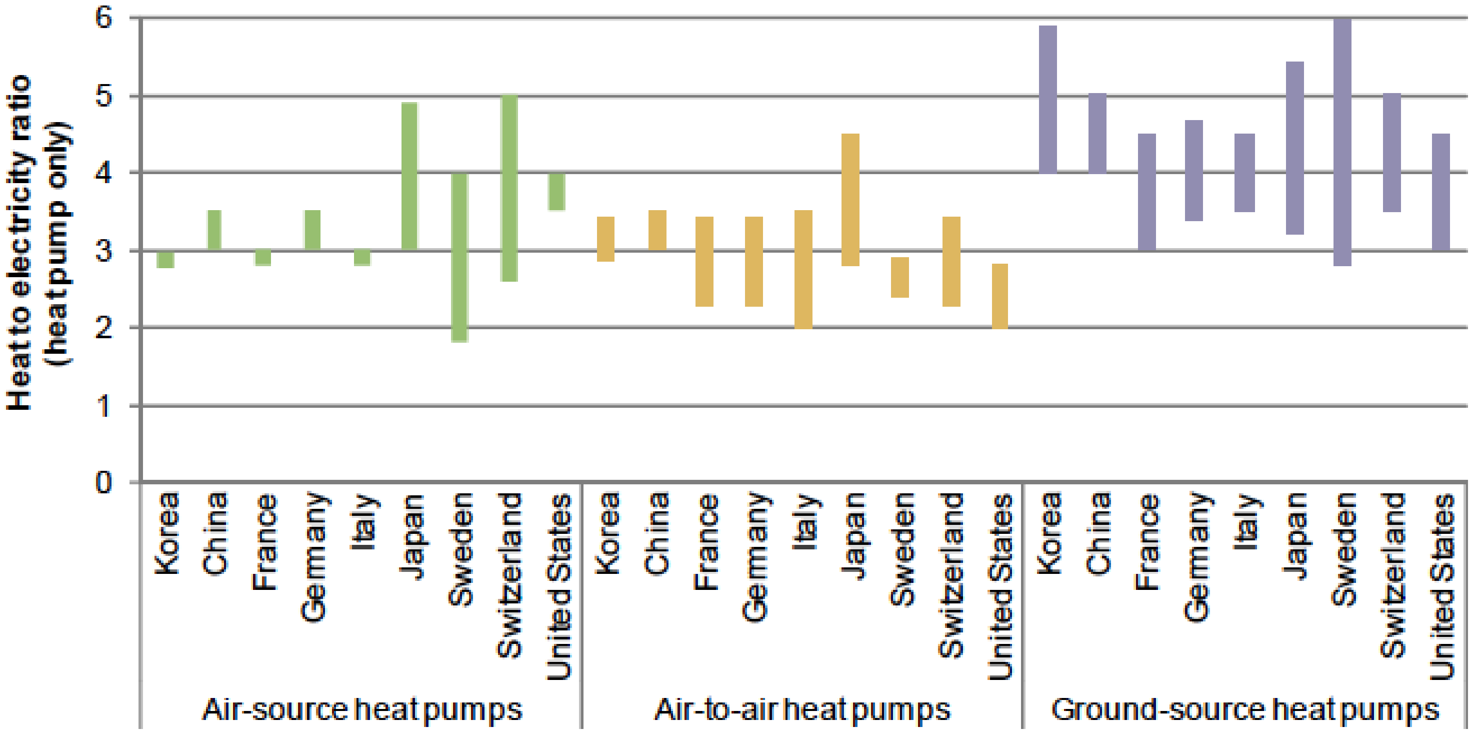
The process may be inverted (reversable units), obtaining heating and cooling systems. Single units may provide 18 kW (cold).

District heating using heat pumps is becoming very popular, and may provide temperature up to 90°C

Heat pumps may have one (40°C) or two (85°C) blocks. COP (coefficient of production, ratio heat/power) is 2.6-3

How Geothermal Energy is used

Figure 28 • Representative efficiencies of air- and ground-source heat pump installations in selected countries



Note: The COP (heat to electricity ratio) values above are based on values provided by the manufacturers, and refer to the heat pump only. Heat to electricity ratios for the whole heat pump cycle typically lie well below the values indicated of the heat pump only.

Source: IEA (2012a), *Energy Technology Perspectives 2012*, OECD/IEA, Paris.

How Geothermal Energy is used

In the European Union, heat generated by hydrothermal, air- and ground-source heat pumps is considered renewable under the Renewable Energy Directive (Directive 2009/28/EC).

According to the EU Directive 2009/28/EC, heat pumps can be considered a renewable technology as long as they result in a primary energy efficiency of at least 115%, which corresponds to a seasonal performance factor of 2.875 at an average efficiency of the electricity production of 40% (EC/RHC Platform, 2012).

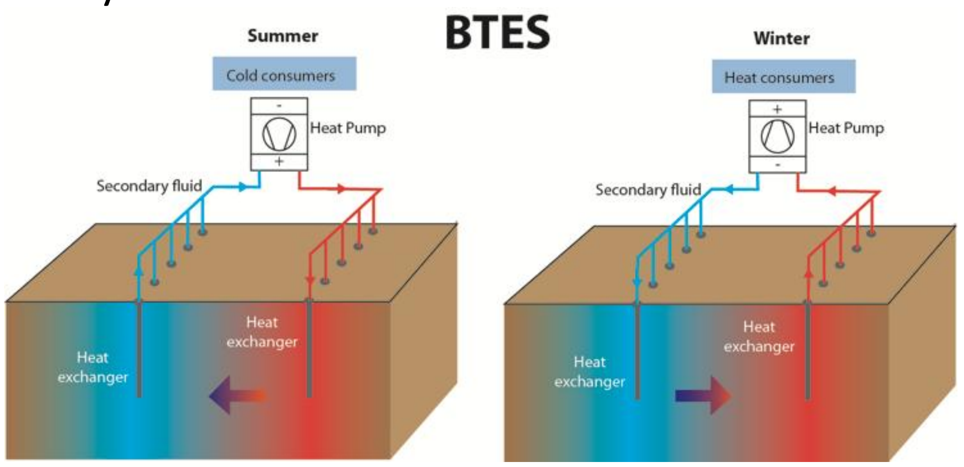
The energy considered renewable is the heat delivered, minus the electricity consumption of the pump.

How Geothermal Energy is used

Heating and cooling system of Palazzo Lombardia, Milan, by geothermal heat pump

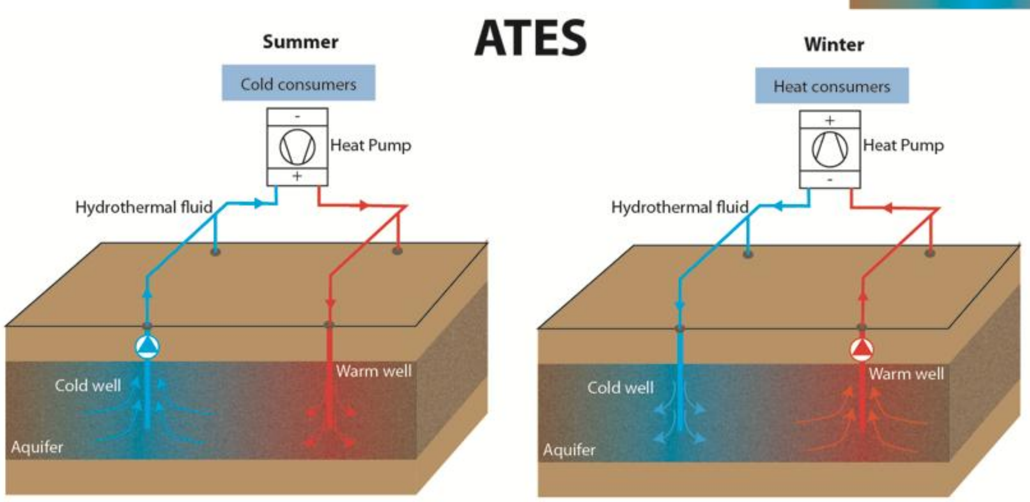
How Geothermal Energy is used

UTES (*Underground Thermal Energy Storage*) is an increasing research field for storing heat/cold and use it when necessary



ATES

Aquifer Thermal Energy Storage



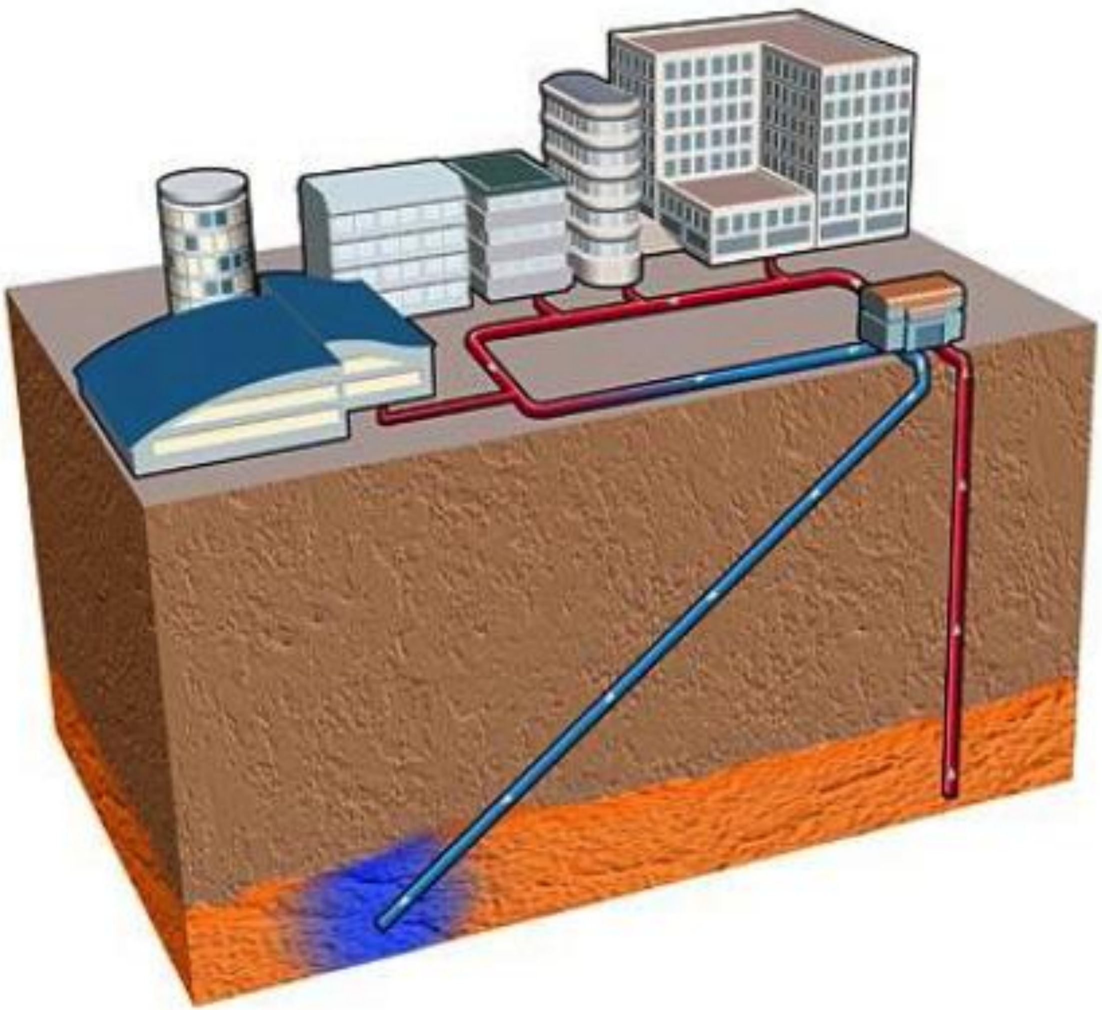
BTES

Borehole Thermal Energy System

How Geothermal Energy is used

Space heating, of which more than 80% are district heating, is among the most important direct uses of geothermal energy

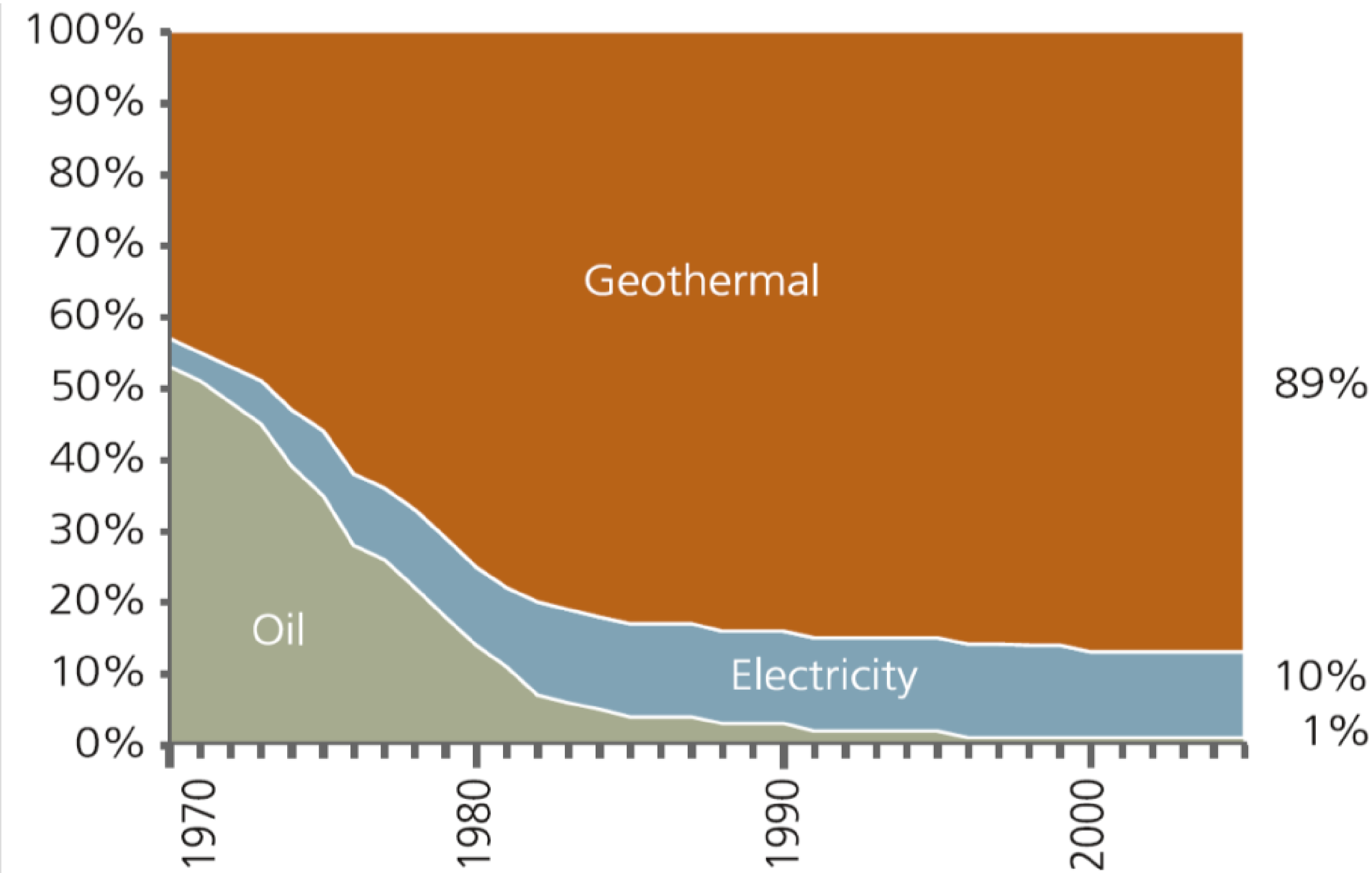
Open loop (single pipe) distribution systems are used where the water quality is good and recharge into the geothermal system adequate (fluids are wasted). In the more commonly used closed loop (double pipe) systems the spent water is disposed into reinjection wells.



How Geothermal Energy is used

These pumps are used to pump the heated water to buildings in a district heating system, after it has passed through the heat exchanger.

How Geothermal Energy is used



Energy source for district heating in Iceland


Reykjavik Using F

Reykjavik Using Geothermal

Untapped geothermal resources could significantly contribute to the decarbonisation of the DH market

12% of the total communal heat demand is DH

Geo-DH would be available for 26% of EU-27 population

heat supply to DH systems:

- power plants: 17%
- waste: 7%
- industrial heat: 3%
- biomass: 1%
- **geothermal: 0,001%**

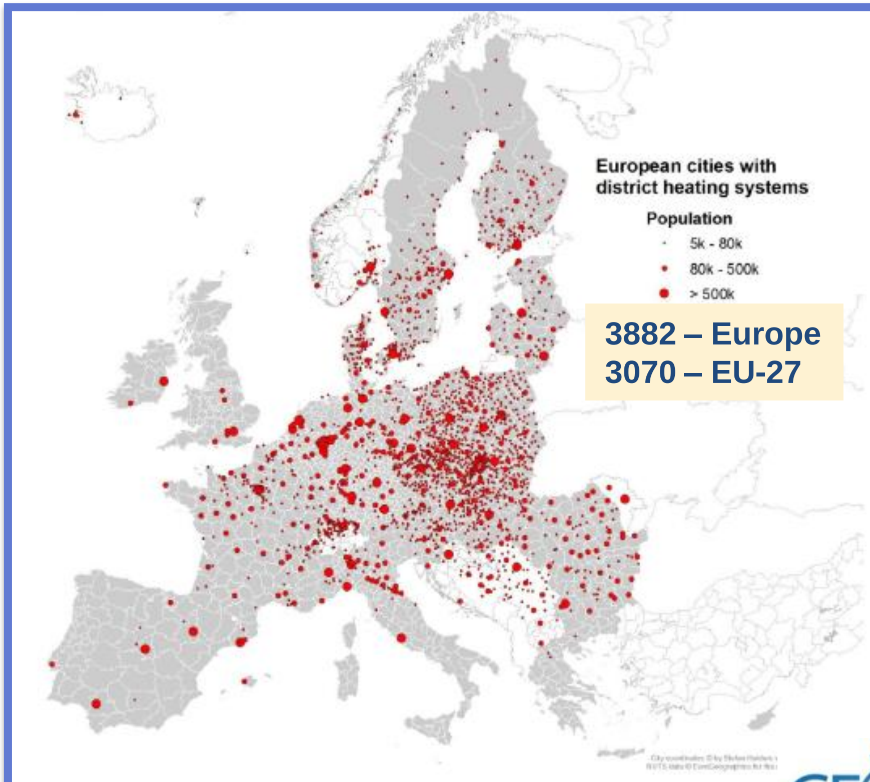
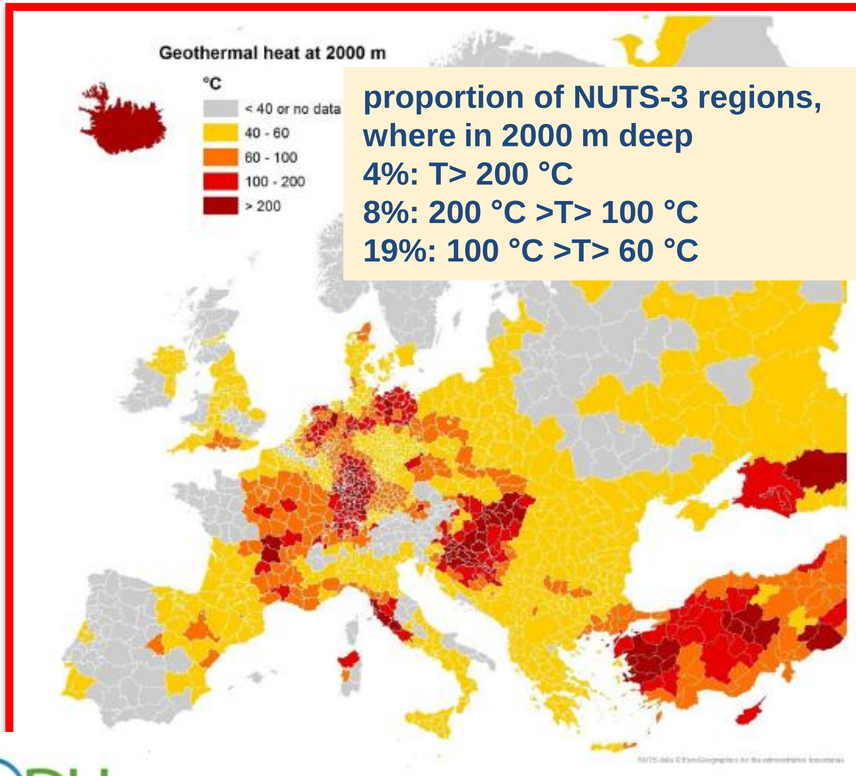


Figure 17: District heating systems in Europe by city size and for cities having more than 5000 inhabitants. The map shows with 2779 systems. Source: Halmstad University DHC Database.

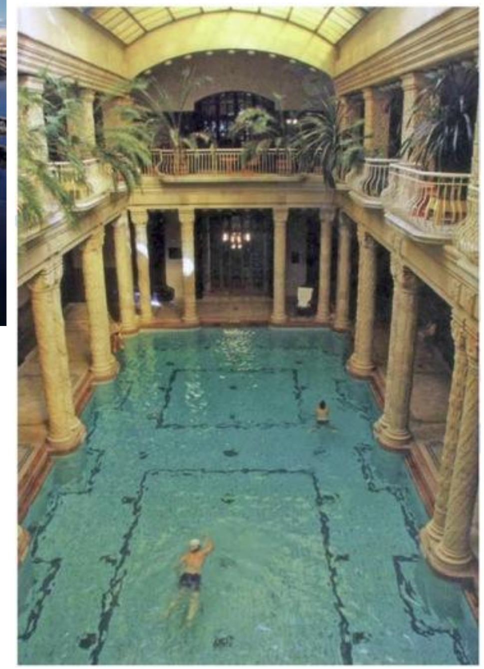


entified geothermal heat resources by temperature at 2000 m depth by NUTS3 region. Source: European Commission, hermal Resources in Europe. Publication EUR 17811, Luxembourg 2002.

How Geothermal Energy is used


Fish and other animal farming farming


Greenhouse heating

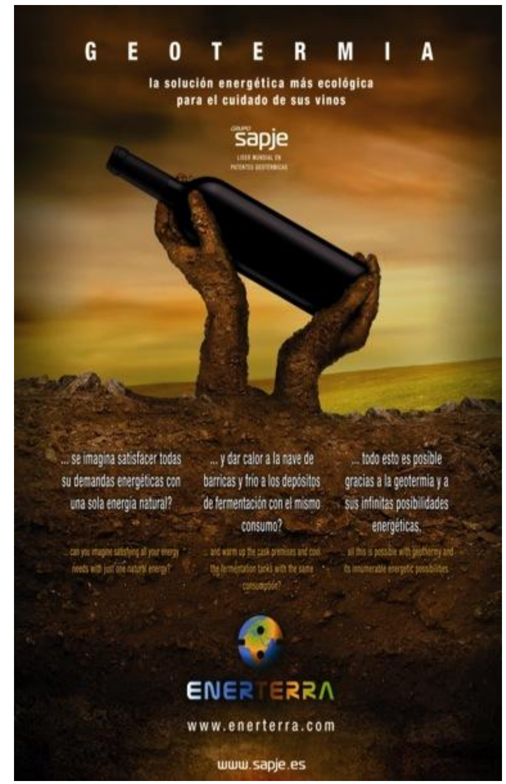


Bathing and balneology

The most common direct uses of geothermal heat

How Geothermal Energy is used

Food processes using heated fluids or heating&cooling may benefit from geothermal energy

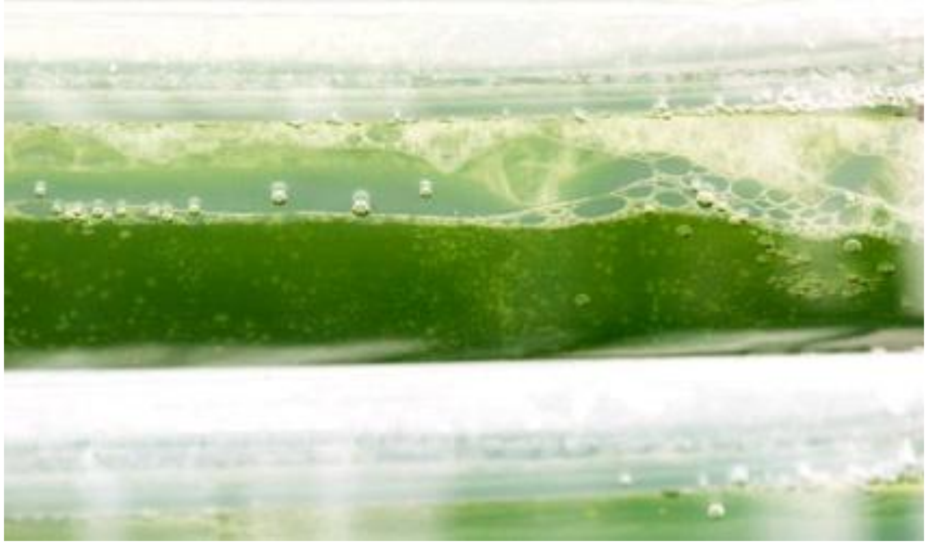


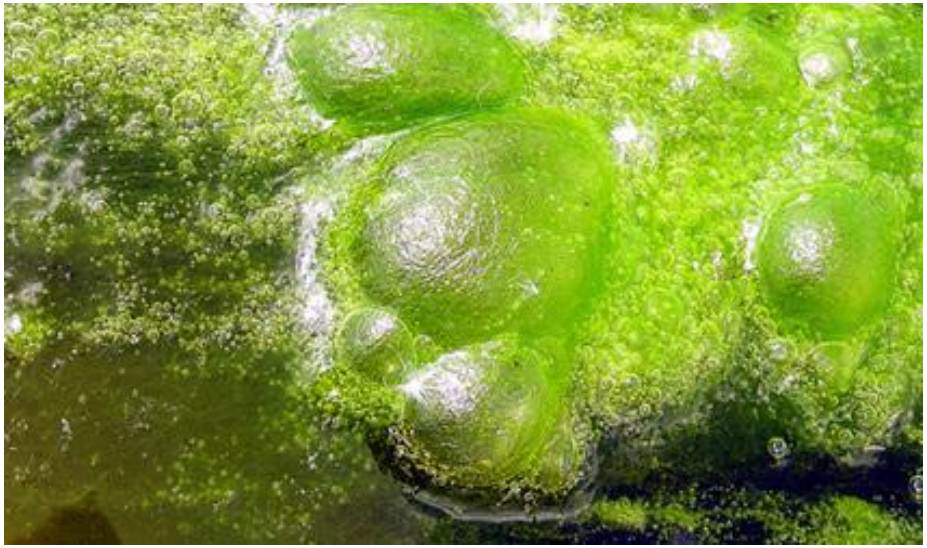
How Geothermal Energy is used

Spirulina is being farmed in a number of tropical and sub-tropical countries, in lakes or artificial basins, where conditions are ideal for its fast and widespread growth (a hot, alkaline environment rich in CO_2).

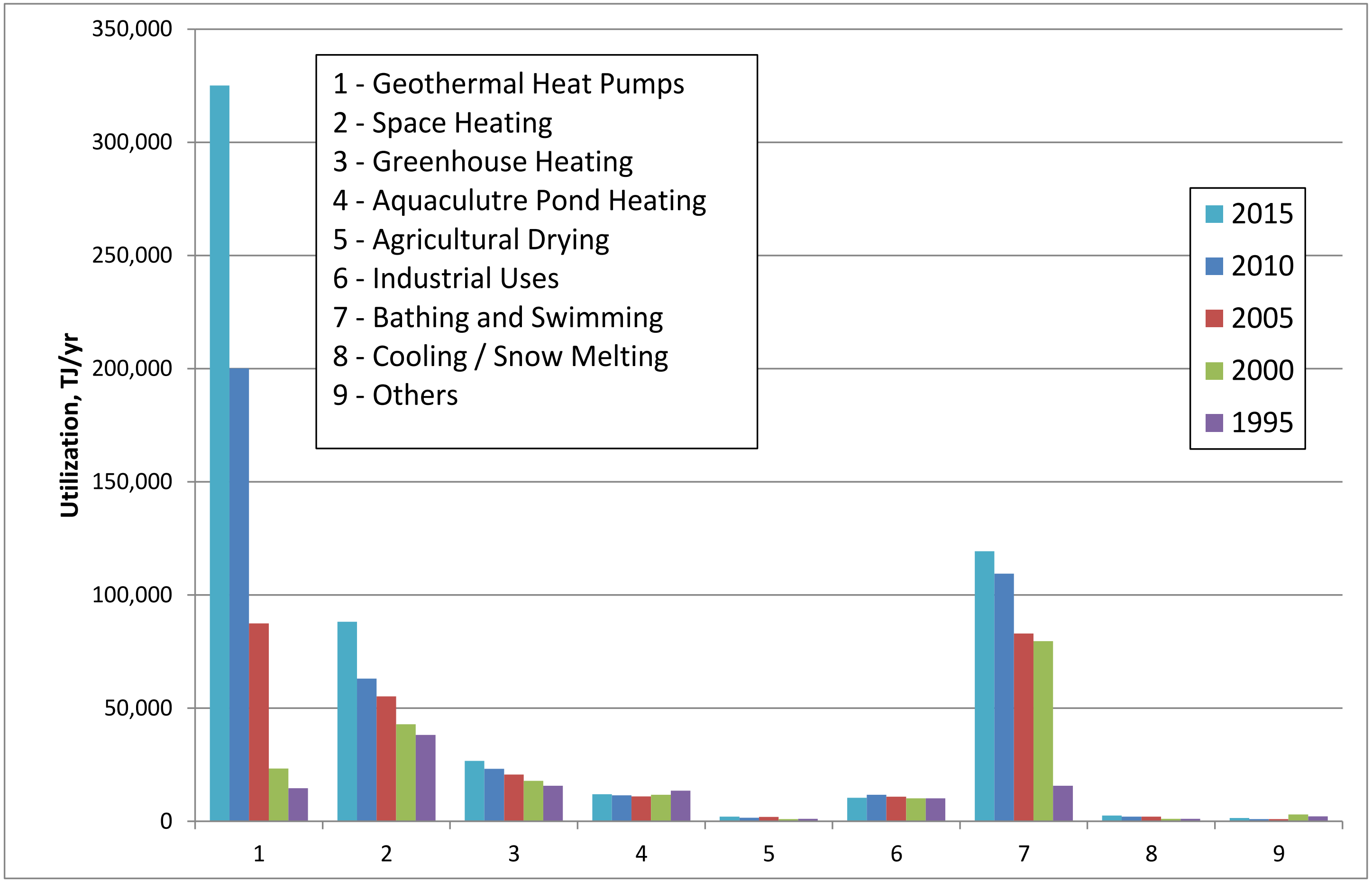
Other kinds of algae are grown to extract oil and produce bio-fuels

A "new" trend is to grow nutriceutical products





How Geothermal Energy is used



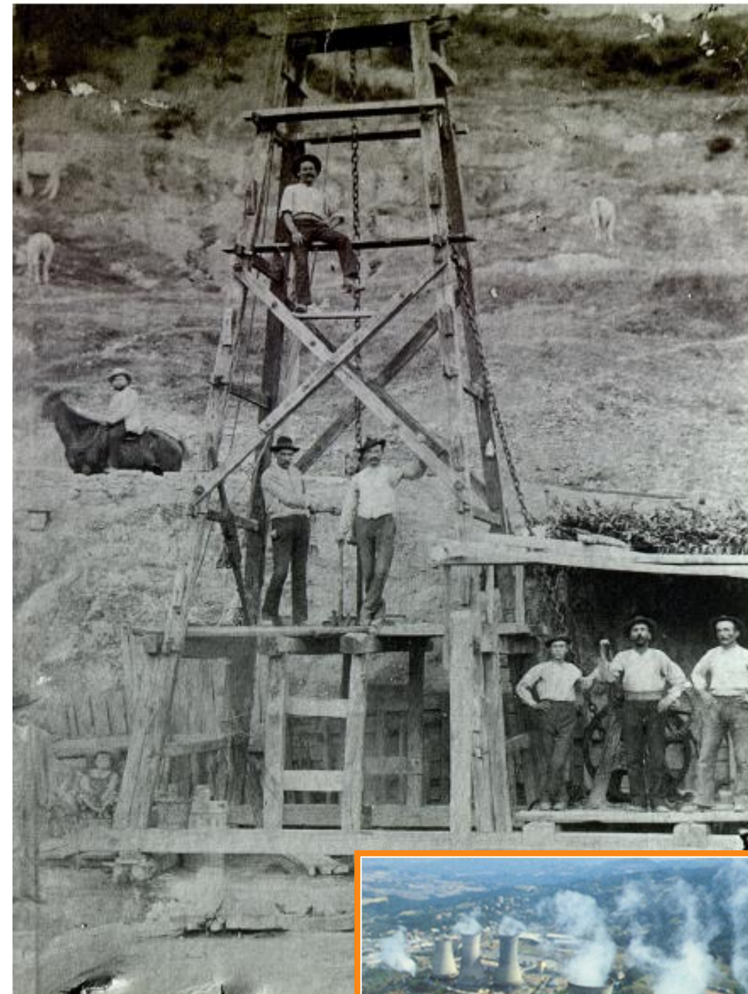
from Lund and Boyd, WGC 2015

How Geothermal Energy is used

Italy has been the first country in the world to produce **electricity by geothermal energy** on 1904.

Power production started on 1908 and increased in Italy and the world since then.

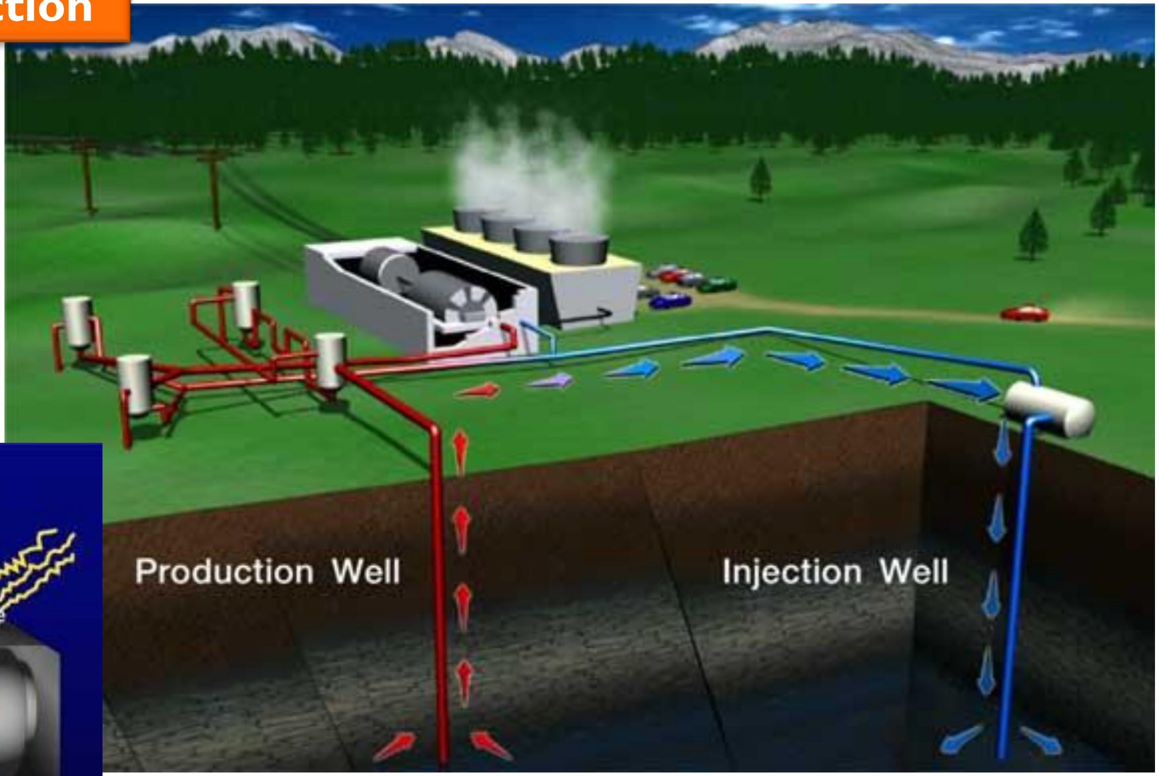
Larderello, 1904

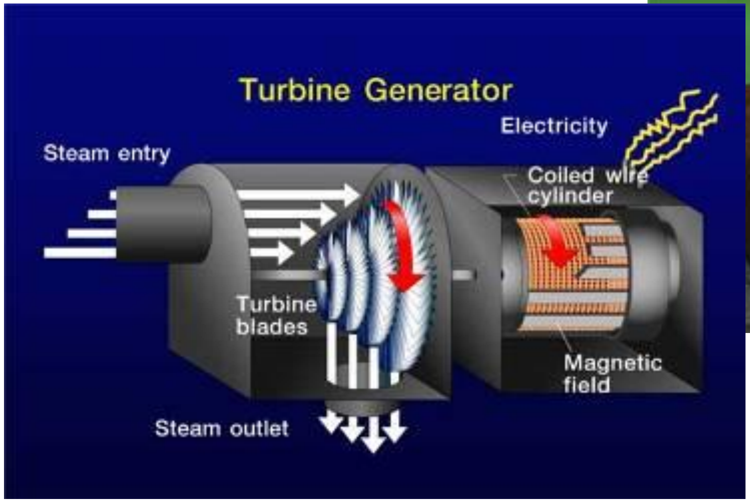


How Geothermal Energy is used

Geothermal power production

By means of turbine generators, geothermal heat (high temperature) is converted in mechanical energy and then in electrical energy





How Geothermal Energy is used

Steam Dominated systems
vapourstatic pressure

Dry steam plants

Liquid dominated systems
hydrostatic pressure

Single or double flash plants
separation of steam and liquid phase

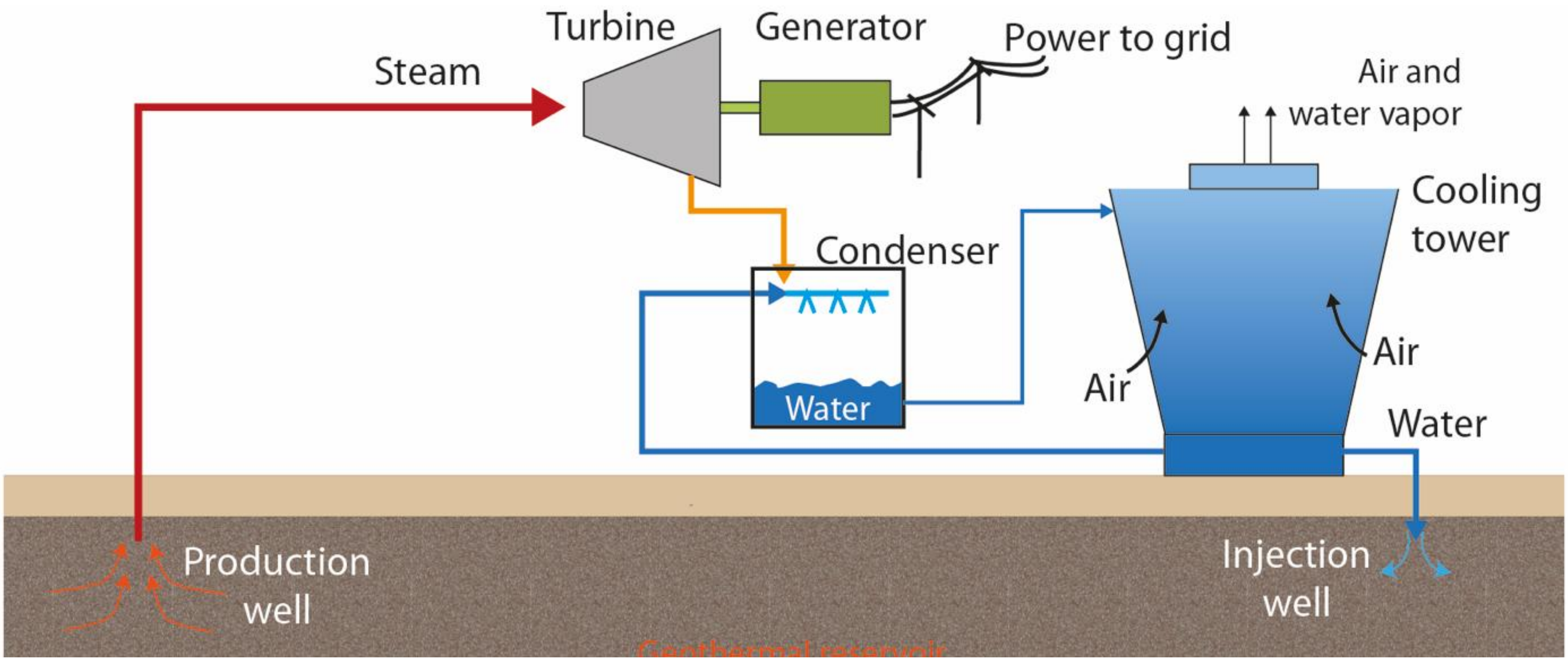
Binary plants

Combined plants
flash and binary, cascade

How Geothermal Energy is used

Dry steam plants

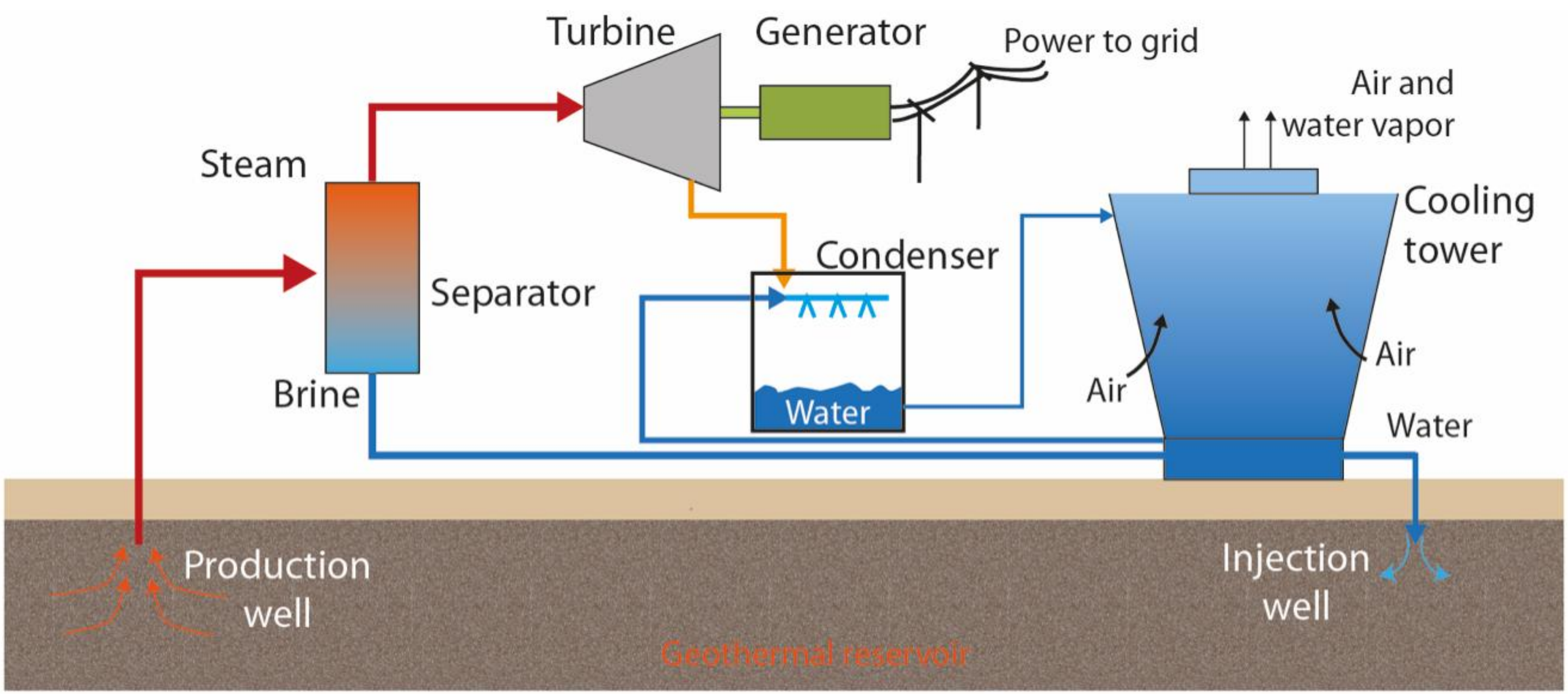
use hydrothermal fluids that are primarily steam. The steam goes directly to a turbine, which drives a generator that produces electricity.



How Geothermal Energy is used

Flash steam power plants

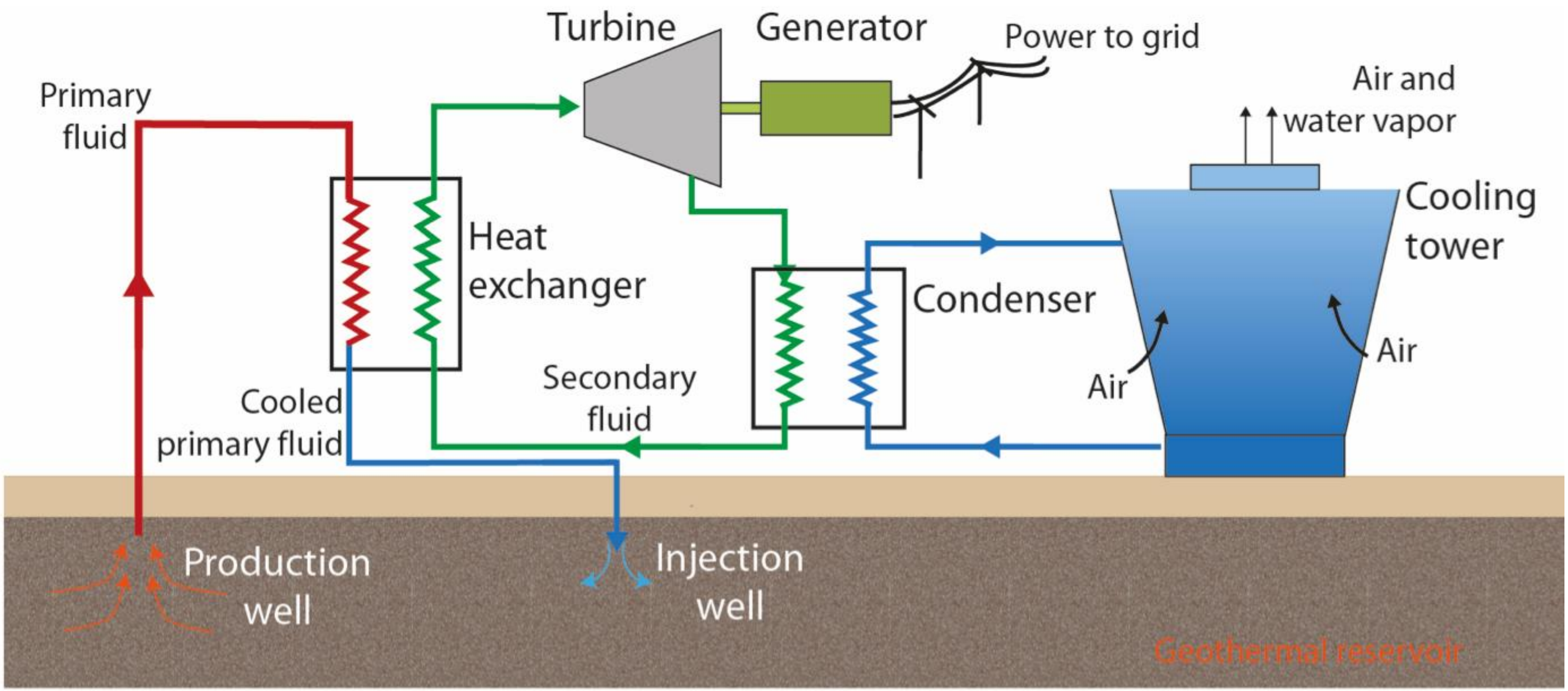
tap into reservoirs of water with temperatures higher than **180° C**. As it flows, the fluid pressure decreases and some of the hot water boils or "flashes" into steam. The steam is then separated at the surface and is used to power a turbine/generator unit



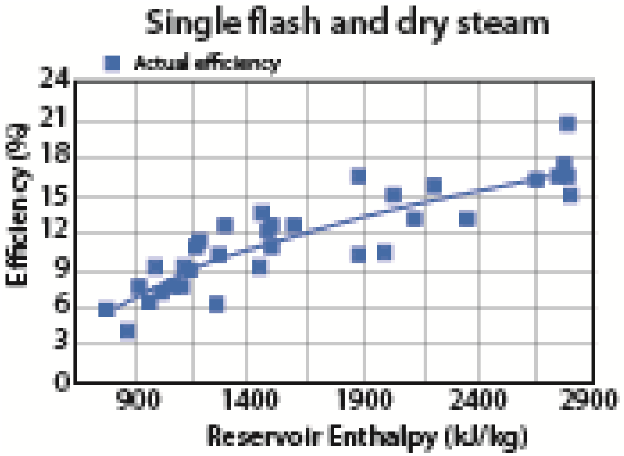
How Geothermal Energy is used

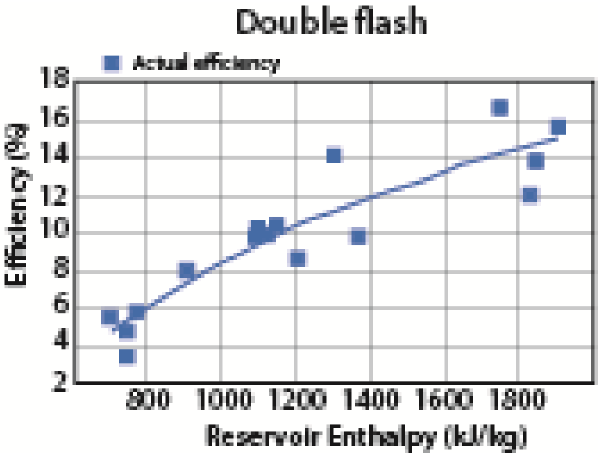
Binary cycle power plants

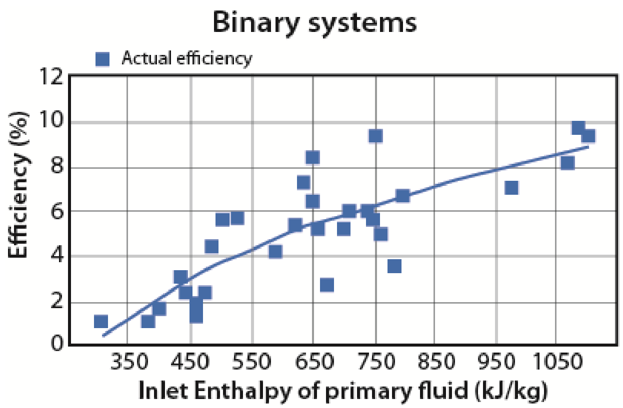
operate on water at lower temperatures of about **105-180° C**. These plants use the heat from the geothermal water to boil a working fluid, usually an organic compound with a low boiling point.



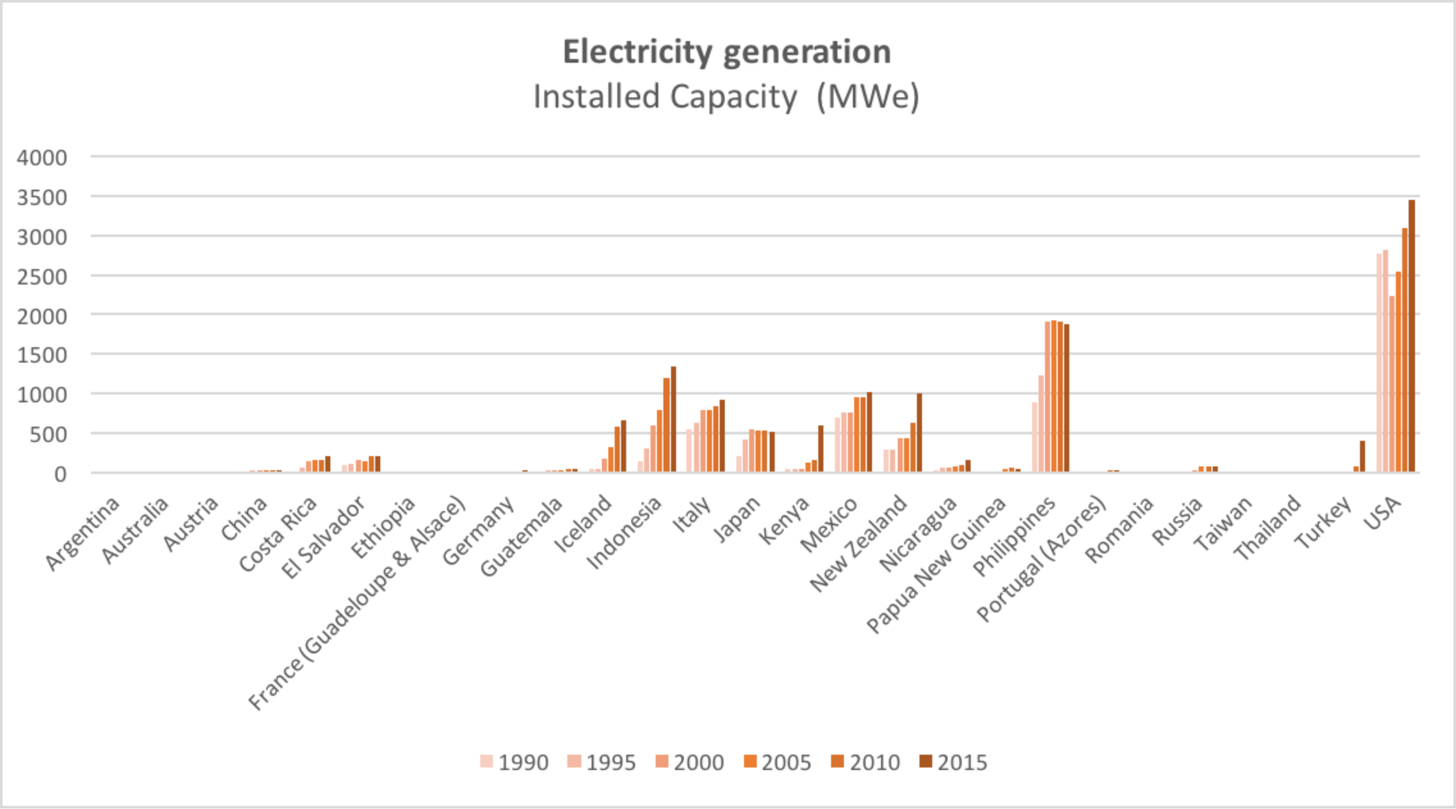
How Geothermal Energy is used







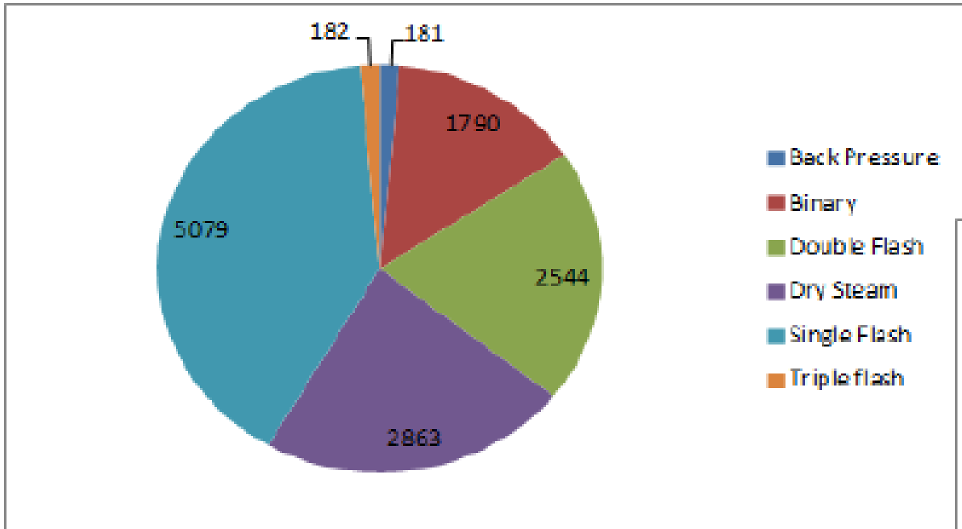
How Geothermal Energy is used



27 countries in the world use geothermal energy for power production (from WGC2015 data)

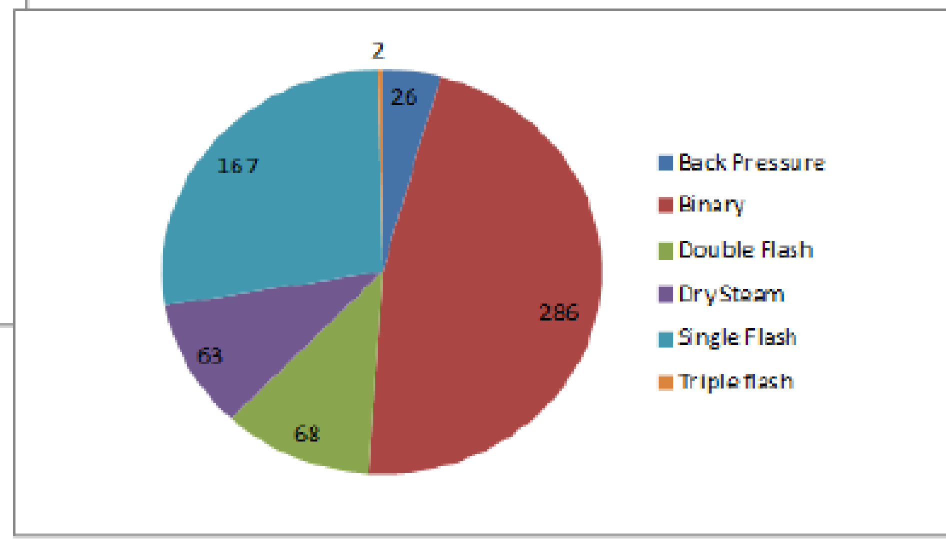
12.7 GWe

How Geothermal Energy is used



Installed capacity in MWe for each typology

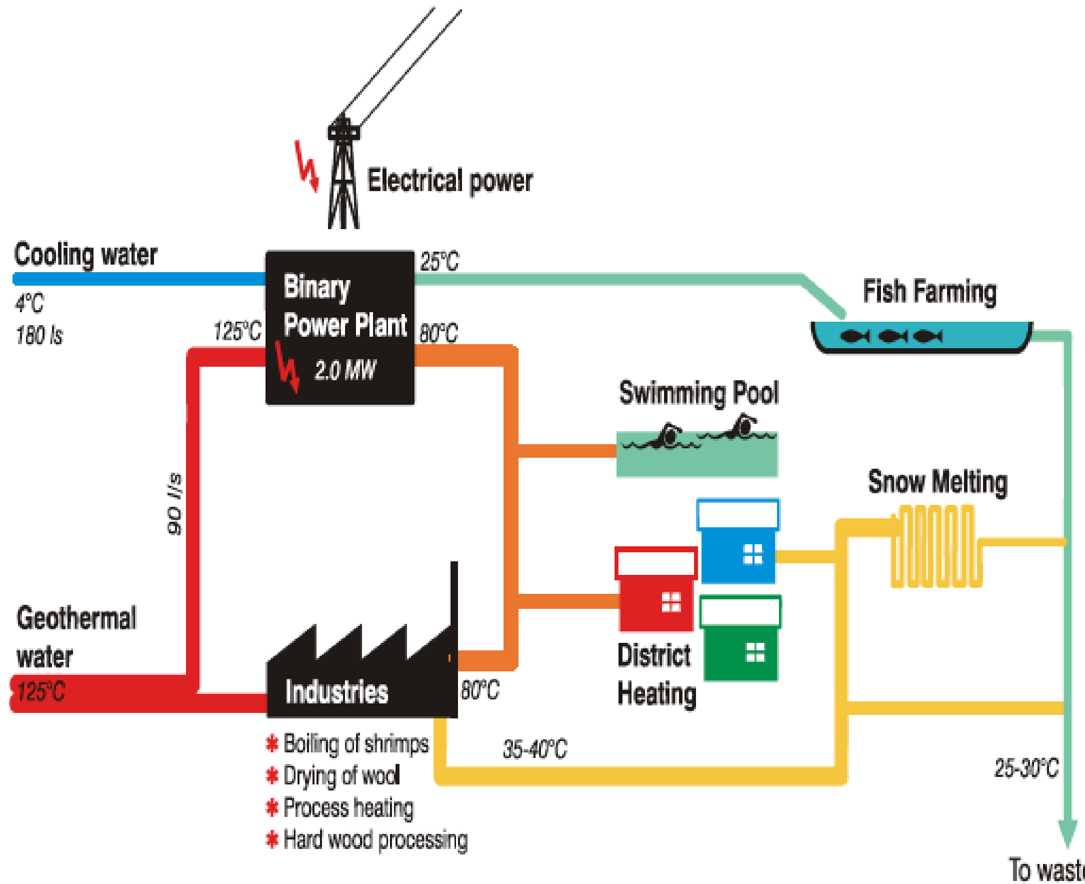
Number of units
for each typology (total 613)



Country	Back Pressure	Binary	Double Flash	Dry Steam	Hybrid	Single Flash	Triple flash	TOTAL
Africa	48	11				543		602
Asia		236	525	484		2514		3758
Europe		268	273	795		796		2133
Latin America	90	135	510			908		1642
North America		873	881	1584	2	60	50	3450
Oceania	44	266	356			259	132	1056
TOTAL	**181**	**1790**	**2544**	**2863**	**2**	**5079**	**182**	**12640**

How Geothermal Energy is used

The efficiency of geothermal utilisation is enhanced considerably by cogeneration plants (combined heat and power plants), compared with conventional geothermal plants. A cogeneration plant produces both electricity and hot water which can be used for district heating as well as other direct uses. A necessary condition for the operation of a cogeneration power plant is that a relatively large market for hot water exists at a distance not too far from the plant.



3

What is the production? What about the cost? And emissions?

The advantages of using Geothermal Energy

Geothermal Energy **pros**

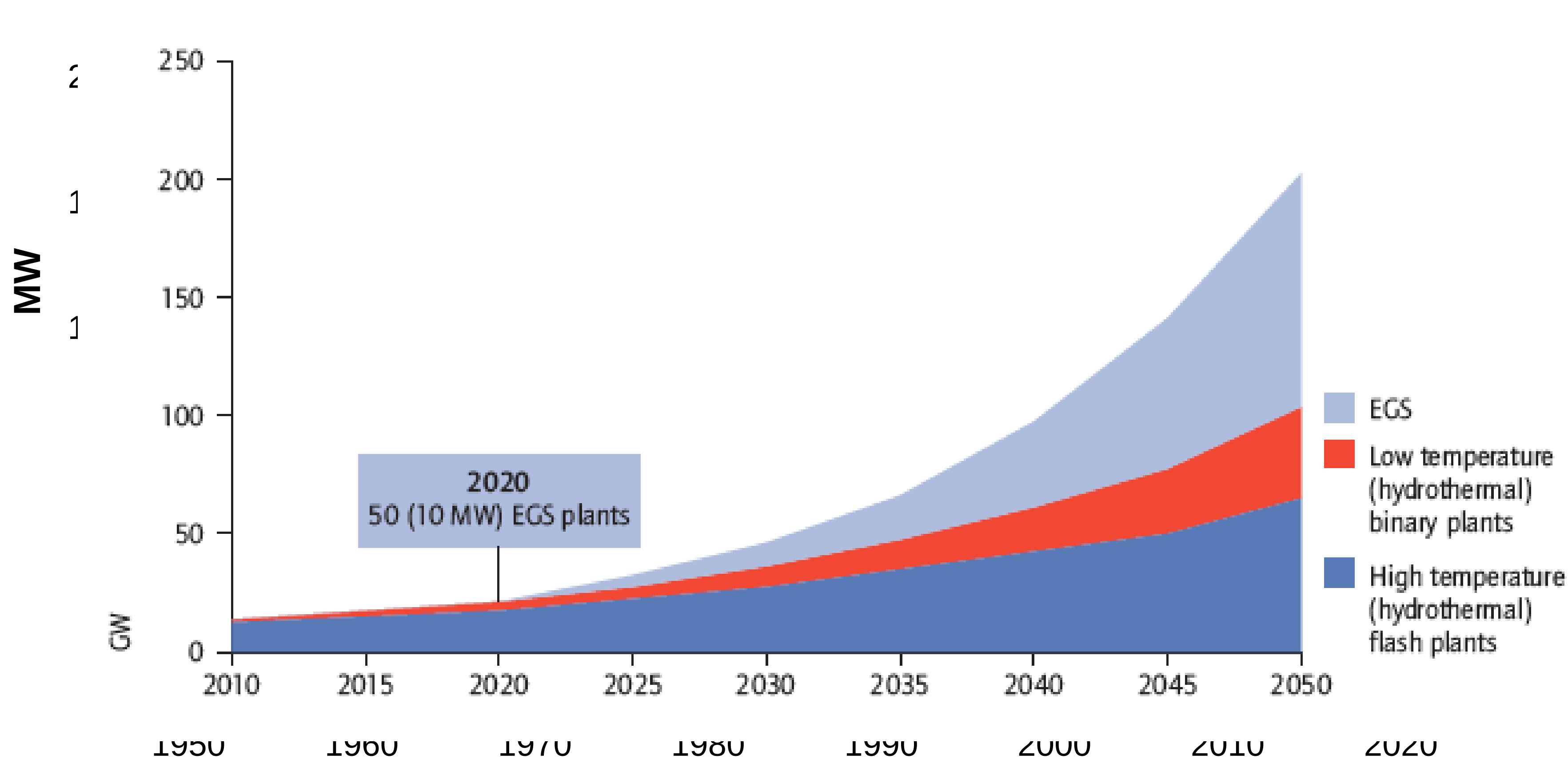
The two main applications of geothermal energy, electric power generation and direct use of heat, are currently producing more than 67 TWh/a_e and 12 GW_e of installed capacity, and about 300 TJ/yr with 30 GW_{th}

And are **constantly growing**.

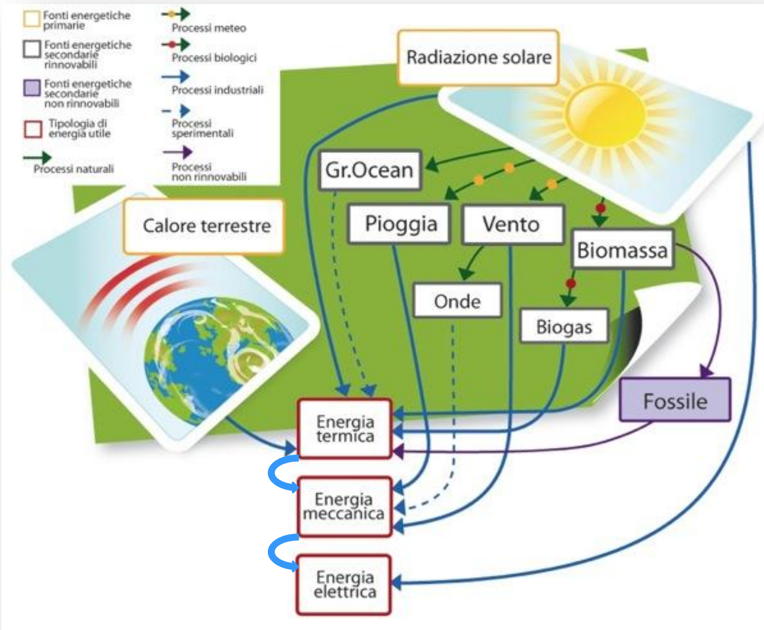
Geothermal Energy **pros**

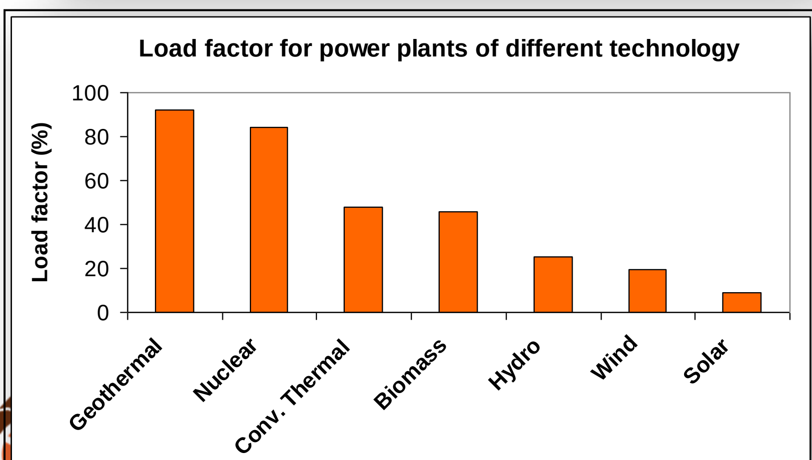
World Geothermal Electricity

Figure 9: Growth of geothermal power capacities by technology (GW)



Geothermal Energy **pros**



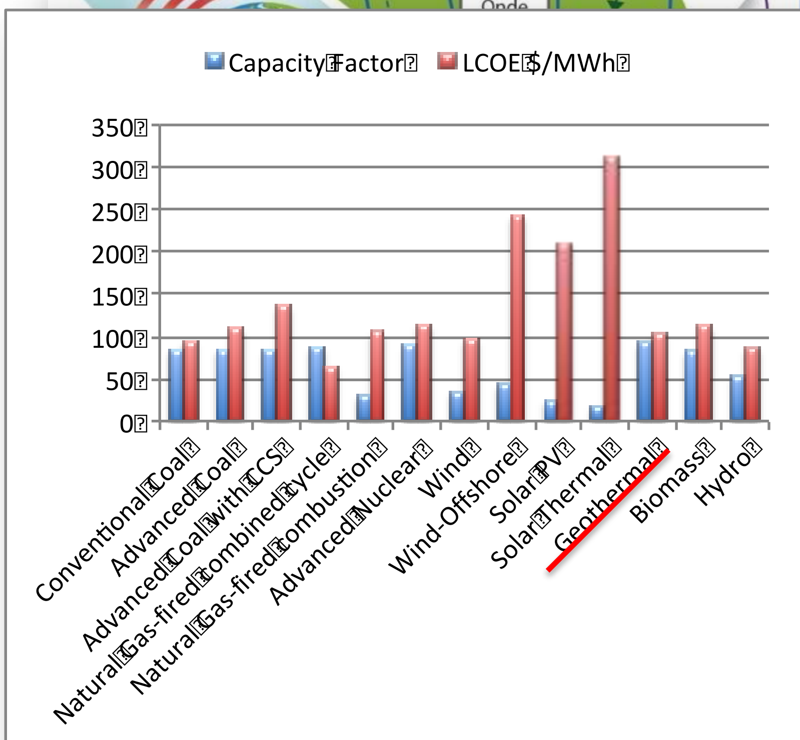


Not depending, directly or undirectly, on sun, geothermal may produce 24 hours per day:

a **base-load energy** like fossil and nuclear sources.

It is most economical for geothermal power stations to serve as **base load** throughout the year.

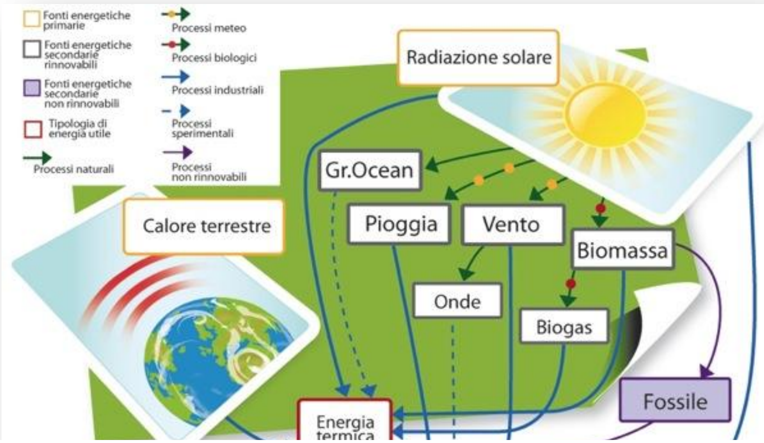
Geothermal Energy **pros**



The **total cost (LCOE)** of geothermal power production is **cheap** if compared to those of others renewables

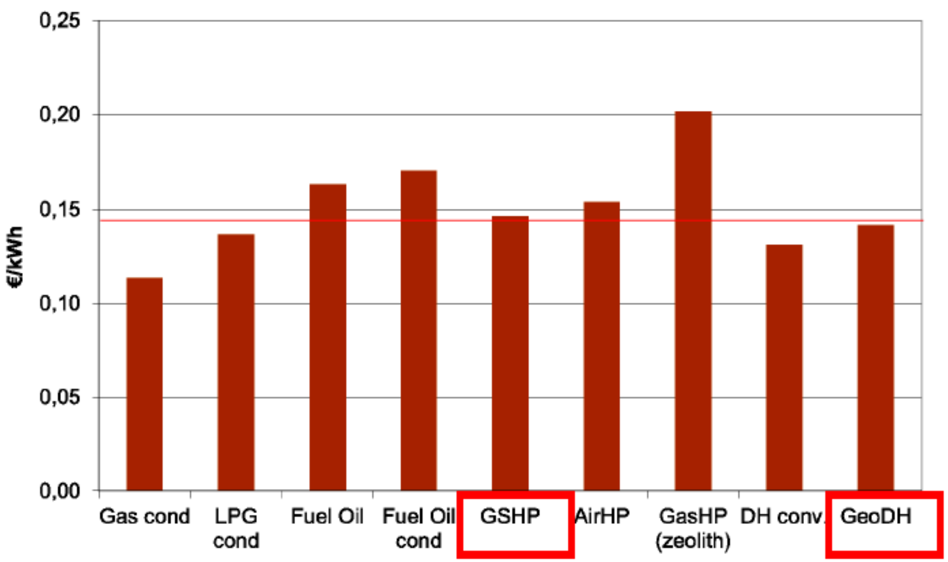
Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011, EIA

Geothermal Energy **pros**

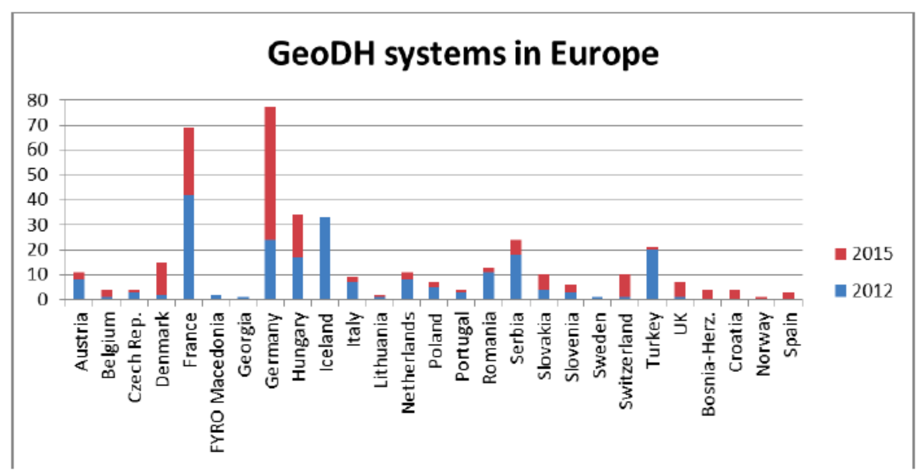


The **total cost (LCOE)** of geothermal heat production is **cheap** if compared to those of others renewables and fuels

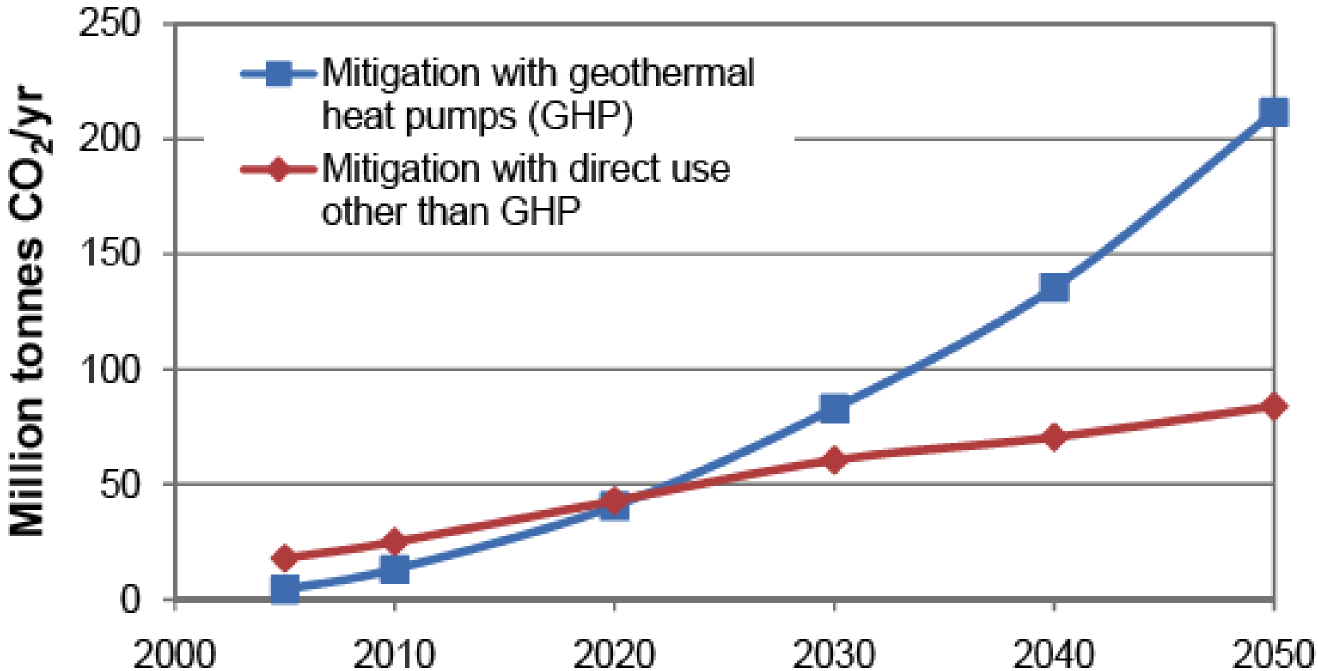
Full cost of Heat, calculated for small building or flat



GeoDH Systems in Europe



Geothermal Energy **pros**



CO_2 emission mitigation of Geothermal Heat. For each Geothermal Heat Pump (blue) it assumes an emission of 50 tonnes CO_2-equivalent/TJ. For other sources of geothermal heating (red) it assumes an emission of 4 tonnes CO_2-equivalent/TJ. Both assume an emission of 100 tonnes CO_2 equivalent/TJ for fossil heat provision. Fridleifsson et al., 2008

4

What are the risks? Environmental impact?

Disadvantages, needs and gaps of Geothermal Energy

Geothermal Energy **cons**

Thanks to the high capacity factor, the total cost (LCOE) of geothermal power production is comparable or cheap if compared to those of others renewables.

However, the **capital, up-front costs remain too high**, due to the scarcity of on-site data, the difficulty to forecast the production prior to drill combined with the high drilling costs.

Geothermal Energy **cons**

The average geothermal capacity on the entire 613 units in operation is 20.6 MW

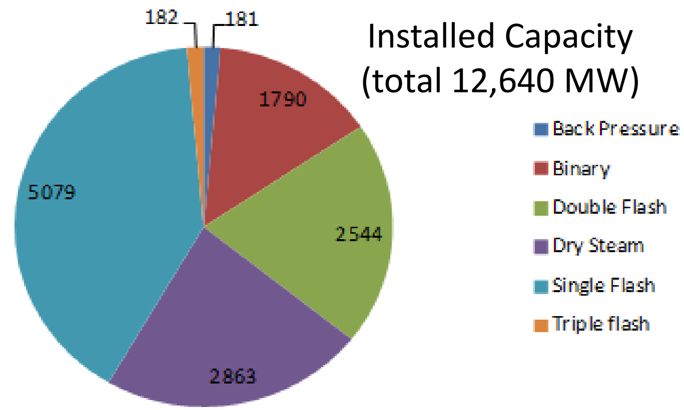
BIG

Only 48 units with capacity > 55 MW, with an average of 79.5 MW.

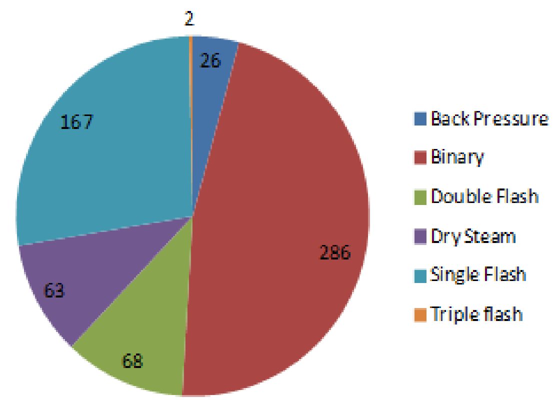
SMALL

There are 259 units with capacity < 10 MW, with an average capacity of 3.2 MW. The majority of them is binary (196 units), 22 are back pressure, 22 are single flash and 17 double flash.

- The economics of electricity production is influenced by the drilling costs and resource development;
- The productivity of electricity per well is a function of reservoir fluid thermodynamic characteristics (phase and temperature);
- The small dimension of most plants enhance the risk of investment



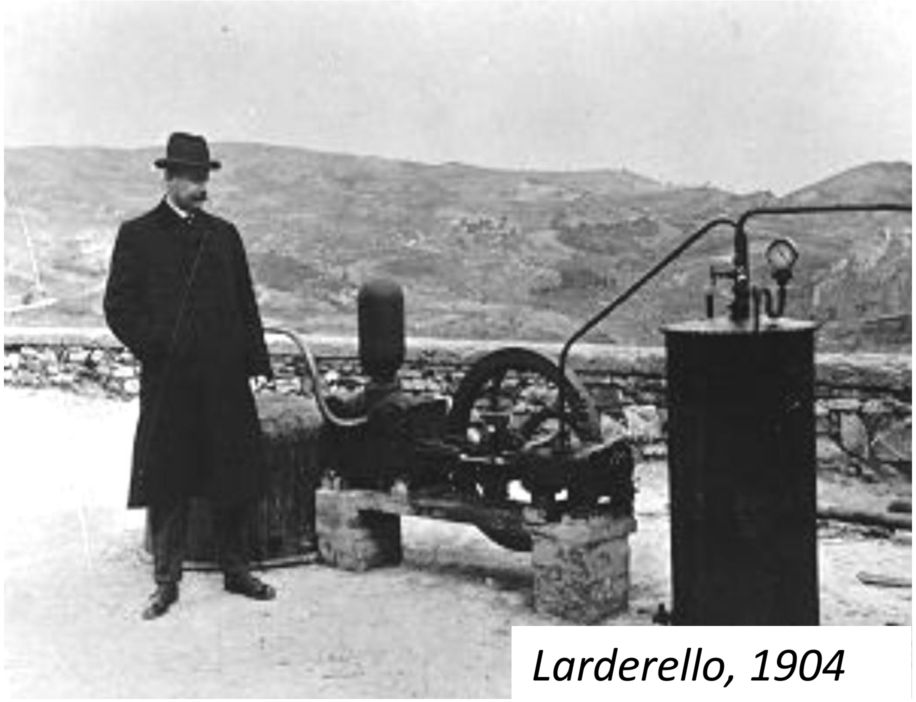
Installed Capacity (total 12,640 MW)



Number of units for each typology (total 613)

Geothermal Energy **cons**

The real **geothermal potential is scarcely known**, it is seldom defined in detail by the countries and properly introduced in the Energy Plans



Larderello, 1904

Although geothermal energy has a long tradition for application in Italy, there is little **awareness** of its potential, and the role it might play for energy production among renewables.

Geothermal Energy **cons**

Power (mainly) and heat production from geothermal resources may have an impact on any environmental matrix (air, water, ground, ecosystems).

The potential impacts are:

surface-visual effects (land use, landscape, flora and fauna);

physical effects (induced seismicity, subsidence, geological hazards);

acoustic effects (noise during drilling, construction and management);

thermal effects (release of steam in the air, ground heating and cooling for fluid withdrawal or injection).

chemical effects (gaseous emissions into the atmosphere, re-injection of fluids, disposal of liquid and solid waste).

Monitoring, mitigation, remediation are a must

5

Reducing cons while increasing pros: how?

Research frontiers of Geothermal Energy

Research in Geothermal Energy

Exploration and investigation technology: Improvement of the probability of finding an unknown geothermal reservoir and better characterize known reservoir, optimizing exploration and modeling of the underground prior to drill. Require also clear terminology, methodology and guidelines for the assessment of geothermal potential. It will result in an ***increased success rate***.

Drilling technology: improvements on conventional approaches to drilling such as more robust drill bits, innovative casing methods, better cementing techniques for high temperature, improved sensors, electronic capable of operating at higher temperature in downhole tools, revolutionary improvements utilizing new methods of rock penetration. It will result in ***reducing the drilling cost*** and it will allow to ***access deep and hot regions***.

Power conversion technology: improving heat-transfer performance for low temperature fluid, developing plant design with high efficiency and low parasitic losses. It will ***increase the available resource basis*** to the huge low-temperature regions, not only those having favorable geological conditions.

Research in Geothermal Energy

Operation technology: increasing production flow rate by targeting specific zones for stimulation, improving heat-removal efficiency in fractured rock system. Refine stimulation methods (permeability enhancement) for Engineered Geothermal Systems (EGS) and reduce the risk associated with induced seismicity. It will lead to an immediate ***cost reduction increasing the output per well and extending reservoir operating life***.

Management technology: retrieve, simulate and monitor geothermally relevant reservoir parameters that influence the potential performance and long-term behavior. It includes the development of a **Zero-emission technology**, by mean of the total reinjection of fluid (and gases) within the reservoir without cooling and secondary effects.

It will secure the ***sustainable production*** achieved by using the correct production rates, taking into account the local resource characteristics (field size, natural recharge rate, etc.), extending the reservoir operating life and producing a benefit for the environment.

Research in Geothermal Energy

Unconventional Geothermal Systems (UGR) technology: emerging activities to harness energy from nowadays non-economic reservoir would make significant progress with qualified input from research. In particular, ***EGS***, reservoirs with ***supercritical fluids*** (fluids in the thermodynamic area above the critical temperature and pressure) and ***geopressurized reservoirs*** (deep sedimentary basins where fluids show high pressure and are rich of chemical elements or gases). This includes, beside peculiar power conversion and reservoir technology, also Operation & Maintenance techniques in aggressive geothermal environments, since they require specific solutions for corrosion and scaling problems. It will lead to an ***overall increase in power production***

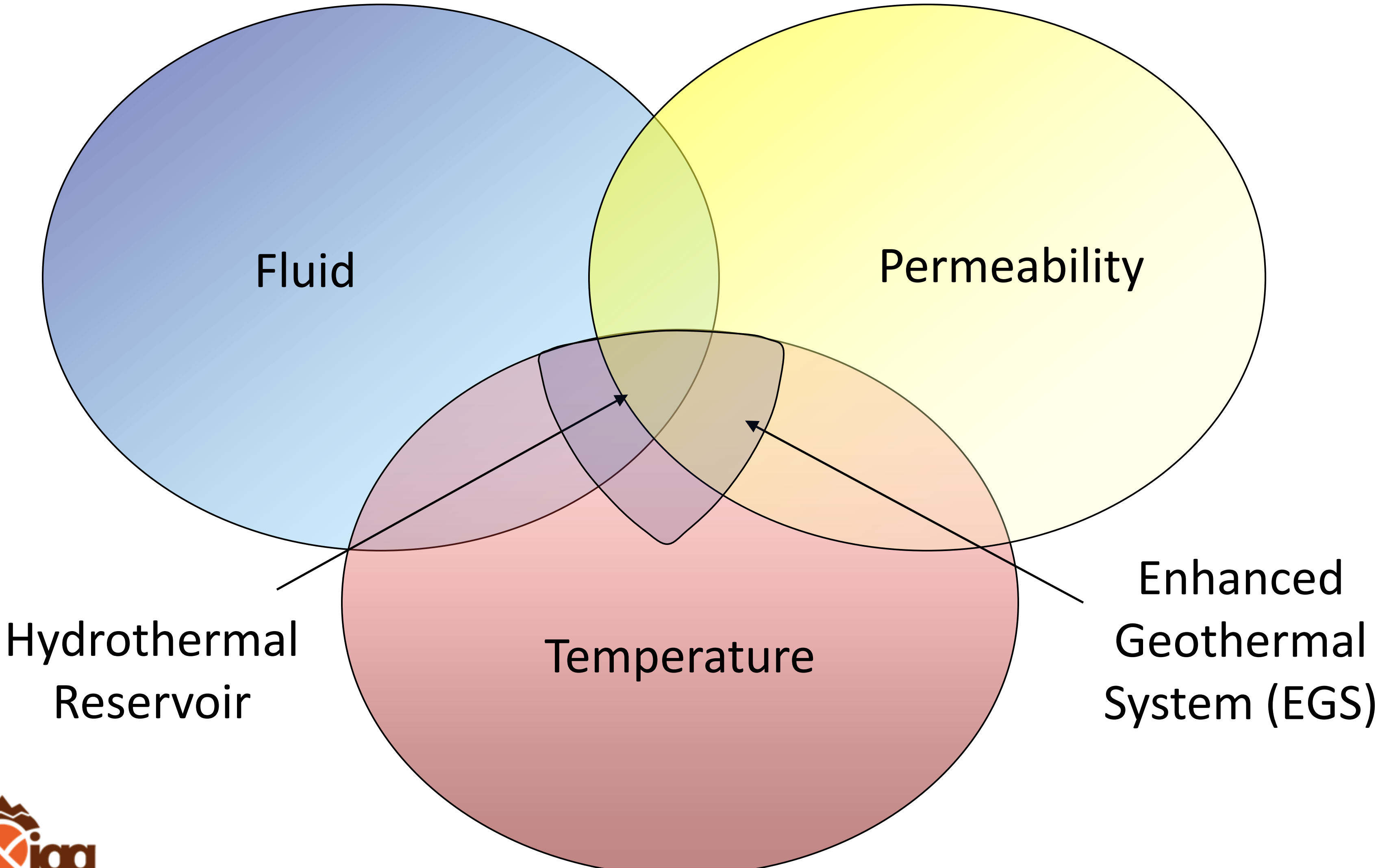
EGS Systems

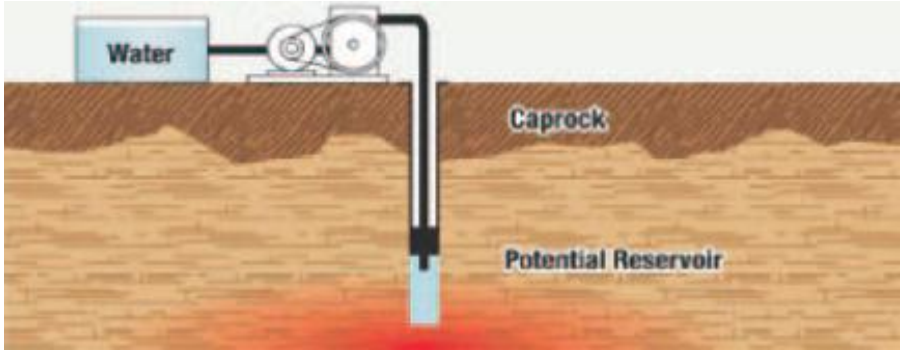
Originally Hot Dry Rocks (HDR), then Hot Wet Rocks (HFR), nowadays **Enhanced or Engineered Geothermal Systems**, these systems comprehend the development of geothermal systems where the natural flow capacity of the system is not sufficient to support adequate power production but where artificial fracturing of the system by chemical and/or hydraulic stimulation can allow production at a commercial level. The reservoirs are created to produce energy from geothermal resources that are otherwise not economical due to lack of water and/or permeability.

The term is rather confused, and sometime EGS is referred to unconventional geothermal systems.

Research in Geothermal Energy

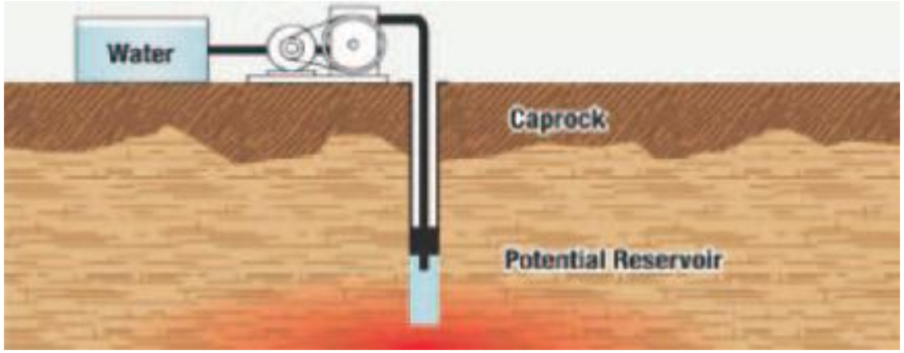
Target1: > fluid mass, > permeability

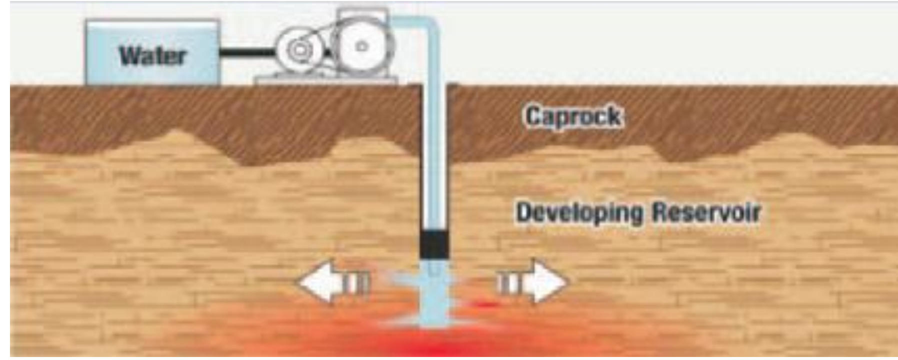




ebility rocks

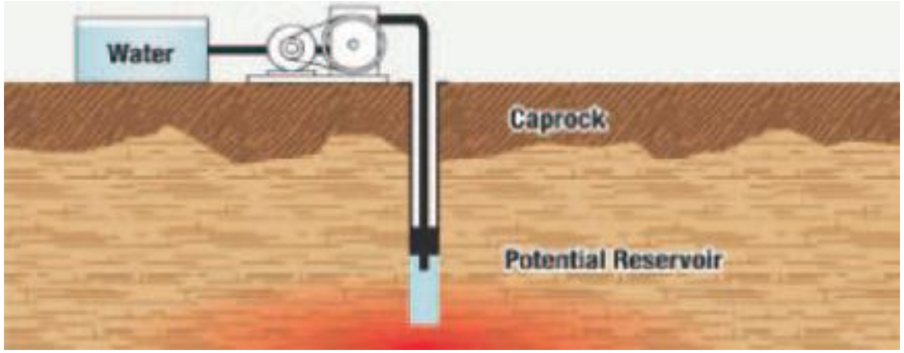
How it works

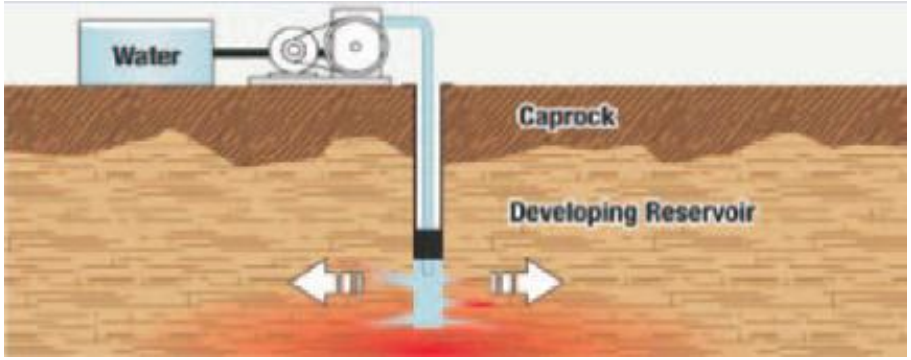




How it works

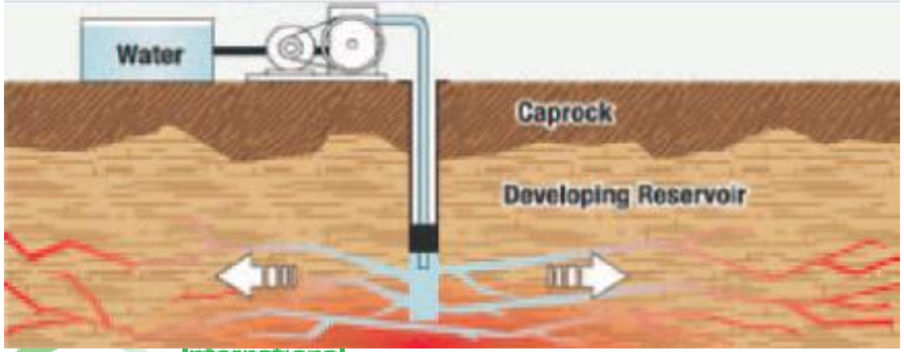
Water is injected at P able to fracture or expand existing fractures



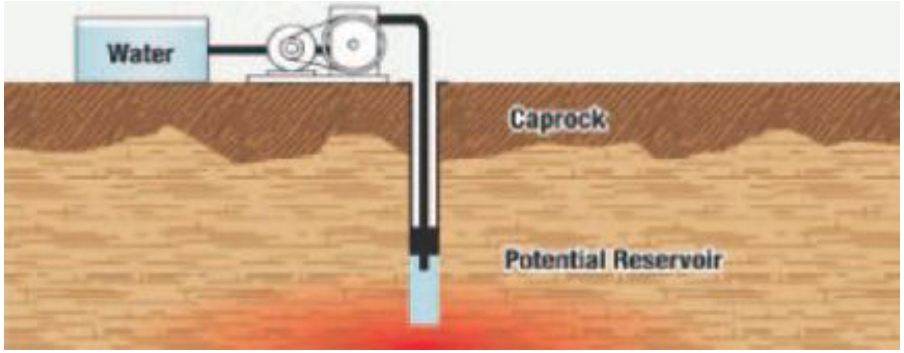


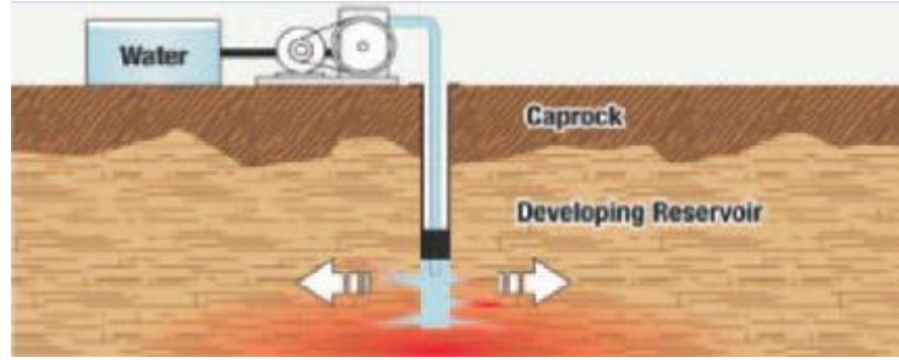
How it works

Hydrofracturing expand fractures



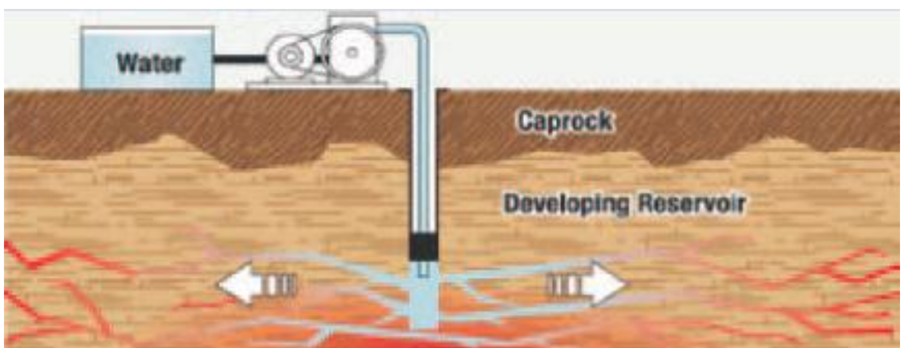
International Energy Agency

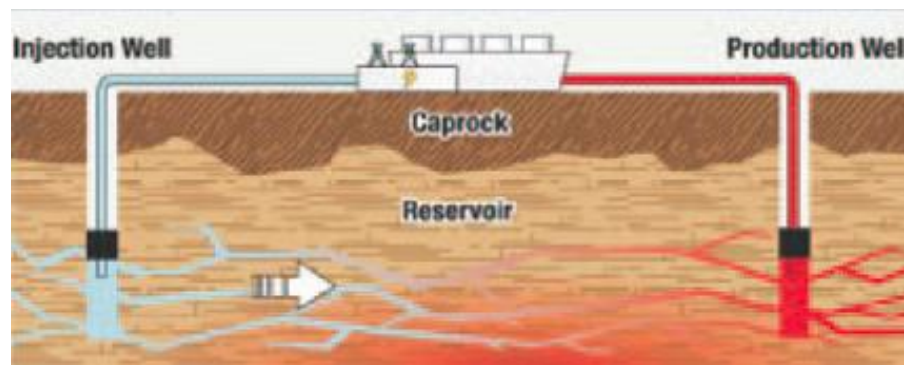




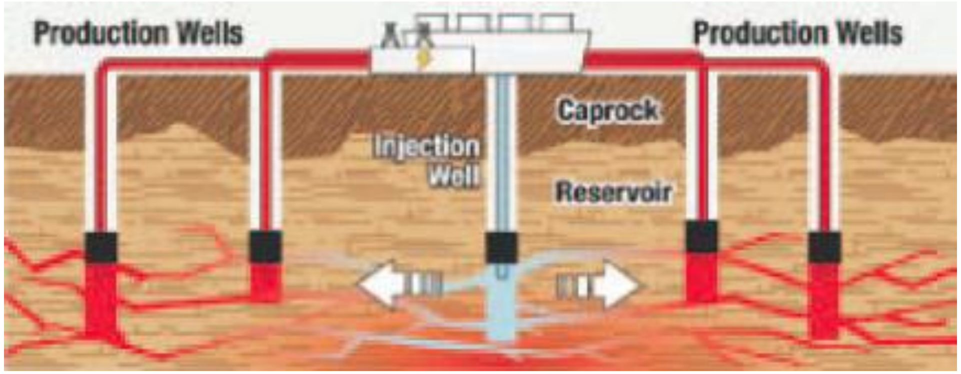
How it works

Through a **production well** fractures are intercepted and water is circulated and heated





iea International Energy Agency



Production by new wells and enhanced fracturation/circulation

Supercritical fluid Systems

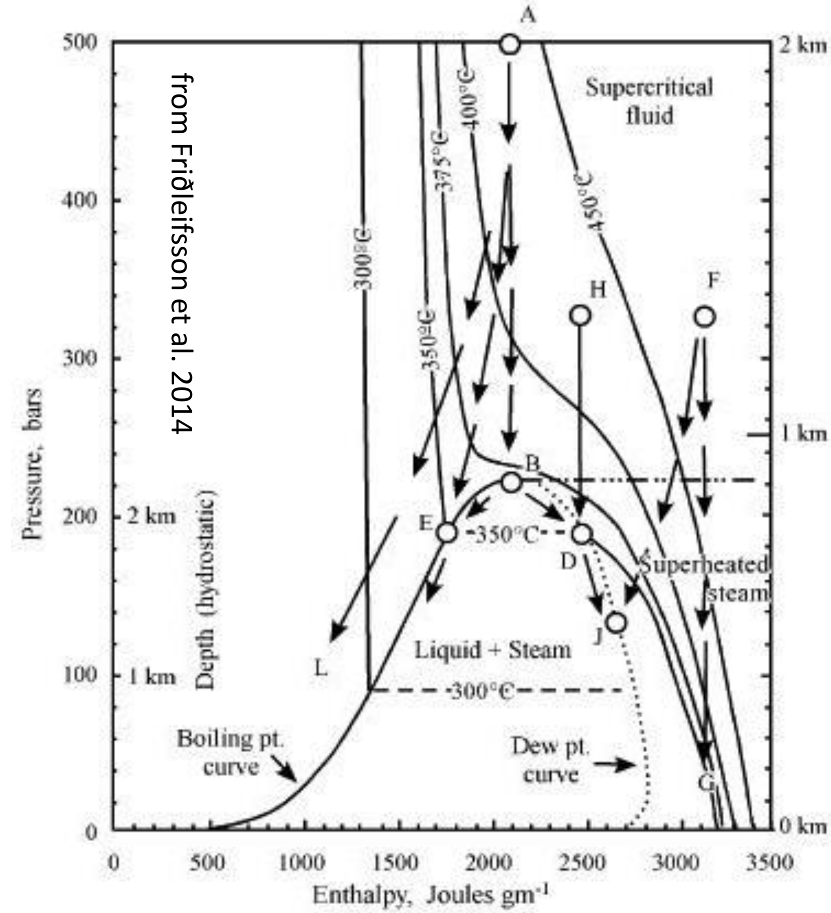
A fluid is called “super-critical” when temperatures and pressures are high enough (for pure water T>374°C and P>22 MPa) that there is **no longer any distinction between its liquid and vapour phases.**

Super-critical water occurs naturally in deep underground reservoirs close to magmatic intrusions, where minerals in aqueous solutions near or above the critical point have existed for millions of years.

Lab experiment (Hashida et al., 2001; Tsuchiya et al., 2001) proved that at about 25-50 Mpa and 400-600 °C, fluid circulation within unsealed fractures is possible in a granitic rock.

Supercritical fluid Systems

The basic idea of deep well development is to bring water-dominated super-critical fluid to the surface in such a way that it is directly transformed to superheated steam along an adiabatic decompression path.



from Friðleifsson et al. 2014

Supercritical fluid Systems

The enthalpy is one order of magnitude higher, per unit volume, than for a conventional hydrothermal fluid.

A deep well producing 2500 m^3/h of steam from a reservoir with a temperature significantly above 450° C **could yield enough high-enthalpy steam to generate 40-50 MW of electric power**.

This exceeds by a factor of ~10 the power typically obtained from conventional geothermal wells, implying that much more energy could be obtained from presently exploited high-temperature geothermal fields from a smaller number of wells.

Fluids are supposedly rich of F and Cl, and probably rich of other, possibly ecomically viable, materials and chemicals.

To be considered:

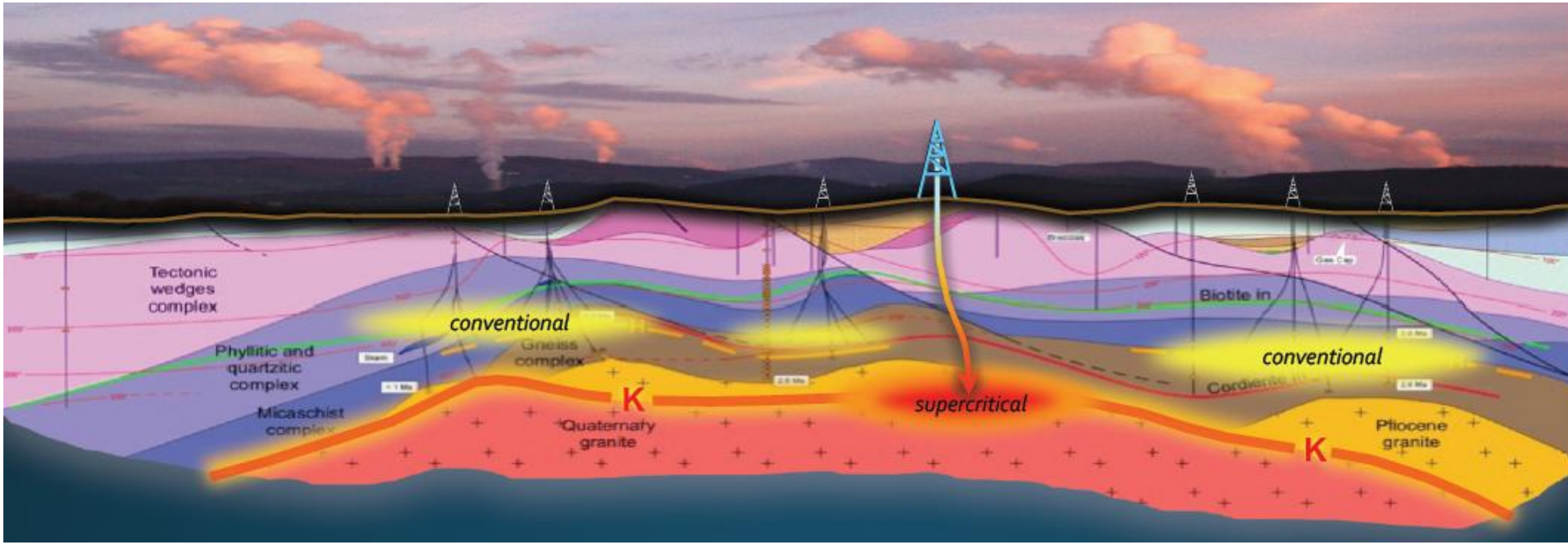
- electricity production
- heat production (e.g. by in-hole heat exchange)
- material production (lithium? metals? …)

Supercritical fluid Systems

A deep investigation. A consortium of Icelandic power companies and the Icelandic government in January drilled in Iceland a geothermal well that is 4.7 km deep—deep enough to reach fluids at supercritical conditions—at the Reykjanes geothermal field, which is a region characterized by high volcanic activity and submarine hot springs. *Courtesy: DEEPGS Geothermal*

DESCRAMBLE

Drilling in dEep Super-CRitical AMBient of continentaL Europe



Drilling down to a new frontier of the geothermal development:

the deep supercritical fluids In Larderello, Italy

DESCRAMBLE
Foreseen development

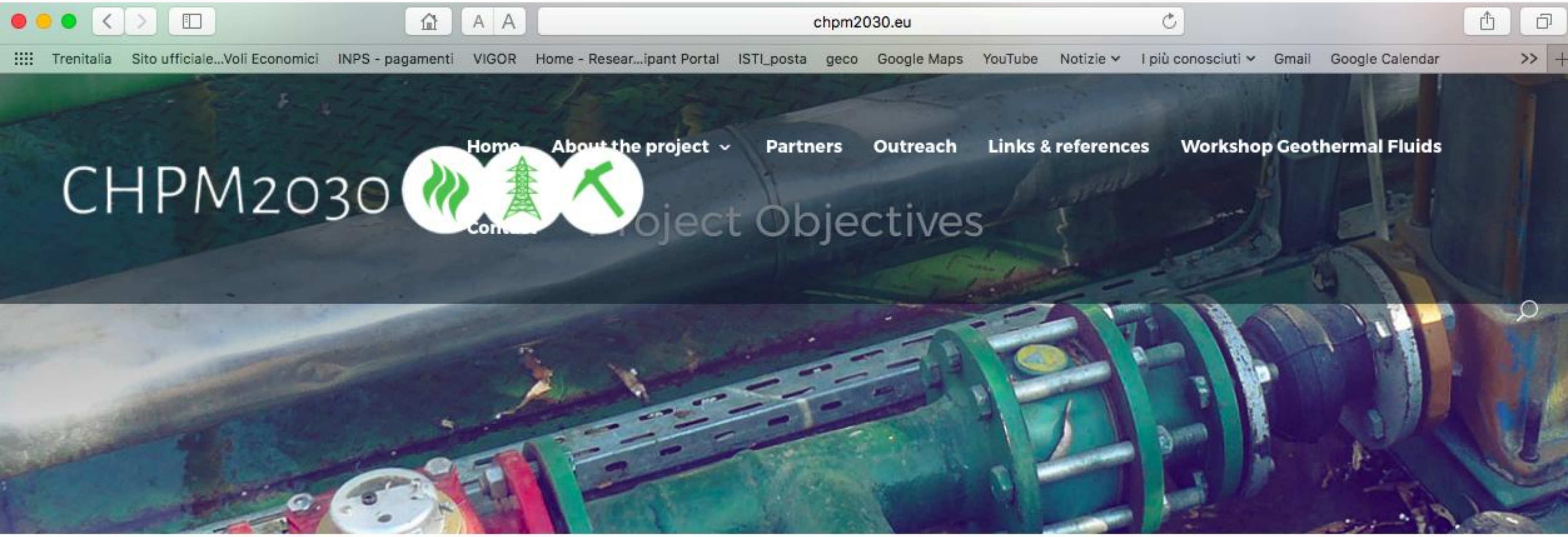
The DESCRAMBLE PROJECT is the first part of an innovation path in three phases:

• **PHASE I – R&D:** the activity partly financed by H2020 of deepening the Venelle_2 well, for testing new material and procedure for drilling and fluid handling in supercritical conditions (450°C and 250 bar);

• **PHASE II - PILOT:** in case of success of PHASE I, a Pilot Plant of 40 MW could be realized, fed by a two supercritical wells, with possibility of grants from EU (as follow up of DESCRAMBLE), MIUR and Tuscan Region;

• **PHASE III - Deployment:** after the R&D and Pilot phases, the supercritical plant could be replied in different locations in Italy and abroad, with a substantial cost reduction due to a learning curve effect.

Geothermal Co-production



"The strategic objective is to develop a novel and potentially disruptive technological solution"

The strategic objective of CHPM2030 is to develop a novel and potentially disruptive technological solution that can help satisfy the European needs for energy and strategic metals in a single interlinked process. In the CHPM technology vision the metal-bearing deep geological formation will be manipulated in a way that the co-production of energy and metals will be possible, and may be optimised according to the market demands.

European Technology

Deep Geothermal

& Innovation Platform

STRATEGIC TARGETS of the SET Plan - Declaration of intent

in the context of an Initiative for Global Leadership in Deep Geothermal Energy (adopted in September 2016)

1. Increase reservoir performance resulting in power demand of reservoir pumps to below 10% of gross energy generation and in sustainable yield predicted for at least 30 years by 2030.
2. Improve the overall conversion efficiency, including bottoming cycle, of geothermal installations at different thermodynamic conditions by 10% in 2030 and 20% in 2050;
3. Reduce production costs of geothermal energy (including from unconventional resources, EGS, and/or from hybrid solutions which couple geothermal with other renewable energy sources) below 10 €ct/kWhe for electricity and 5 €ct/kWhth for heat by 2025
4. Reduce the exploration costs by 25% in 2025, and by 50% in 2050 compared to 2015;
5. Reduce the unit cost of drilling (€/MWh) by 15% in 2020, 30% in 2030 and by 50% in 2050 compared to 2015;
6. Demonstrate the technical and economic feasibility of responding to commands from a grid operator, at any time, to increase or decrease output ramp up and down from 60% - 110% of nominal power.

Conclusions

Geothermal is a “cheap”, sustainable, clean, flexible and base load energy

… when we are lucky enough to produce it economically (T and fluid). Co-production of power, heat and materials will help

Geothermal is an energy known and used since the dawn of civilization

… but very few are aware of it

Geothermal energy still requires a lot of efforts in research, to optimize technology, to use new materials and to reduce the investment risk

Geothermal energy may provide an important contribution to energy efficiency in many processes (most of our energy consumption is for heating!)

Geothermal energy is very suitable for co-production, co-generation, hybrid systems. We need to test and prove it!