



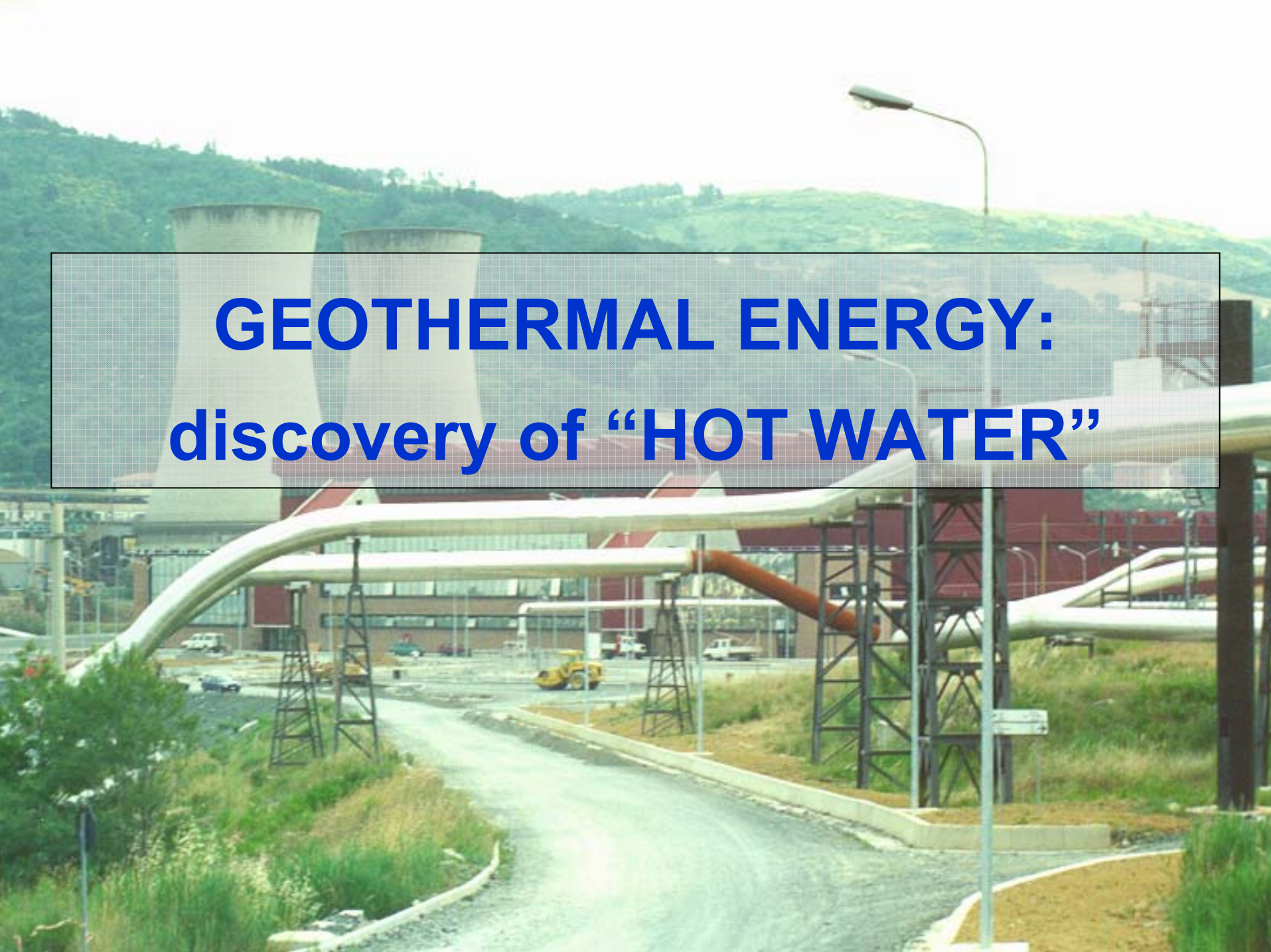
***Più sole,
più vento,
più acqua,
più terra.***

Geothermal Energy: From the Heart of the Earth

Ruggero Bertani

***Enel
Renewable Energy Division
Geothermal Department***

***International Geothermal
Association***

A photograph of a geothermal power plant. In the background, two large, white, cylindrical cooling towers stand against a backdrop of green, hilly terrain. In the foreground, a network of large, white pipes is supported by metal scaffolding. A dirt road or gravel path runs through the middle ground. A yellow construction vehicle is visible in the distance. The sky is overcast.

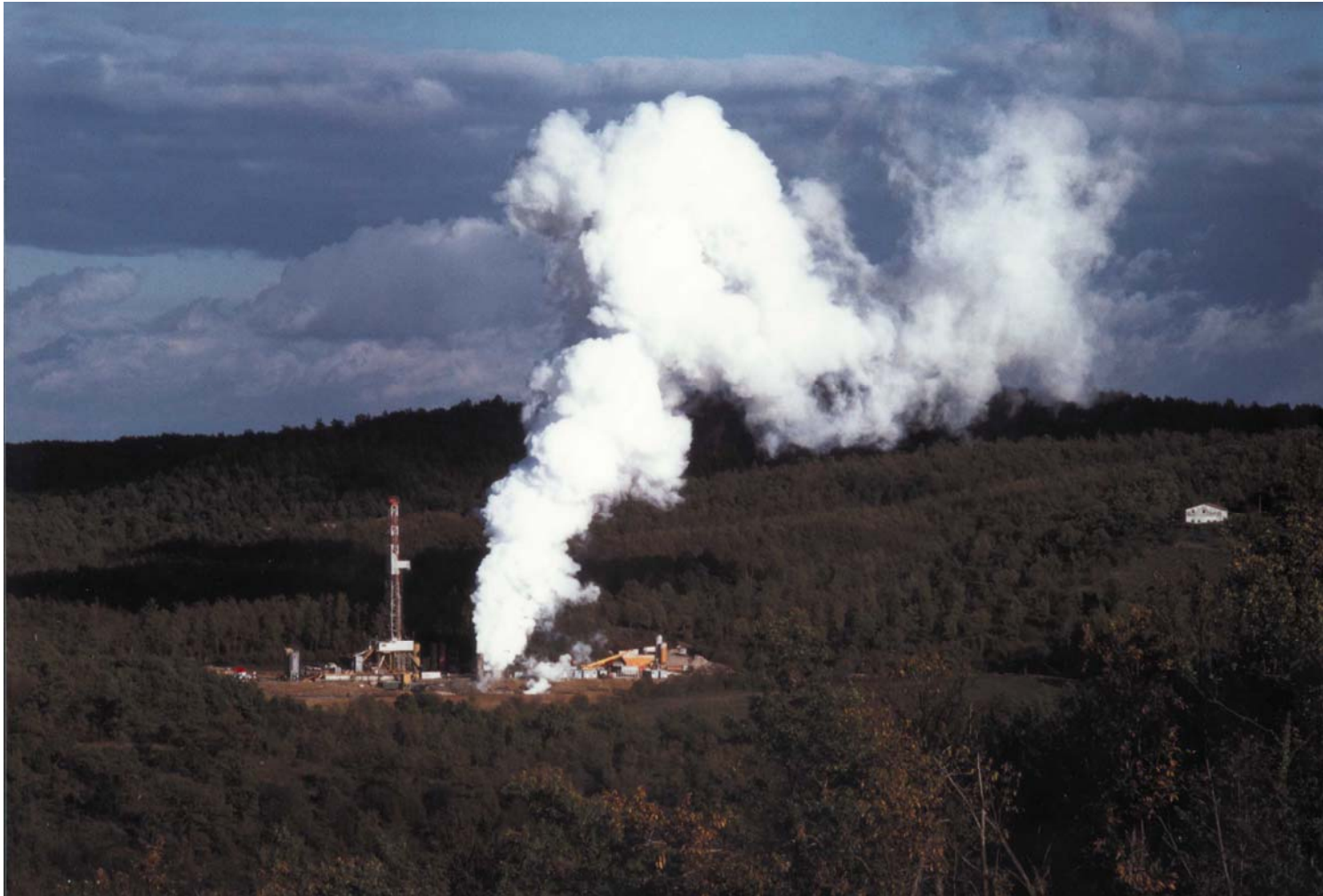
**GEO THERMAL ENERGY:
discovery of “HOT WATER”**

What is Geothermal Energy?

Heat is a form of energy and *geothermal energy* is literally the heat contained within the Earth that generates geological phenomena on a planetary scale.

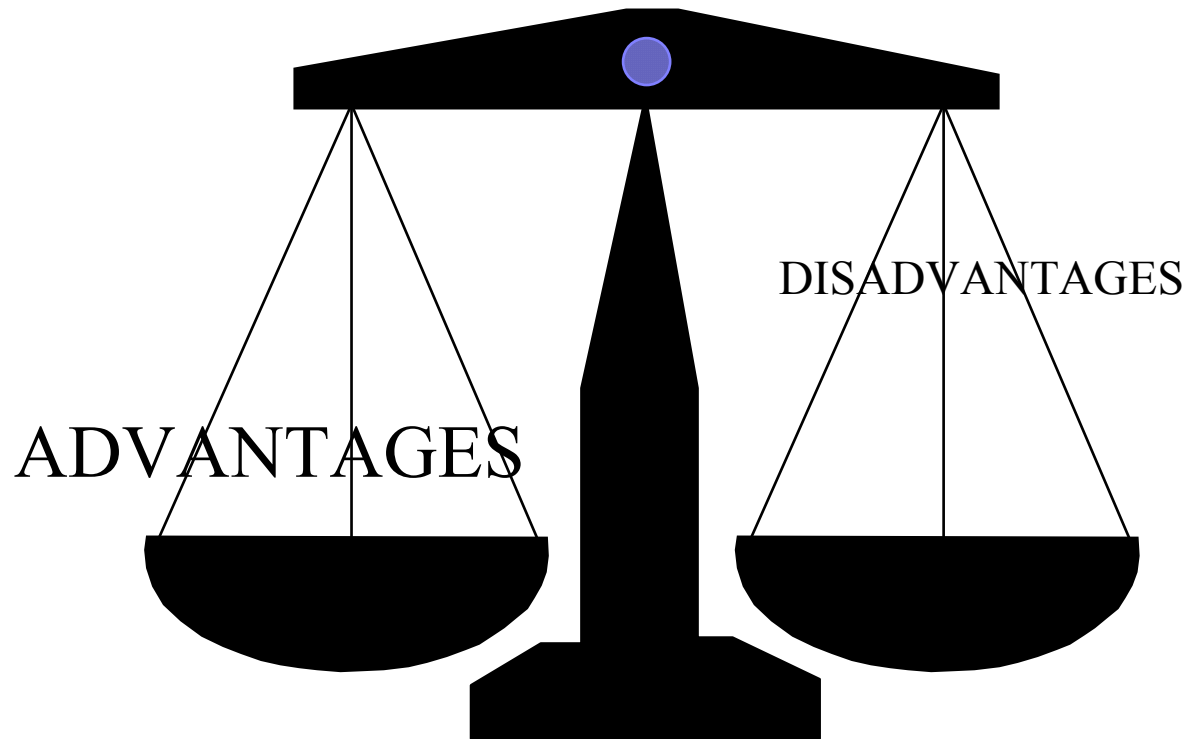
"Geothermal Energy" is often used to indicate **that part of the Earth's heat that can be recovered and exploited by man.**

What is Geothermal Energy?



Montieri 1 well: 30 MW, Italian Record

What is Geothermal Energy?



What is Geothermal Energy?

ADVANTAGES

Indigenous and Sustainable Resource

Environmentally Benign

Readily Available, Easily Tapped

Competitive Cost

Enormous Resource Base

High Availability, not bounded by external factors

Appropriate for Electricity Generation as Base Load Resource

Numerous Direct-Heat Utilization

What is Geothermal Energy?

ADVANTAGES

IT IS CLEAN

IT IS HOMEGROWN

IT IS SUSTAINABLE

IT IS CHEAP

What is Geothermal Energy?



“Geothermal herd” in New Zealand

Geothermal Exploitation: electricity



Blue Lagoon in Iceland

What is Geothermal Energy?

DISADVANTAGES

Electricity production, with present technology, is
bounded only to limited areas
where geological conditions are favorable

It requires **big initial investment**,
generally not accessible to small companies

It requires a **risky exploration phases**,
which can result as a no-profit activity
in case of negative results

What is Geothermal Energy?

Geothermal energy can change
the face of the world



Reykjavik in 1933, when only 3% of the houses used
geothermal energy for heating



Reykjavik today: "Europe's lung" for its low level of air
pollution, now that 99.8% of houses are connected to the
geothermal district heating system

Geothermal
Energy:

**FIRE
WITHOUT
SMOKE**

What is Geothermal Energy?

Earth's temperature is increasing with depth

A major source is the radiogenic heat,
generated by the decay of U^{238} , U^{235} , Th^{232} and K^{40}
which are present in the Earth's rocks

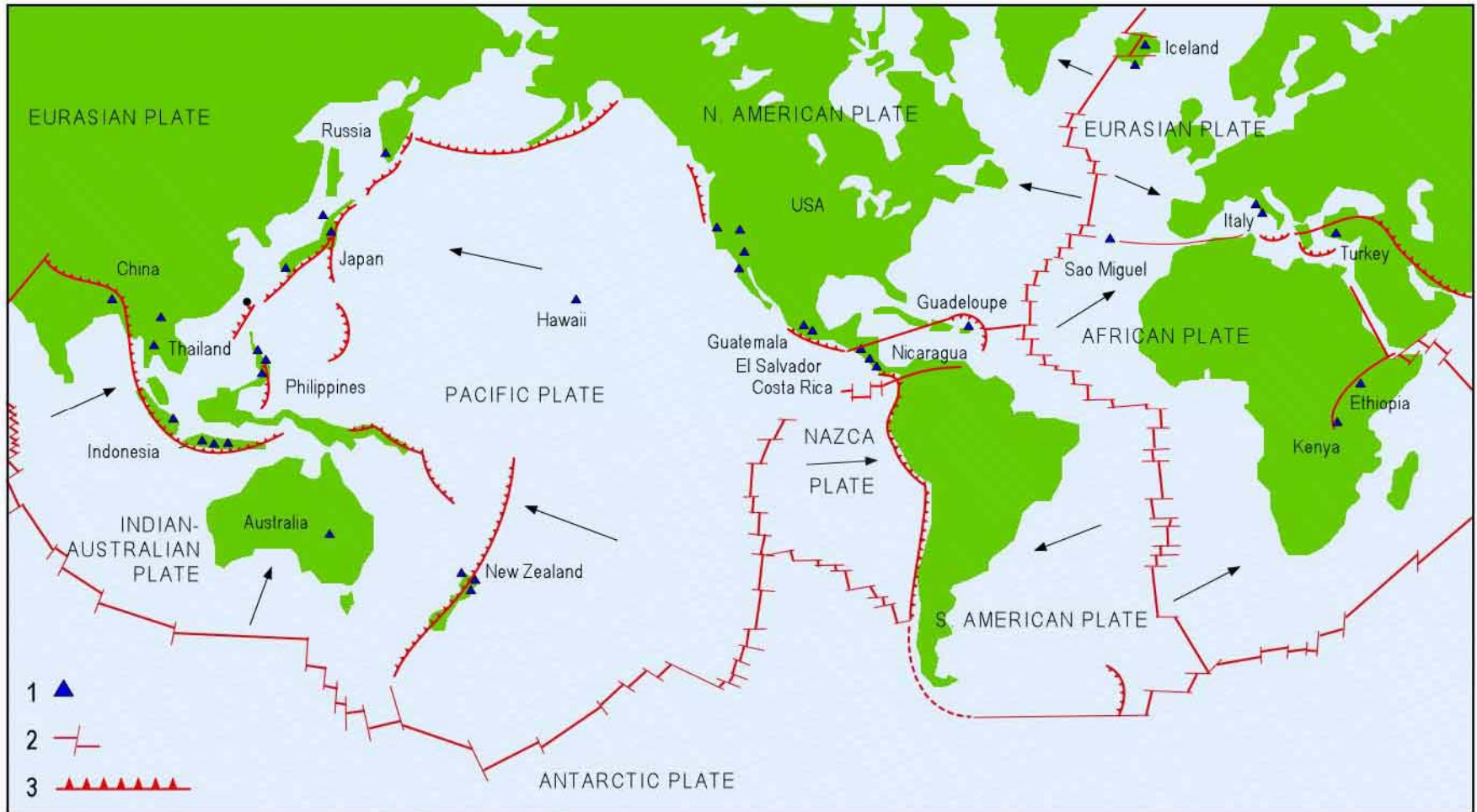
What is Geothermal Energy?

The vertical transport of heat through the surface of the Earth takes place through **three crustal processes:**

- Thermal conduction
- Advection of magma in the crust which is sometime associated with volcanic eruptions
- Advection of geothermal fluid

The heat loss is higher at plate boundaries than within the tectonic plates.

What is Geothermal Energy?



- (1) Geothermal fields producing electricity
- (2) Mid-oceanic ridges
- (3) Subduction zones.

What is Geothermal Energy?

Total heat content of the Earth in the
first 3 km depth below the continents is

43×10^{18} MJ

World energy consumption per year

42×10^{13} MJ

It can fulfill the world energy needs for 100,000 years

What is Geothermal Energy?

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

So far our utilization of this energy has been limited to areas in
which geological conditions permit
a **carrier** (water in the liquid phase or steam)
to "transfer" the heat from deep hot zones to or near the surface,
thus giving rise to geothermal resources.

What is Geothermal Energy?



Boiling lake – New Zealand

What is Geothermal Energy?



What is a *geothermal system* and what happens in such a system? It 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"**.

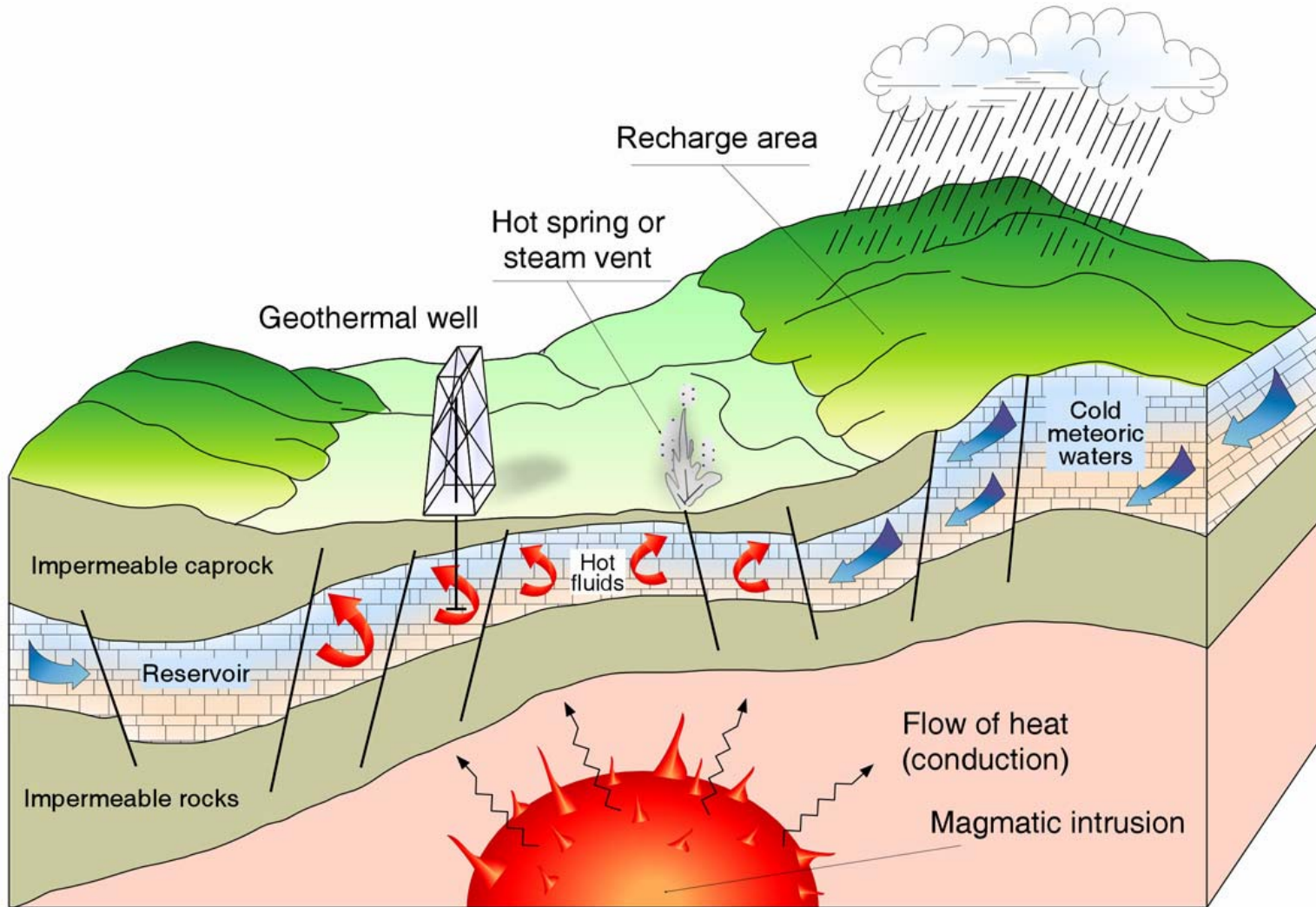
three main elements:

a *heat source*

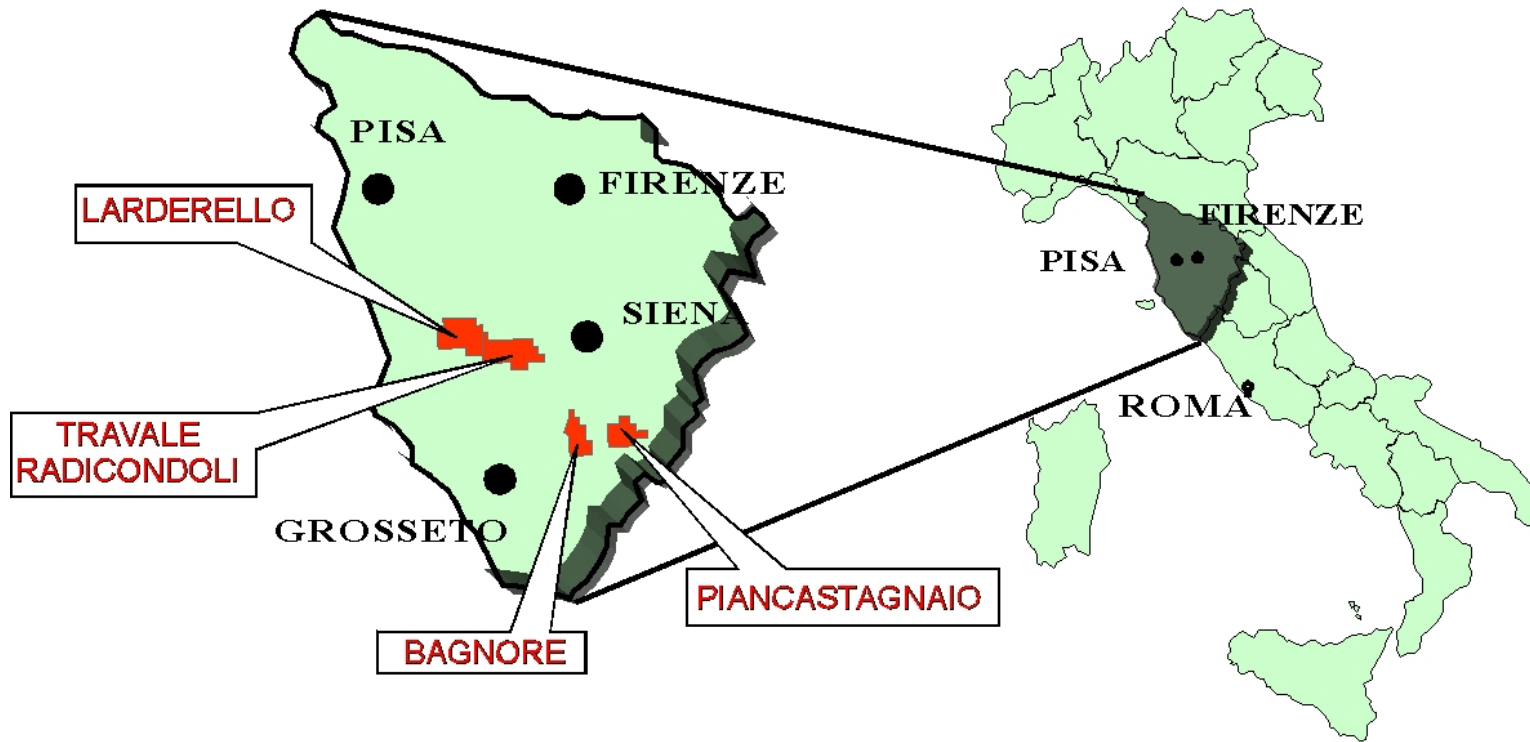
a *reservoir*

a *fluid*, which is the carrier that transfers the heat.

Geothermal System



Geothermal Exploitation



Location of Geothermal Fields in Italy

Geothermal Exploitation

In the 18th and 19th centuries the geothermal fluids were already being exploited for their energy content.

A chemical industry was set up in that period in Italy, in the zone now known as **Larderello**, to extract boric acid from the hot waters issuing naturally or from specially drilled shallow boreholes.

Between 1910 and 1940 the low pressure steam in this area of Tuscany was brought into use to heat the industrial and residential buildings and greenhouses.

Geothermal Exploitation

The first attempt at generating electricity from geothermal steam was made at Larderello in **1904**.

The success of this experiment indicated the industrial value of geothermal energy and marked the beginning of a form of exploitation that was to develop significantly from then on.

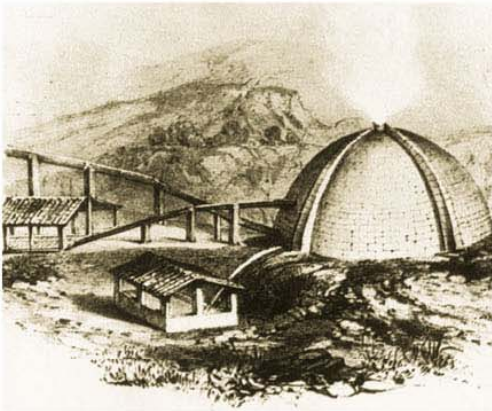
Electricity generation at Larderello was a commercial success.

By **1942** the installed geothermoelectric capacity had reached **130 MW**

Geothermal Exploitation

1775 - 1904

Chemical production



Covered lagoon



Old chemical factory

1904 - 1905

Start of geothermal power production
first experiments



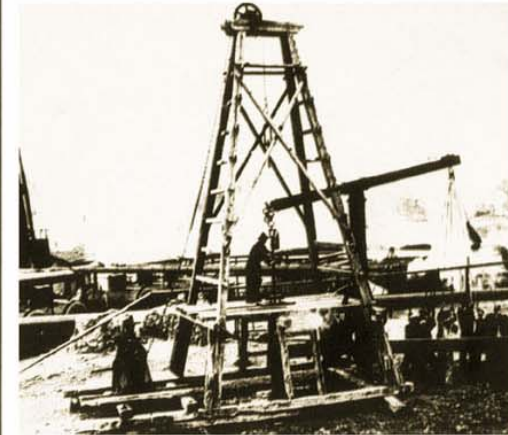
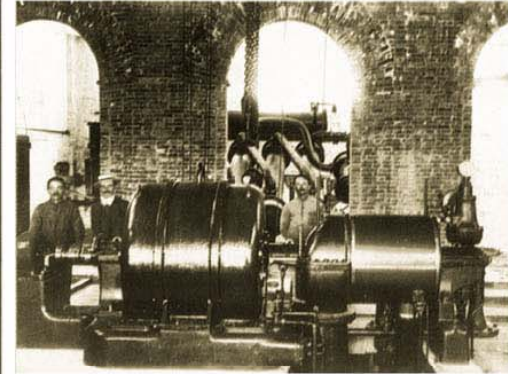
First experiments by P. Ginori Conti



Carriage mounted sampling laboratory

1913

First power plant (250kW.)



Historical pictures from Larderello.

Geothermal Exploitation

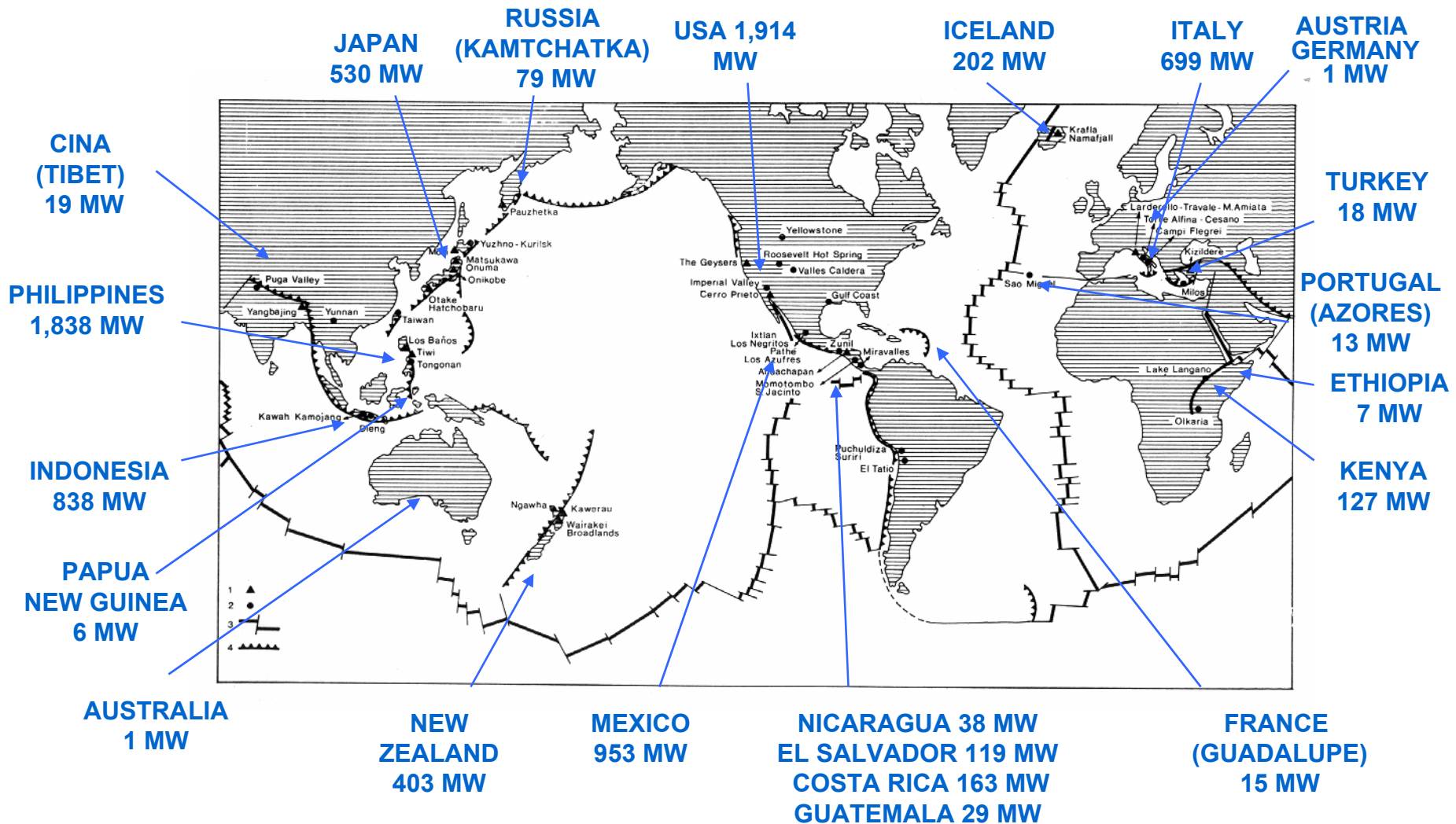
The example set by Italy was followed by several countries.

The first geothermal wells in **Japan** were drilled in **1919** and in the **USA** at The Geysers, California, in **1921**.

In 1928 **Iceland**, another pioneer in the utilization of geothermal energy, also began exploiting its geothermal fluids (mainly hot waters) for domestic heating.

In **1958** a small geothermal power plant began operating in **New Zealand**, in **1959** in **Mexico**, in **1960** in the **USA**, and in many other countries in the years to follow.

Geothermal Exploitation: World Electricity Production

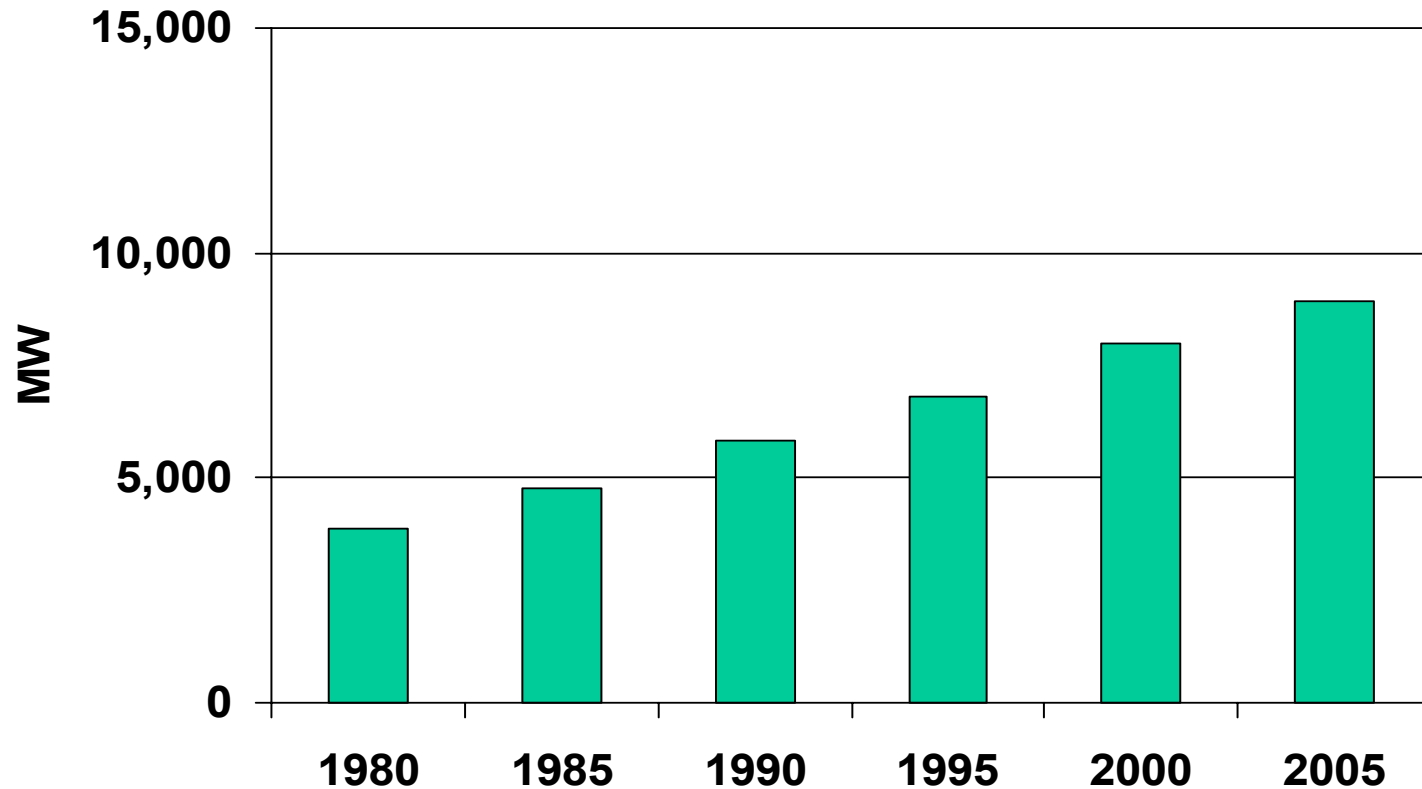


- Total Geothermal Installed Capacity: about 9,000 MW,
- Geothermal Electricity Production in 2004: 57,000 GWh



Geothermal Exploitation: Installed Capacity Trend

Growth of geothermal installed capacity



In the last 20 years the geothermal installed capacity in the world has been **increased by about 1,000 MW every 5 years.**

Geothermal Exploitation: Potential

It's difficult to estimate the overall world-wide potential, due to the presence of too many uncertainties.

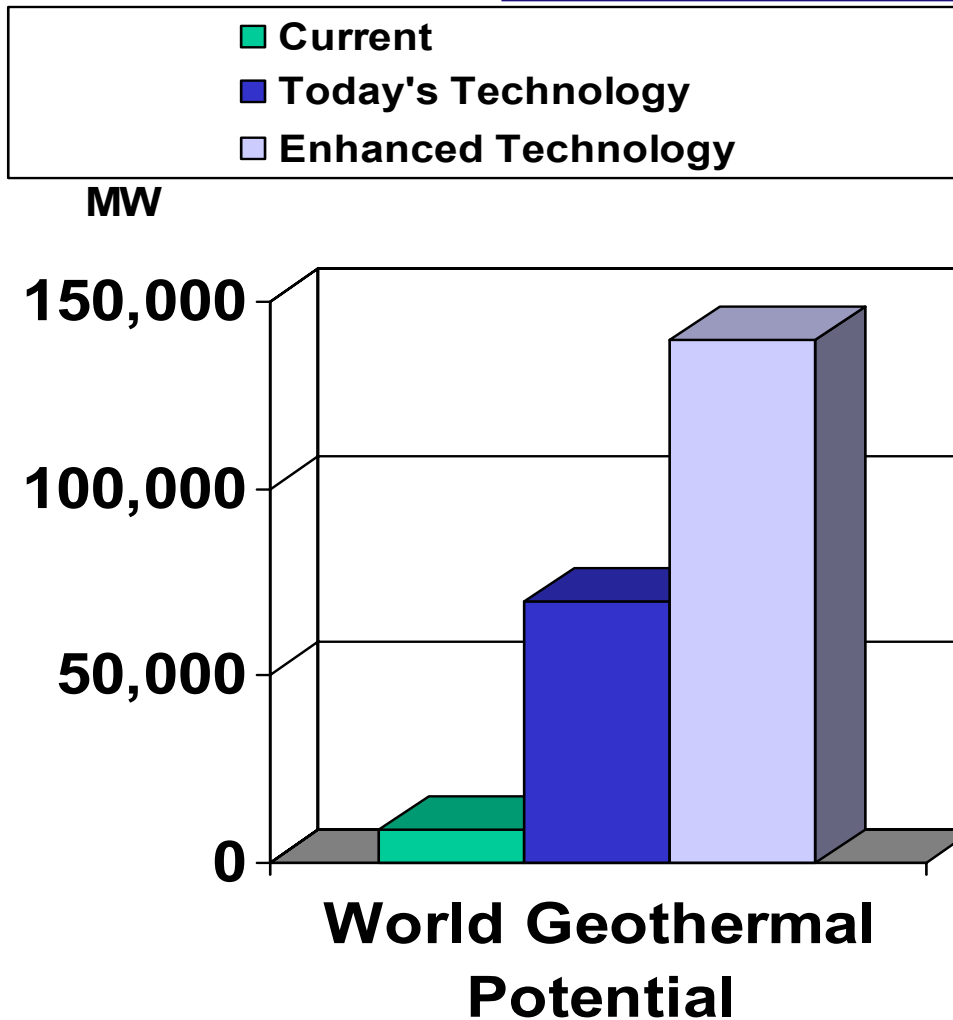
Nevertheless, it is possible to identify a range of estimations, taking into consideration also the possibility of new technologies

permeability enhancements,
drilling improvements,
hot dry rocks,
supercritical fluids,
low temperature electricity production,
improvement of exploration techniques.

Minimum: 35/70 GW

Maximum: 140 GW

Geothermal Exploitation: Potential

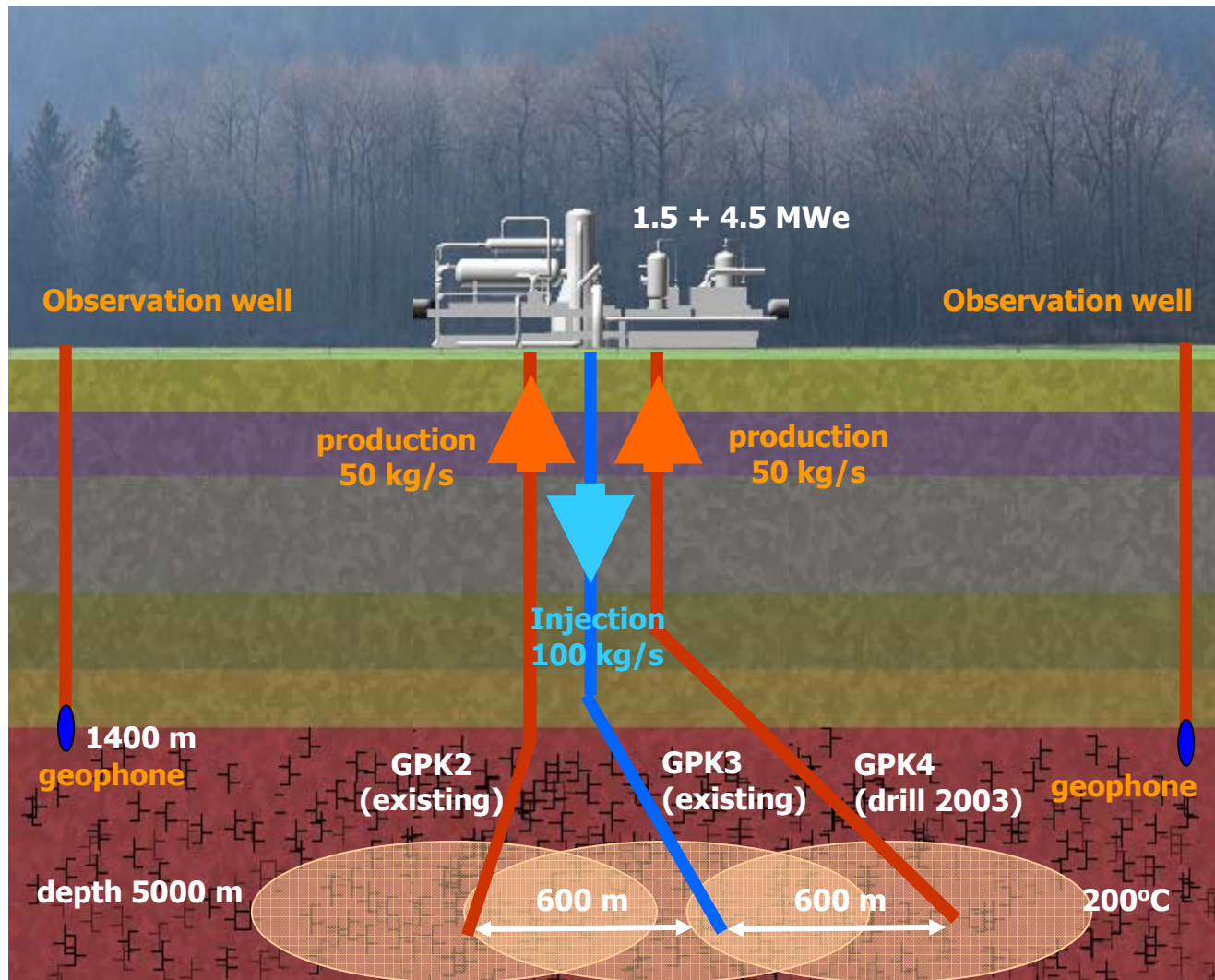


It is possible to produce up to **8.3%** of total world electricity production, serving **17%** of world population.

40 countries (located mostly in Africa, Central/South America, Pacific Ring) can be

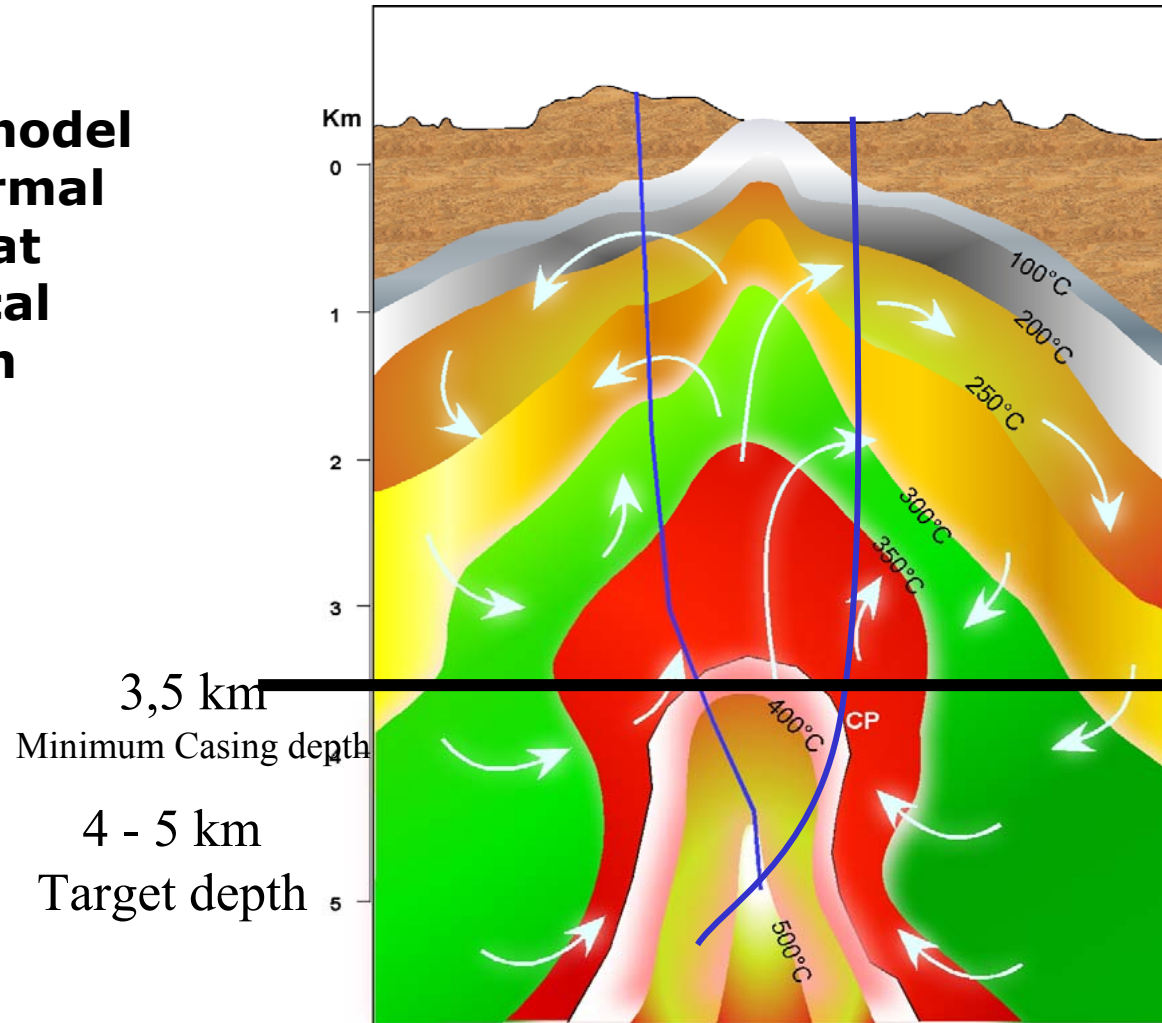
100% geothermal powered.

European HDR Project at Soultz

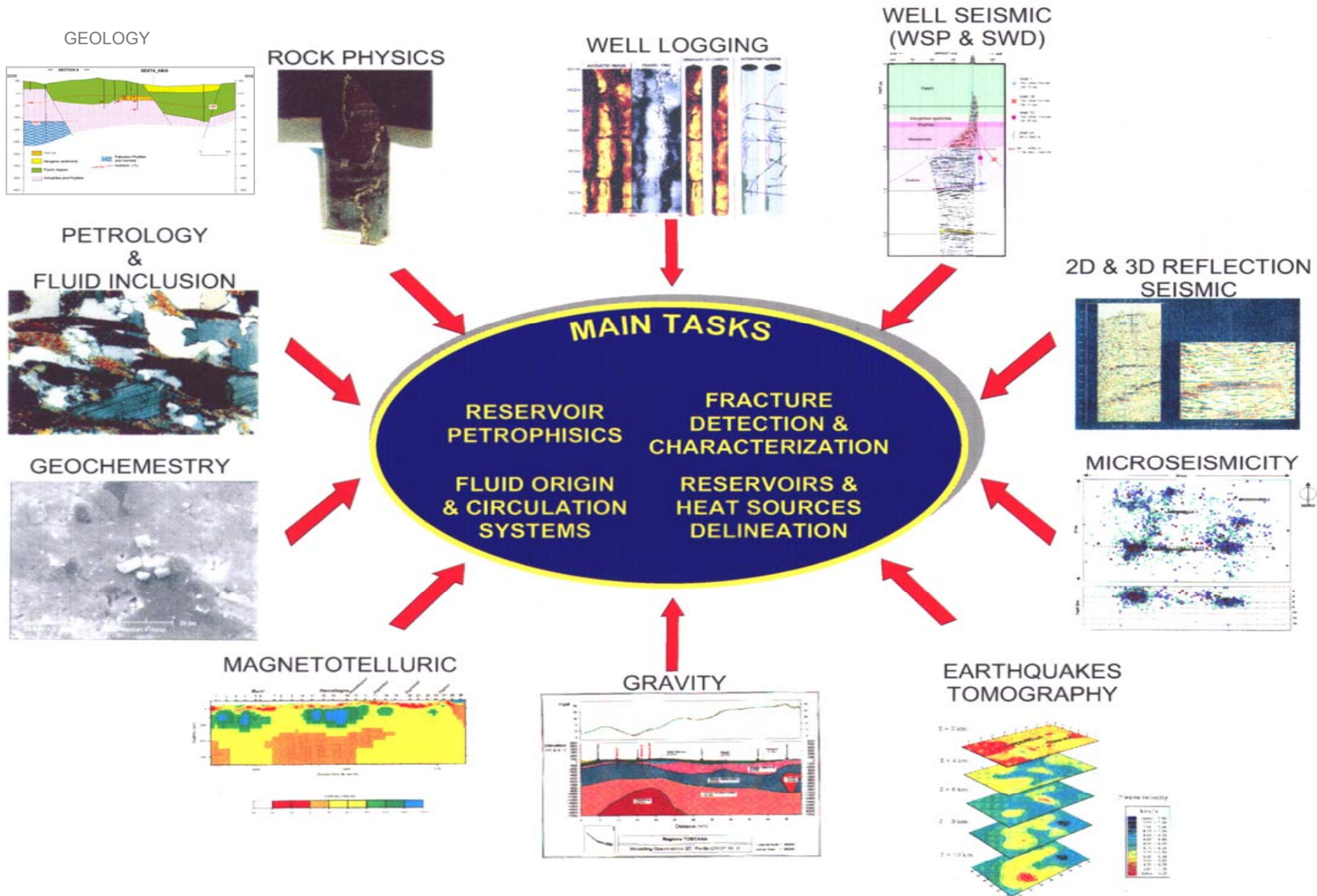


Icelandic Deep Drilling Project

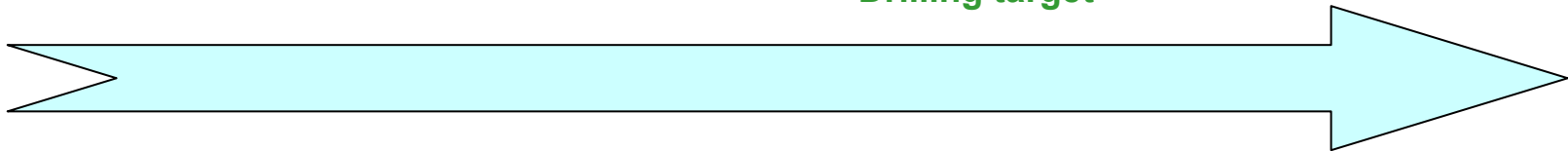
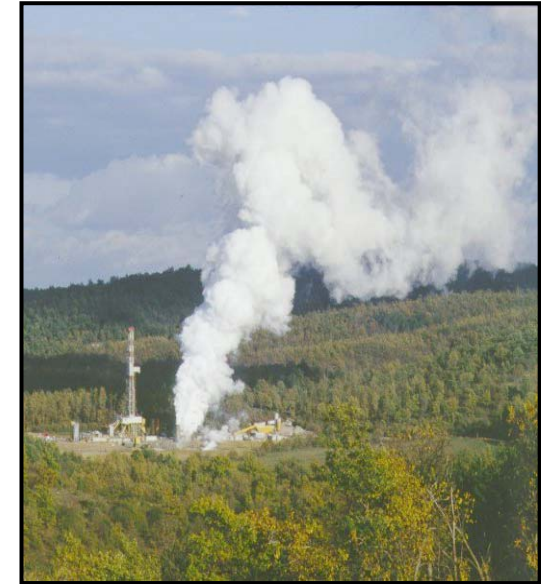
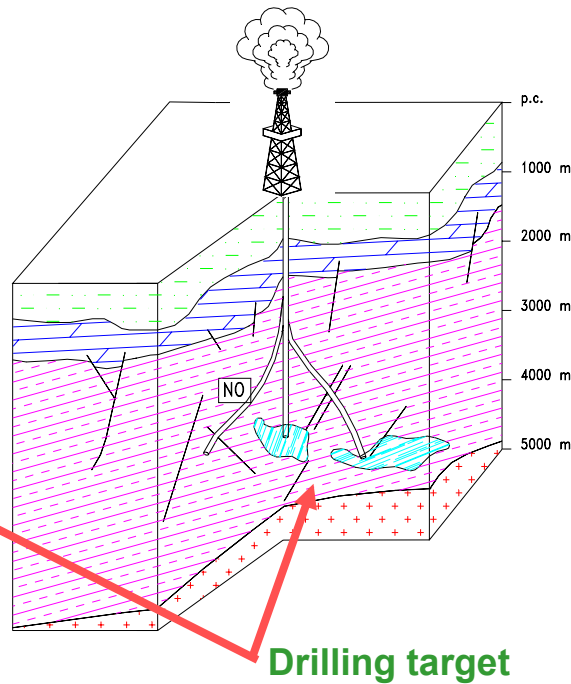
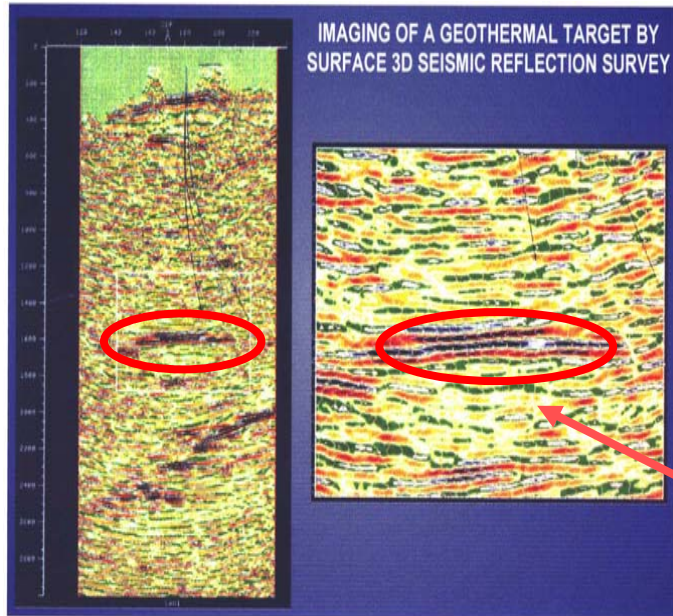
**Conceptual model
of a geothermal
reservoir at
supercritical
condition**



Geothermal Exploration



Geothermal Exploration



Advanced exploration technology
Better delineation of deep reservoir
Better definition of drilling targets

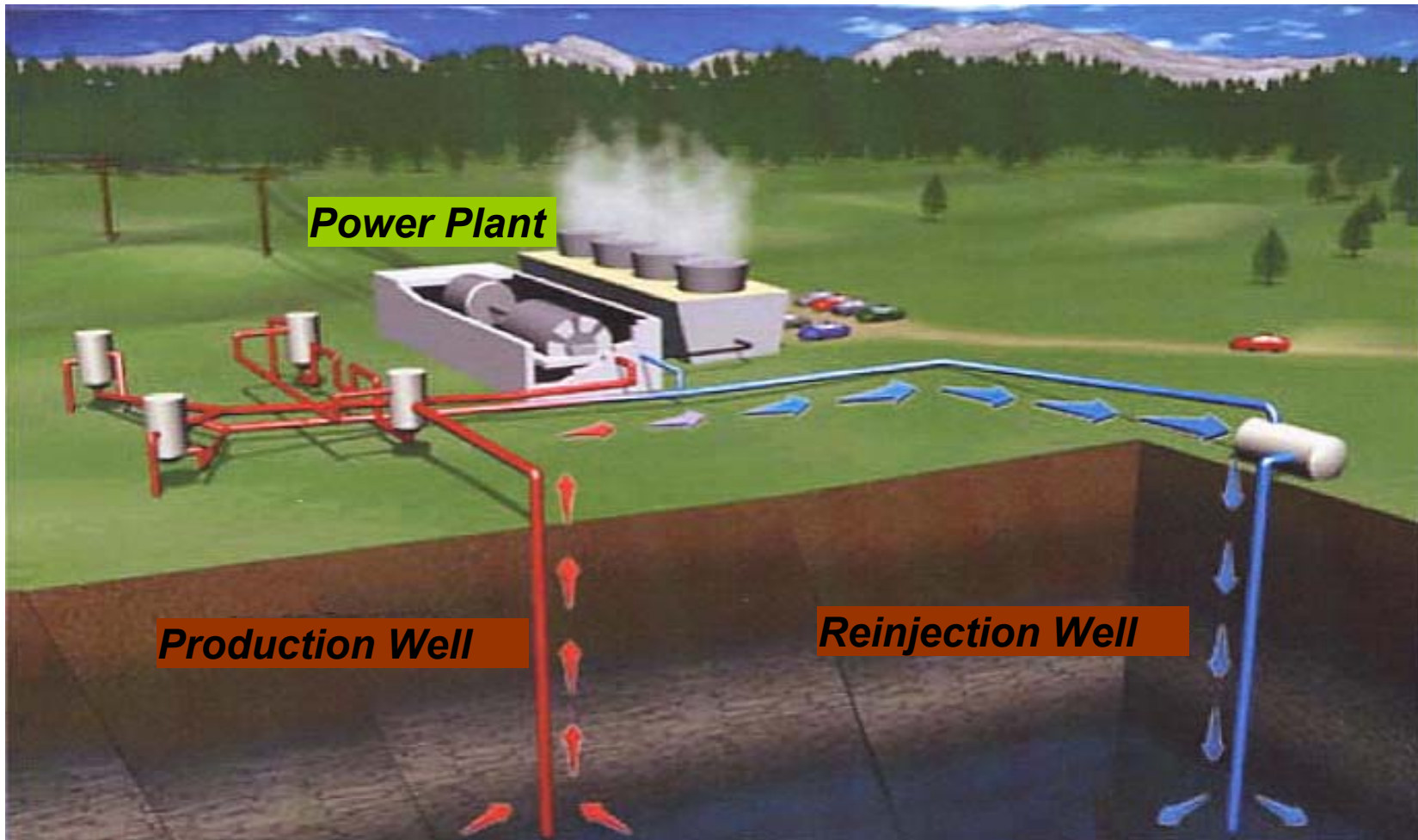
Drilling technology upgrading
forked wells to hit the target
shorter rig time & environmental impact

Payback
more production
lower cost



Continuous technologies improvement

Geothermal Exploitation: Electricity



Geothermal Exploitation: Electricity

There is a
“pot of gold”
at the
end of the
rainbow
-
USA



Geothermal Cost

	Capacity factor %	Current energy cost US¢/kWh	Potential future energy cost US¢/kWh	Turnkey investment cost US\$/kW	Increase in inst. capac. last 5 years %/year
Hydro	20-70	2-10	2-8	1,000-4,000	2
Biomass	25-80	5-15	4-10	900-3,000	3
Geothermal	45-90	2-10	1-8	800-3,000	4
Wind	20-30	5-13	3-10	1,100-1,700	30
(photovoltaic) Solar (thermal electricity)	8-20 20-35	25-125 12-18	5-25 4-10	5,000-10,000 3,000-4,000	30 5
Tidal	20-30	8-15	8-15	1,700-2,500	0

Comparison from different Renewable Energies Costs

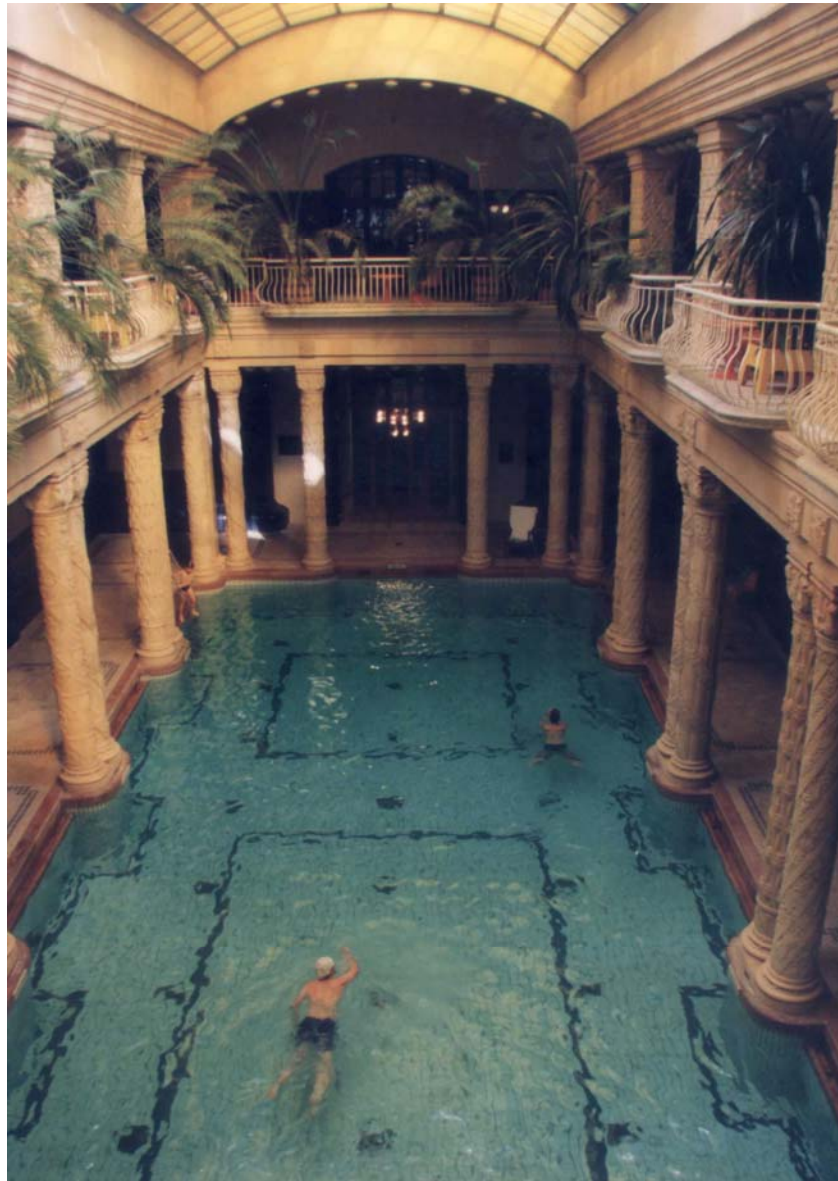
Geothermal Exploitation: Direct Uses

Direct heat use is one of the oldest, most versatile and also the most common form of utilization of geothermal energy.

SPA and bathing,
agricultural/greenhouses/ aquaculture applications,
space and district heating,
other industrial uses

Are the best known and most widespread forms of utilization, but other forms are already in use or in the late planning stages.

Geothermal Exploitation: Direct Uses



Gellert Hotel
geothermal pool
-
Hungary

Geothermal Exploitation: Direct Uses



Fujinoi Hotel spa - Japan

Geothermal Exploitation: Direct Uses



Prawn Farm
-
New Zealand

Geothermal Exploitation: Direct Uses



Alligator farm - USA

Geothermal Exploitation: Direct Uses



Geothermal greenhouse – New Zealand

Geothermal Exploitation: Direct Uses



Geothermal
greenhouse

—

Italy

Geothermal Exploitation: Direct Uses



Reykjavik
District Heating
-
Iceland



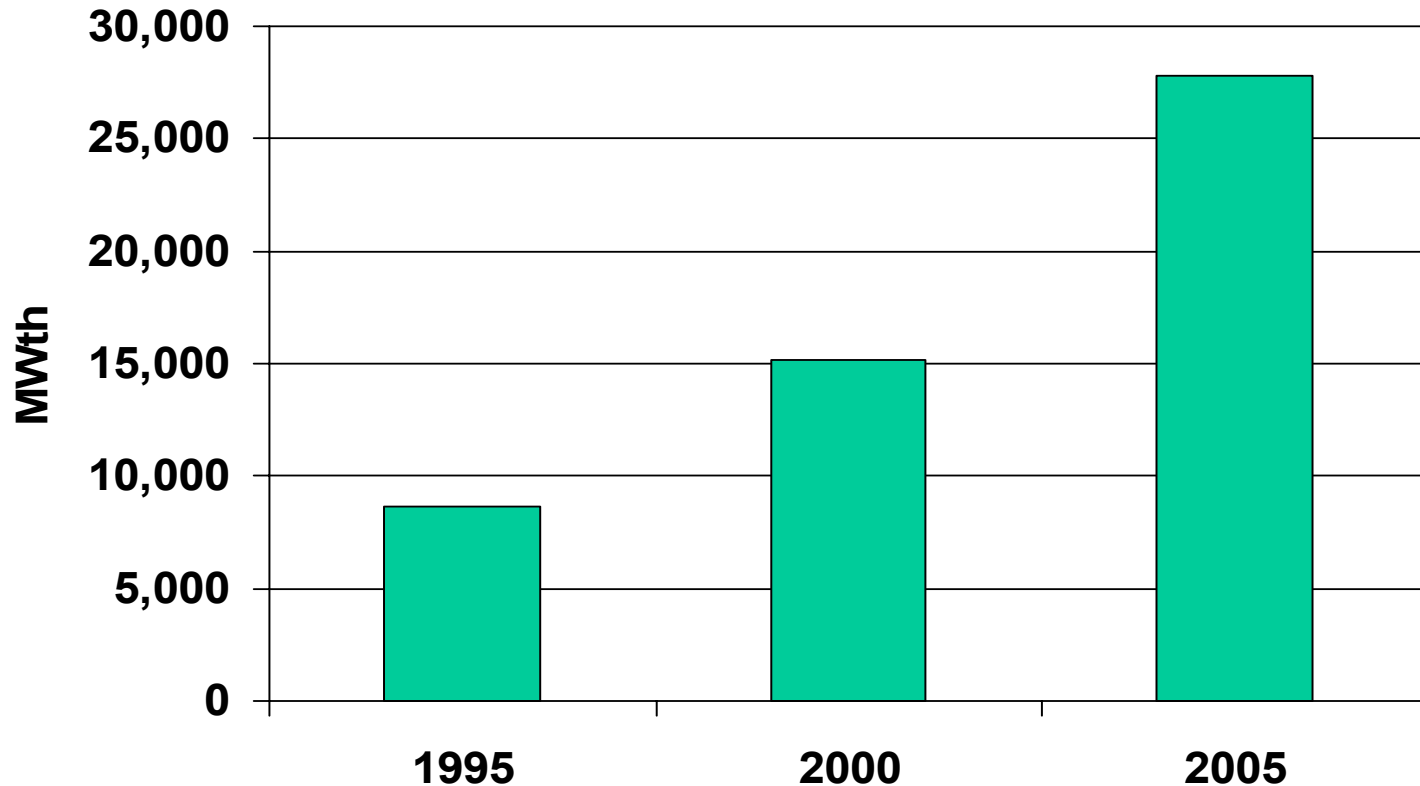
Geothermal Exploitation: Direct Uses



Castelnuovo
District Heating
-
Italy

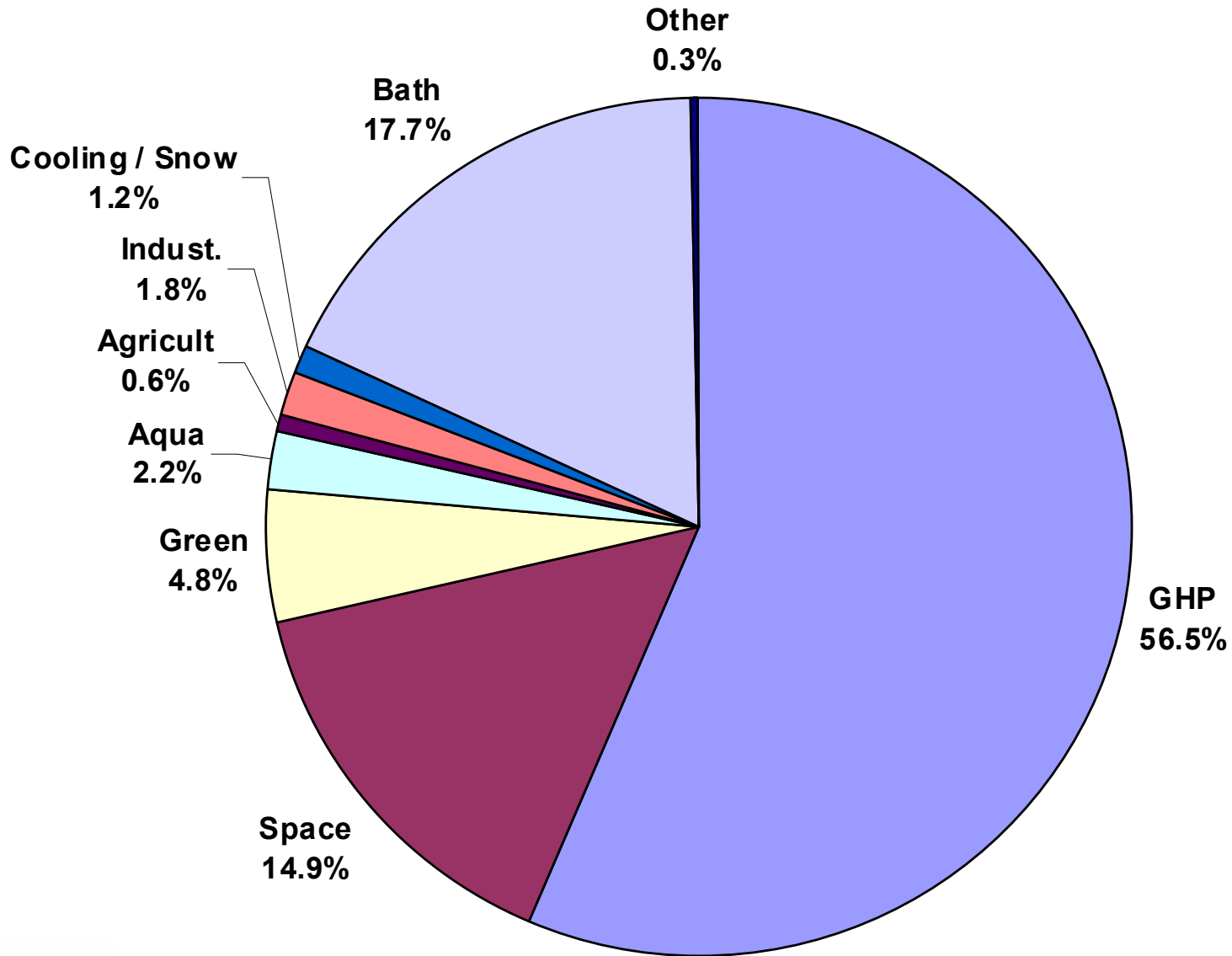
Geothermal Exploitation: Direct Uses

Growth of geothermal Direct Utilizations



In the last 10 years the geothermal installed capacity in the world has been increased by two times every 5 years.

Geothermal Exploitation: Direct Uses



Geothermal energy has established itself as a source of
reliable and environmentally responsible power.

Its installed capacity is equivalent to 9 nuclear plants, with
no atmospheric emissions nor hazardous wastes.

- **High Availability and Load Factors,**
- **No Dependence on sunlight and weather,**
- **Huge Resource Bases.**

Geothermal Energy is

a key resource in a sustainable energy future

Right now, some 30 to 40 million people worldwide derive their electricity from geothermal resources.

This number could be increased by a factor of 10 or 20 just using today's basic technology, or technology we can reasonably expect to develop over the next 20 years.

Think of this

800 million people deriving their energy needs from clean, reliable geothermal resources.

This is the promise of geothermal energy

THANKS FOR YOUR ATTENTION

