Geothermal Energy:
New Challenges and opportunities

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Geothermal Energy is Renewable

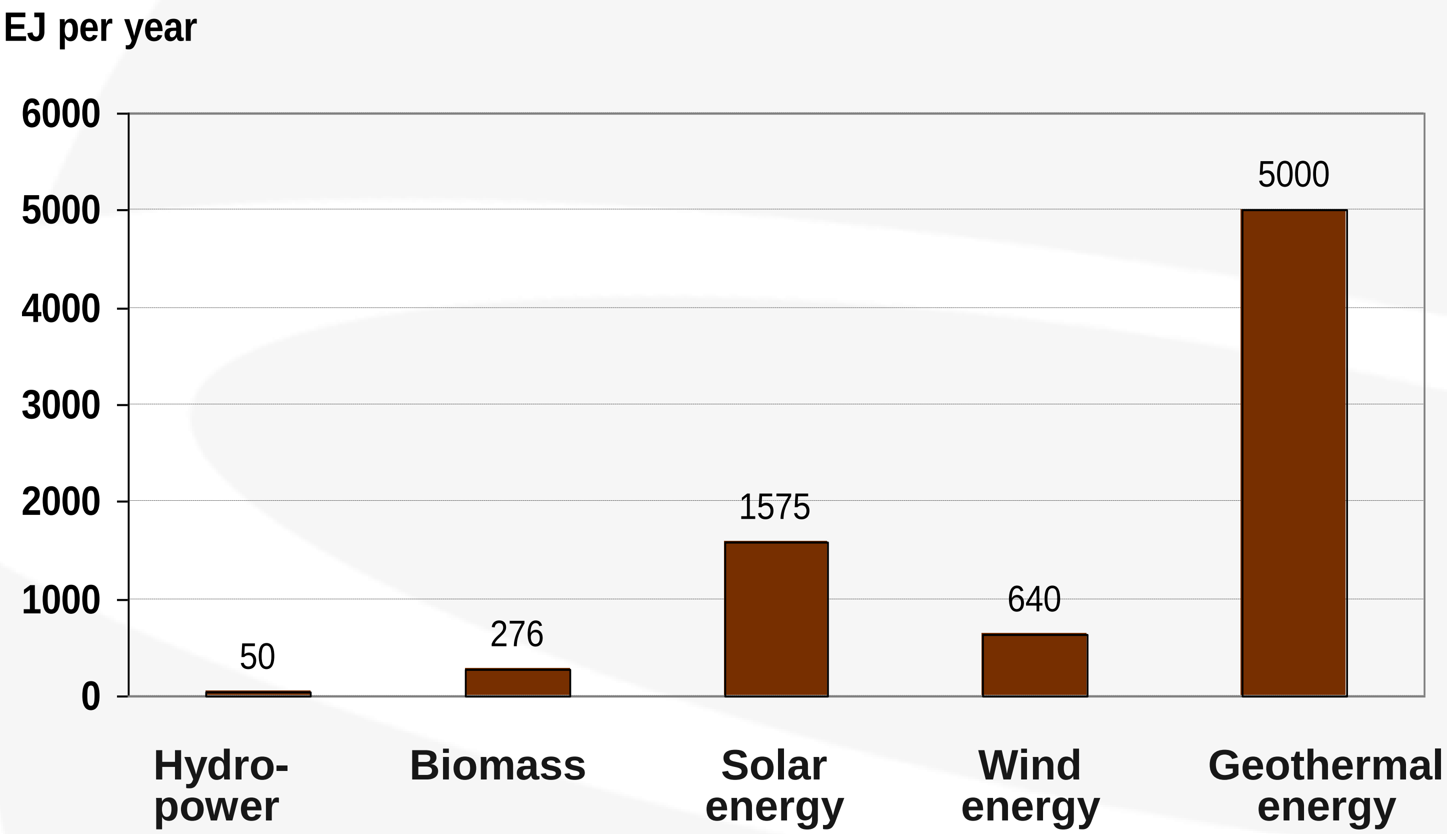
From the RES directive of the EU, 2009/28/EG:

Energy from renewable sources' means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases;

'Geothermal energy' means energy stored in the form of heat beneath the surface of solid earth;

'hydrothermal energy' means energy stored in the form of heat in surface water;

Worldwide technical potential of renewable energy sources (EJ per year)



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World Energy Assessment 2000

The heat stored in the Earth´s crust

The geothermal energy resource is huge

but we have technical problems to harness it.

Classification of geothermal energy

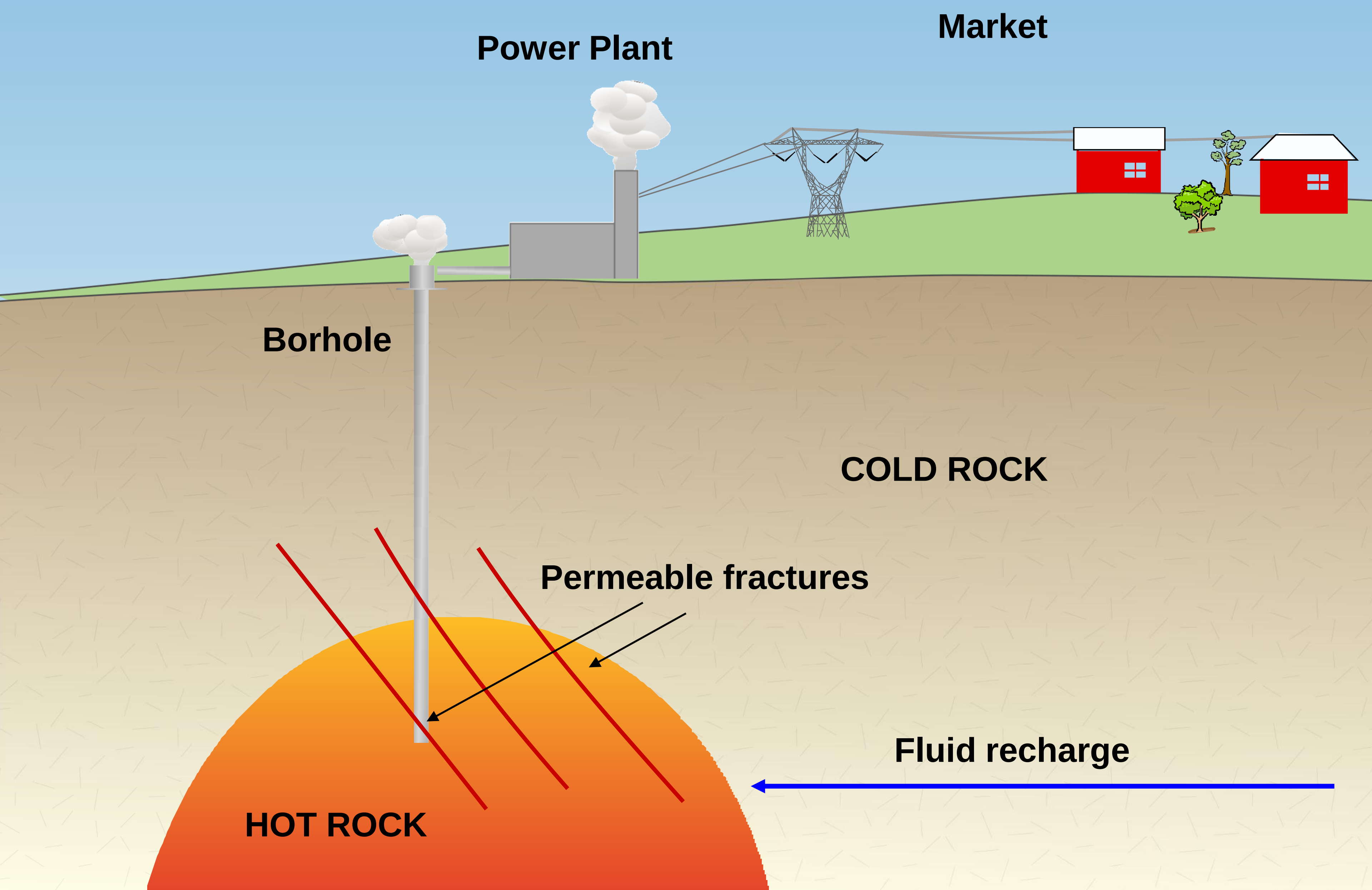
Three main types of geothermal fields for electricity production:

- High temperature fields (T > 200°C at 1 km depth)
- Medium temperature fields (100 <T <200°C at 1 km depth)
- Low temperature fields (T < 100°C at 1 km depth)

We distinguish between:

- Conventional geothermal systems
- Unconventional geothermal systems

Conventional geothermal system



Almost all geothermal power plants in the world today are conventional

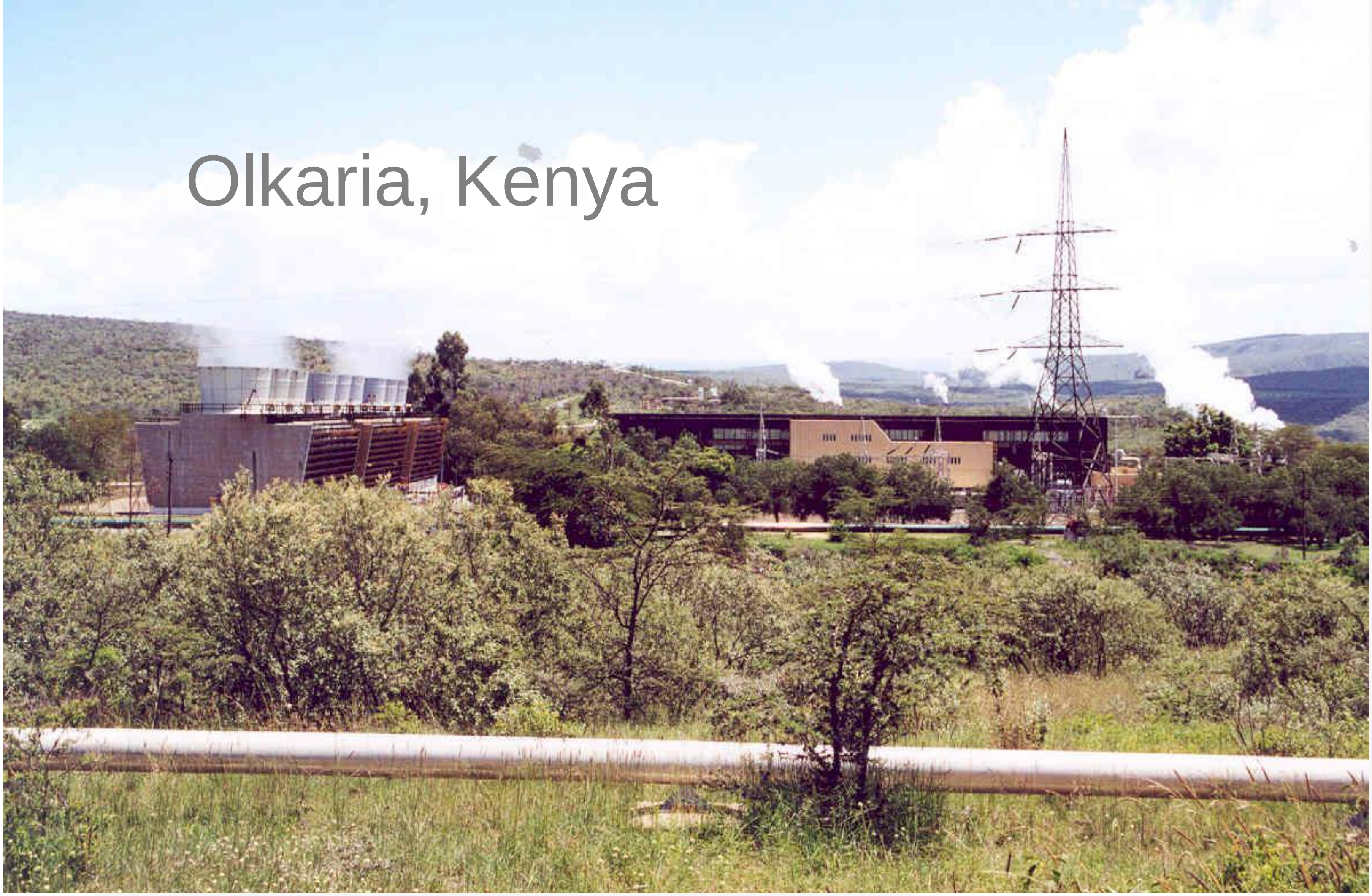


Photo: Ingavar Birgir Friðleifsson

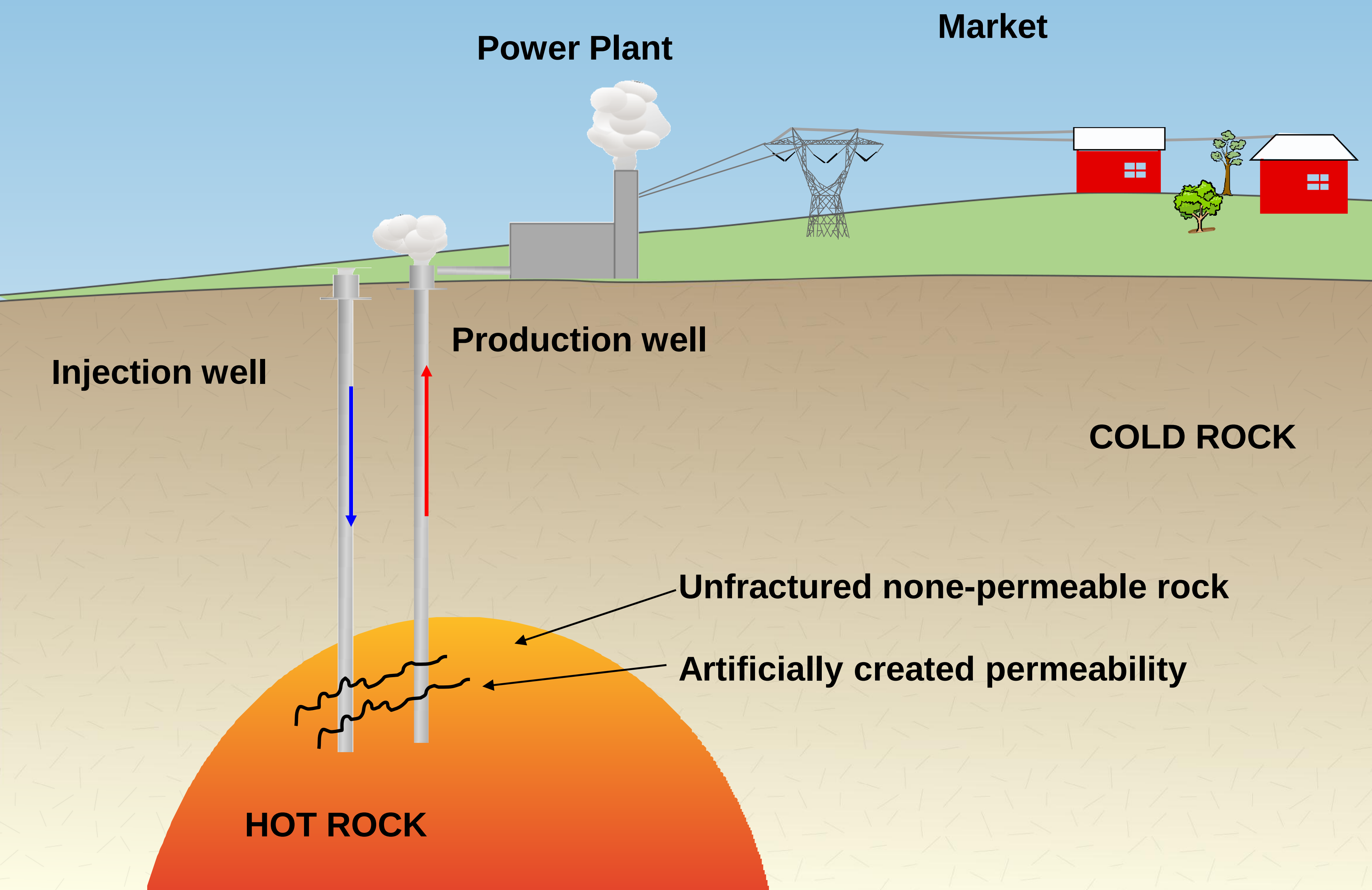
Unconventional geothermal fields are of three main types:

Hot Dry Rock Systems (HDR)

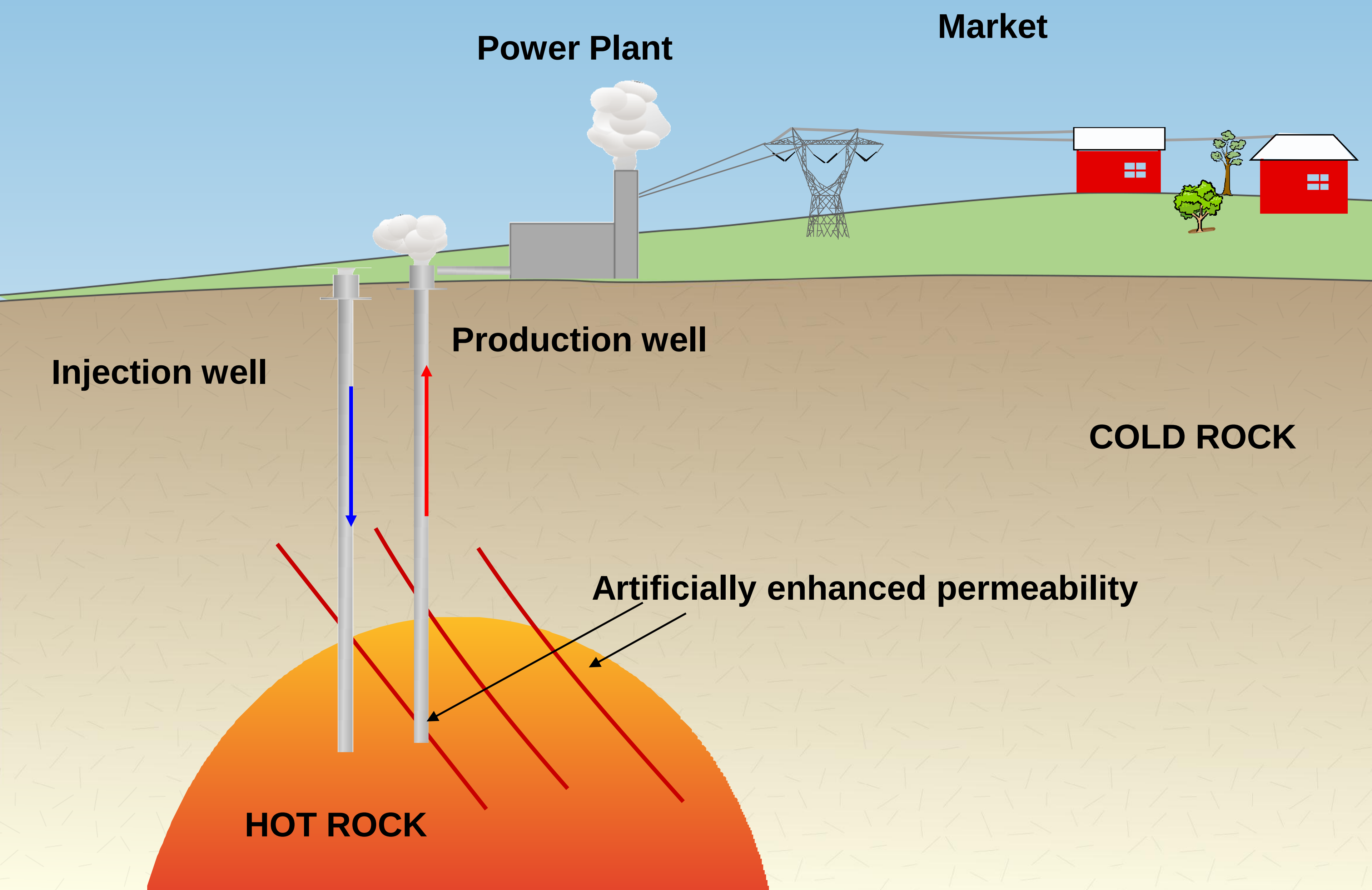
Enhanced Geothermal Systems (EGS)

Supercritical Geothermal Systems (SGS)

Hot Dry Rock Systems (HDR)



Enhanced geothermal system (EGS)

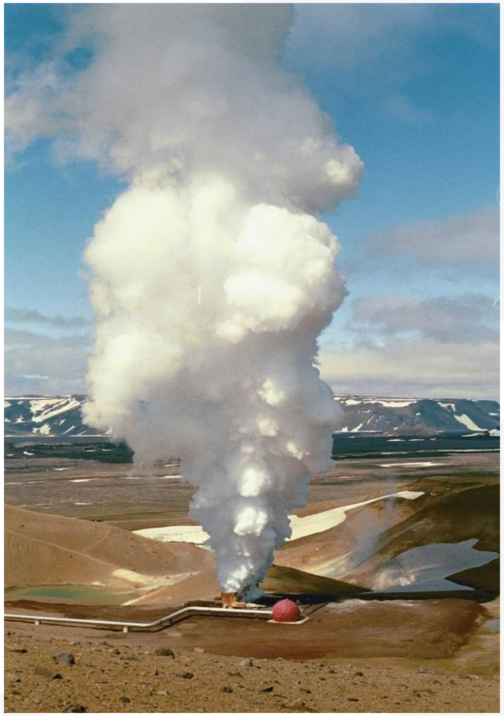


Supercritical geothermal systems

Powerful well with corrosive fluid in Krafla in 2007

- Are supposed to exist in the roots of the high temperature geothermal fields near the magmatic heat source.
- Should give energy intensive fluids.
- Might be chemically difficult to handle.
- Both very high temperature and permeability are necessary to get supercritical fluids.

Geothermal Energy is either used directly or to produce electricity



High temperature geothermal energy is use to produce electricity.

Direct use includes space heating, green houses, bathing and swimming, drying, fish farming, etc.

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Renewable energy – Electricity 2005

	Production TWh	%
Hydro	2837	89.0
Biomass	183	5.7
Wind	106	3.3
Geothermal	57	1.8
Solar	5	0.2
Tidal	<2	<0.1

Source: WEC 2007 Survey of Energy Resources, 427-437. World Energy Council 2007 (www.worldenergy.org)

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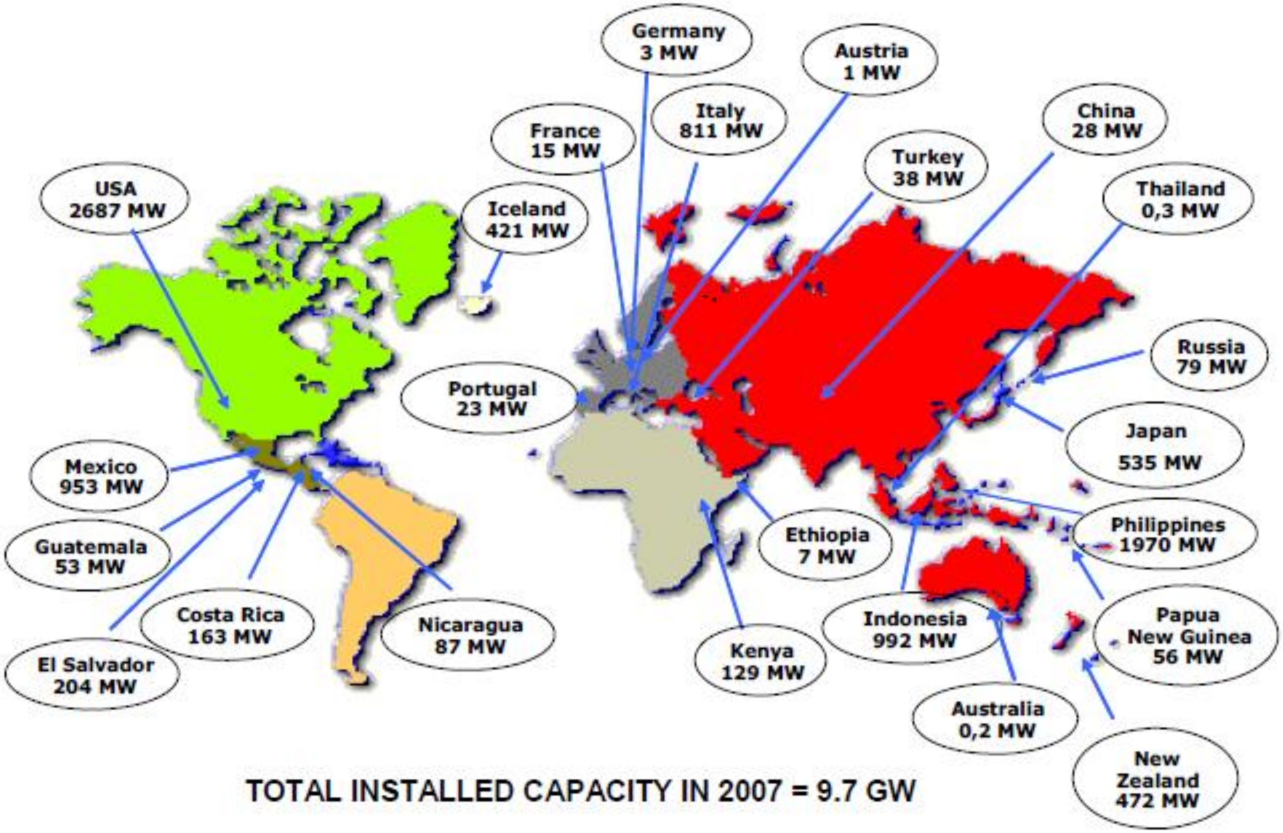
Installed Geothermal power in 2007



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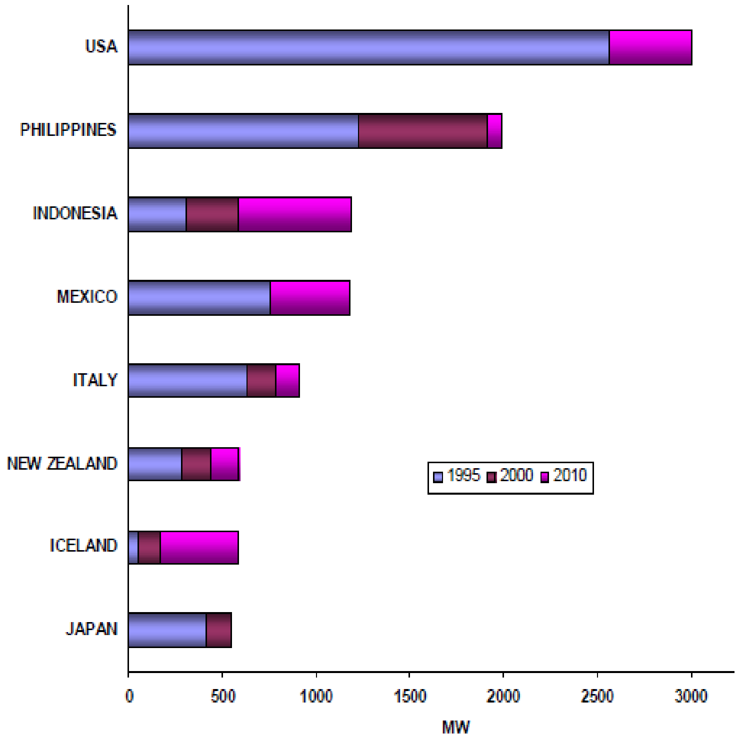
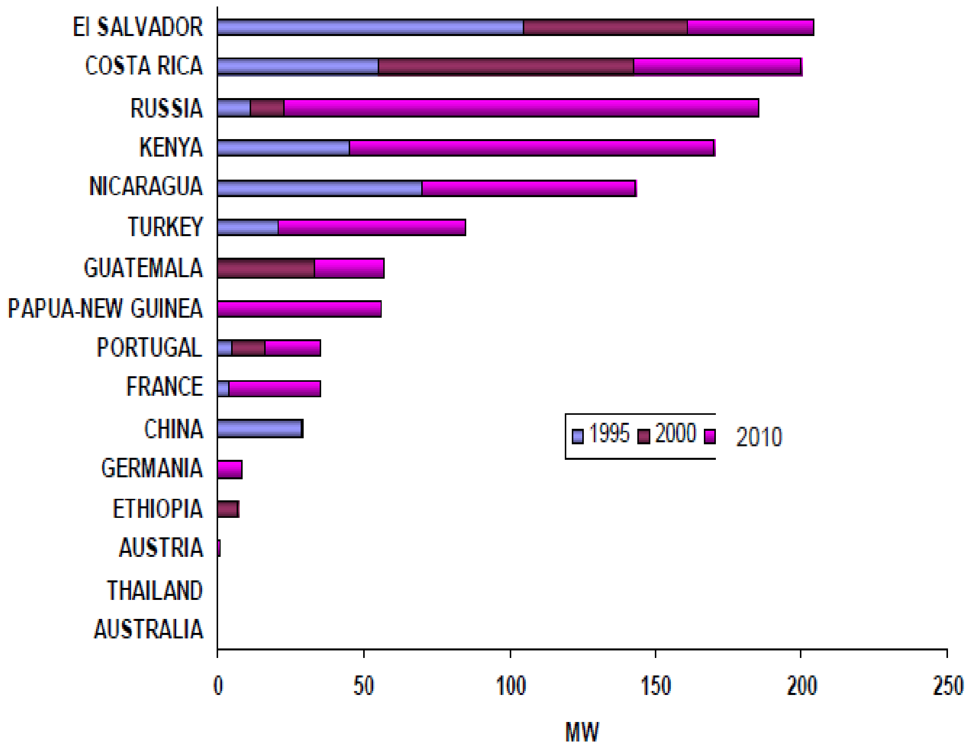
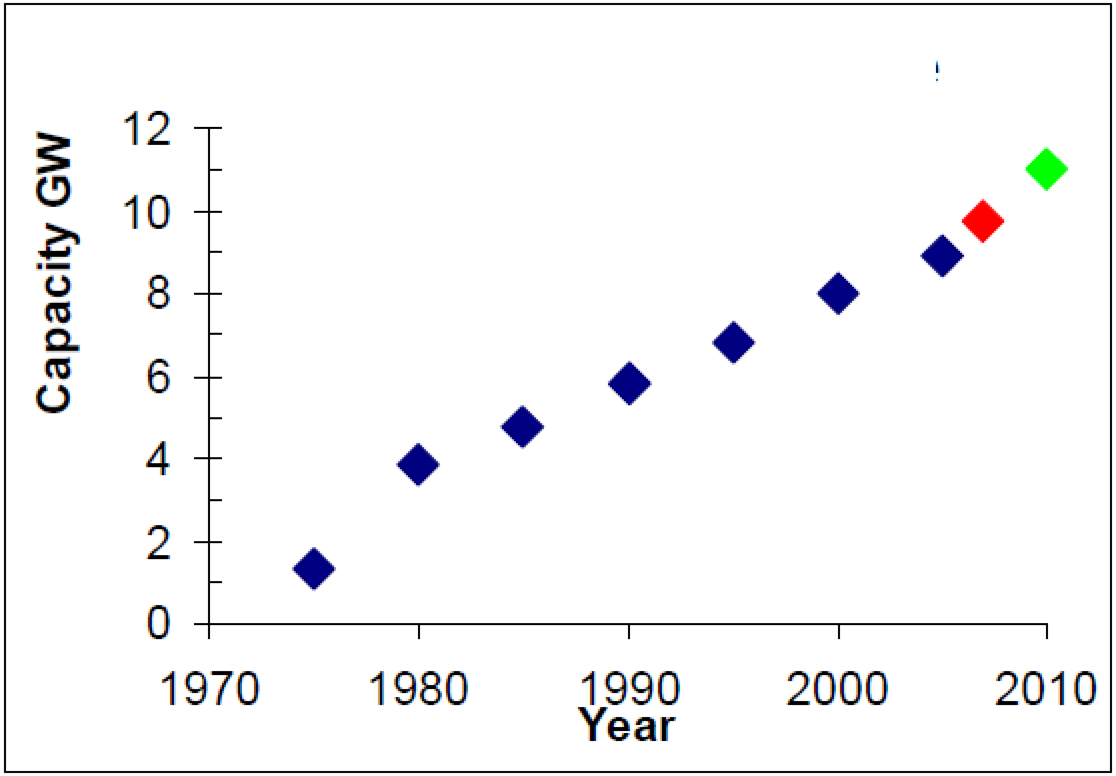
Installed geothermal power 1995, 2000 and expectation for 2010





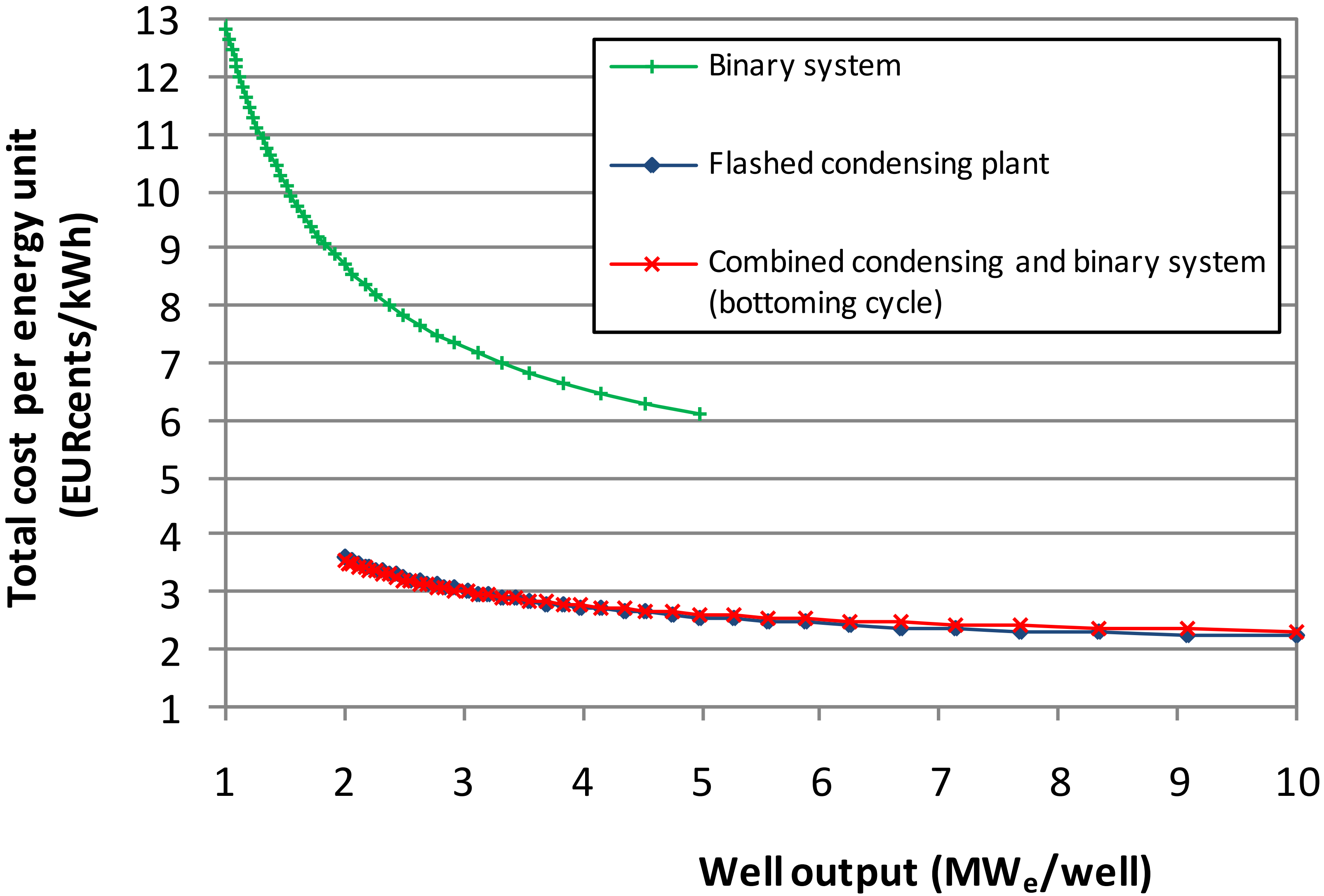
Installed geothermal power in 1975-2010



Average levelized cost of electrcity from different renewables (ESMAP 2007)

Technology	Rated output	Average levelized cost[1], current and predicted, in US¢/kWh		
		2005	2010	2015
Biomass Gasifier	20 MW	7.0	6.7	6.5
Biomass Steam	50 MW	6.0	5.7	5.7
Geothermal (binary)	20 MW	6.7	6.4	6.3
Geothermal (flash)	50 MW	4.3	4.1	4.0
Hydro	100 MW	5.4	5.2	5.2
Pumped Storage Hydro	150 MW	34.7	33.8	33.4
Slolar-thermal (without thermal storage)	30 MW	17.4	15.9	14.5
Solar-thermal (with thermal storage)	30 MW	12.9	11.7	10.7
Wind	100 MW	5.8	5.1	4.7

Total cost per energy unit



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Expected future trend for geothermal electricity:

- Conventional systems
  - South and Central America (Chile, Argentina, Equador, Nigaraqua)
  - USA
  - East Africa (Kenya, Ethiopia, Djibouti, Eritrea)
  - Asia: (Indonesia, Philippines, Iran, India)
  - Europe: Iceland, Turkey, Portugal (Azores), Russia, Italy, Greece
- Enhanced Geothermal Systems (EGS)
  - Ongoing experiments in several countries like Australia and Germany and USA is taking off again. If successful, enormous power supply will open up worldwide. Iceland ha huge resources that might be harnessed by EGS technology

Australia – Extensive EGS projects on-going

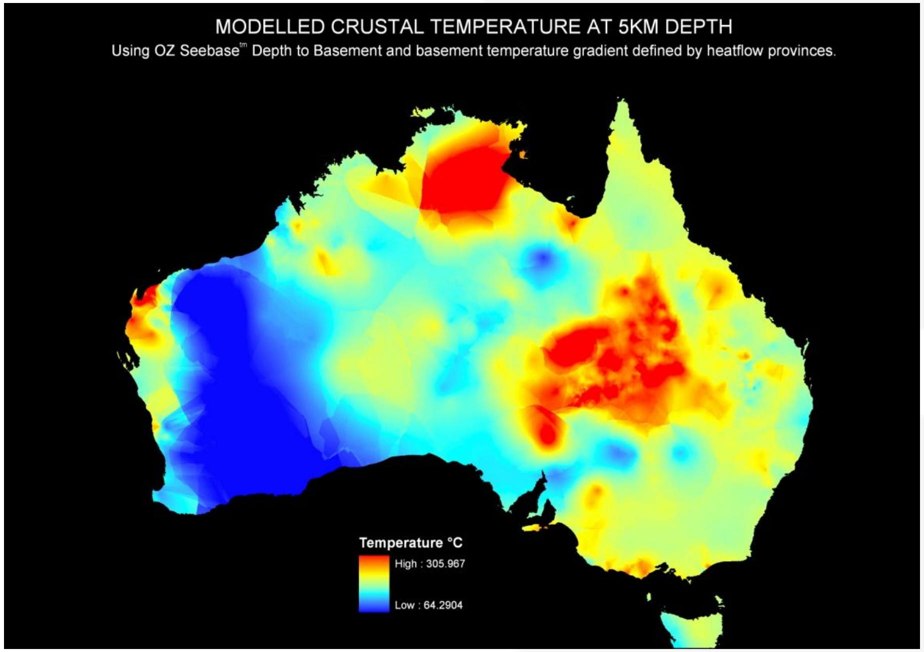


Figure shows Modelled temperature at 5 km depth

- Huge areas with temperature of 200-300°C at ~5 km depth
- In the top of a huge granite complexes insulated by sediments above.
- Horizontal fractures expected at 4-5km depth.
- Expected production in closed loops.

- **Australian Governments committed A$100+ million for research & demonstration since 2000 to 2007**

(From Andy Barnicoat and Ralf Ernst 2008)

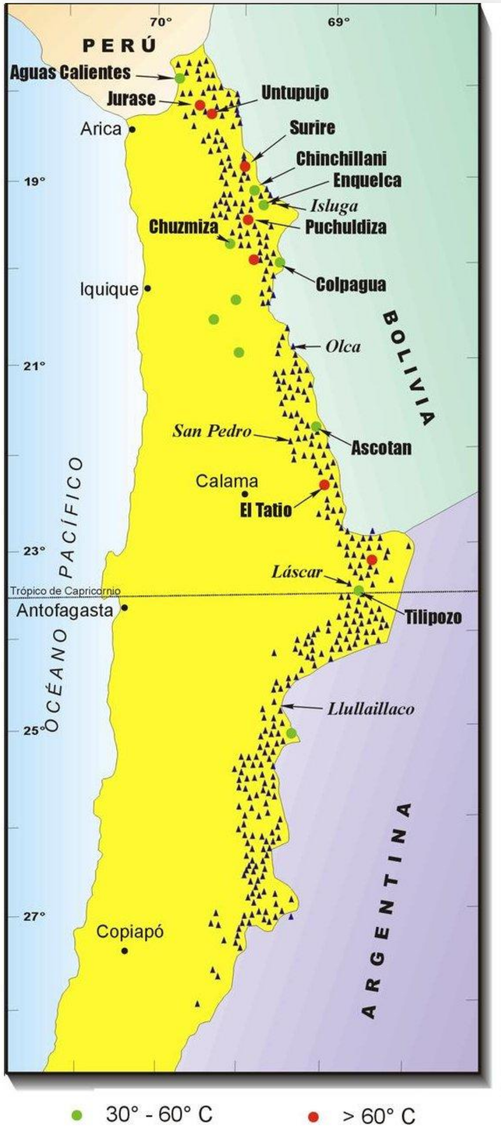
Obama's stimulation package: 350 M$ for Geothermal Energy

U.S. DEPARTMENT OF ENERGY

President Obama Announces Over $467 Million in Recovery Act Funding for Geothermal and Solar Energy Projects

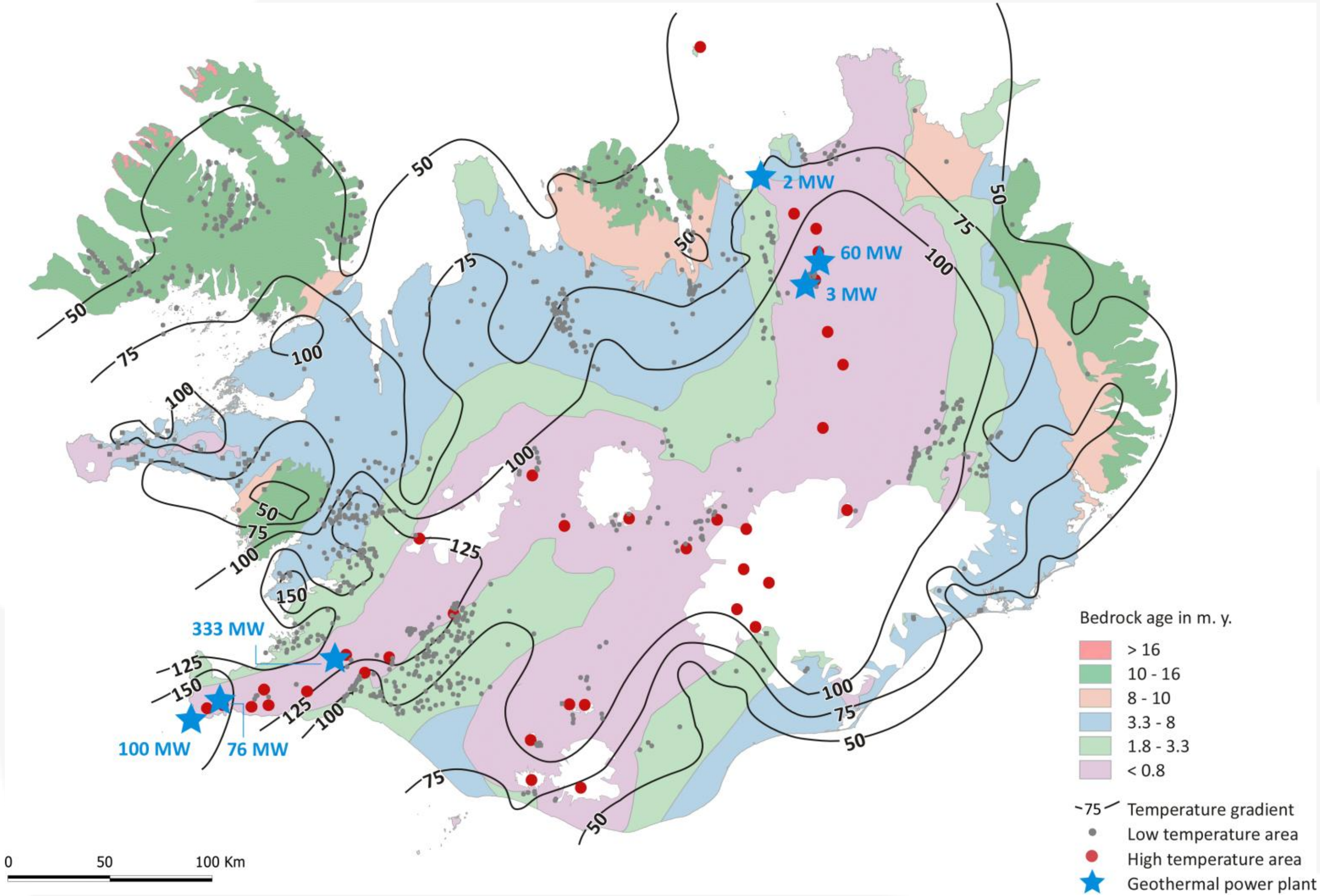
- **Geothermal Demonstration Projects ($140 Million)**
- **Enhanced Geothermal Systems Technology Research and Development ($80 Million)**
- **Innovative Exploration Techniques ($100 Million)**
- **National Geothermal Data System, Resource Assessment, and Classification System ($30 Million)**

Chile: Huge remote resources



- ➢300 probable geothermal fields
- ➢Estimated potential of
- ➢3500 MWe from conventional geothermal resources

Iceland – huge resources for conventional and for EGS-technology:



Iceland – Geothermal volumetric assessment:

Area	Area km²	Harnessible electrical energy		Power
The volcanic zone		Above 130°C. EJ_e	Above 130°C. TWh_e	MW_e for 50 years
Known geothermal fields	600	5.6	1,556	3,551
Other active areas	2,150	13.2	3,667	8,371
Non-active areas	29,250	38.1	10,583	24,163
Total inside the volcanic zone	*32,000*	*56.9*	*15,806*	36,086

From Pálmason et al. 1985

Conclusions

- There is considerable potential world wide for increased production of geothermal power at reasonable prices.
- There is a huge potential for power production world wide from geothermal resources using EGS technology.
- The main challenges in the geothermal sector to day is:
  - Develop EGG technology for medium and high temperature fields.
  - Develop methods for extracting energy from supercritical fluids.
  - Improve technology for conventional geothermal production
  - Make governments, international organizations and decision makers aware of the geothermal potential and help them to understand how to explore and exploit geothermal energy

What can GEORG do?

- Facilitate co-operation between Icelandic geothermal players and strengthen their collaboration with recognized geothermal institutions in Germany, France, USA and New Zealand.
- Promote and increase general awareness of geothermal energy utilization and explain the principles and potential of this renewable and benign source of energy.

Thank you for your attention

ICELAND GEOSURVEY

Photo: Gudmundur Steingrímsson