

# CH1002 Energy Management in Chemical Industries

## Unit - VI

# Geothermal Energy

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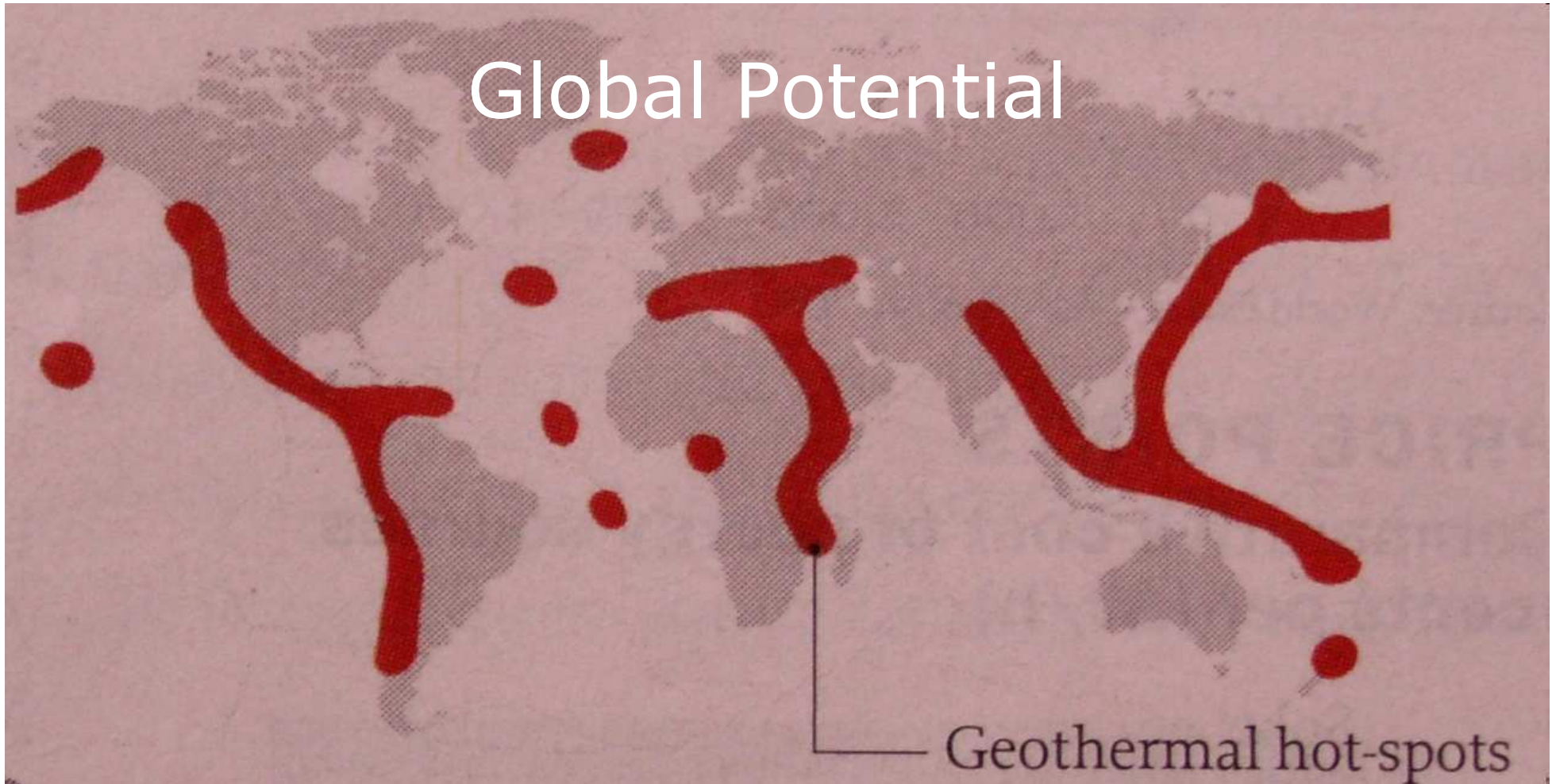
# Introduction

- The earth's interior is subdivided into a crystalline inner core, molten outer core, mantle, and crust. Basalt, a dark volcanic rock, exists in a semi-molten state at the surface of the mantle just beneath the crust.
- Drilling in the earth's crust has shown that the temperature of the crust tends to increase linearly with depth. The interior of the earth is much hotter than the crust.
- The source of heat energy is radioactive decay, and the crust of the earth acts as a thermal insulator to prevent heat from escaping into space.
- Geothermal power has historically been limited to areas near tectonic plate boundaries.

# Introduction (contd.)

- Earth's core temperature is estimated by most geologists to be around 5,000° to 7,000°C. For reference, that is nearly as hot as the surface of the sun (although, substantially cooler than the sun's interior).
- Within the crust there is an outward flow of heat from the earth's interior of approximately 50 mW/m<sup>2</sup> which is accompanied by a temperature gradient of about 30 K/km.
- The most economical sites at which to develop geothermal energy are those where the subsurface temperatures are highest and underground water and steam deposits are closest to the surface. Such sites are found mostly at the borders of the earth's tectonic plates, near active or recently inactive volcanos, hot springs, or geysers.

# Global Potential



Estimates of the electricity generating potential of geothermal energy vary six-fold, from .035 to 2 TW depending on the scale of investments. Upper estimates of geothermal resources assume enhanced geothermal wells as deep as 10 kilometres, whereas existing geothermal wells are rarely more than 3 kilometres deep

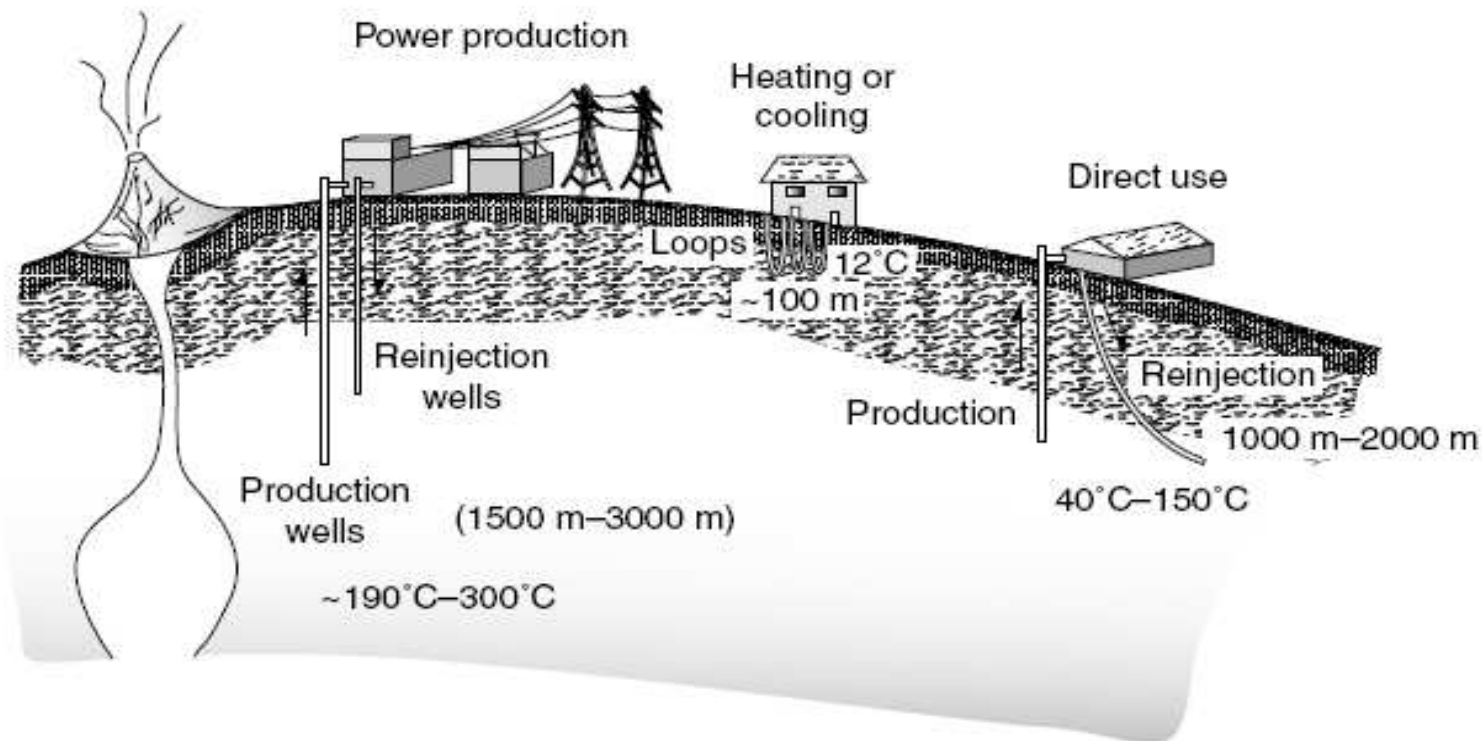
# Geothermal Hotspots

- The areas in the world with the highest underground temperatures are regions with active volcanoes or geologically young (under 1 million years) volcanic events. These “hot spots” occur at tectonic plate boundaries or where the earth’s crust is thin enough to let the heat through.
- The Pacific Rim, with its many active volcanoes, has many hot spots, along with Alaska, Hawaii, and much of the western United States. These regions are also seismically active with earthquakes and magma movement, which breaks up rock structures and allows water to circulate. As the water rises to the surface, natural hot springs and geysers occur.

# Conversion of Geothermal Energy

Geothermal power uses the heat of magma below the Earth's crust, which comes from radioactive decay

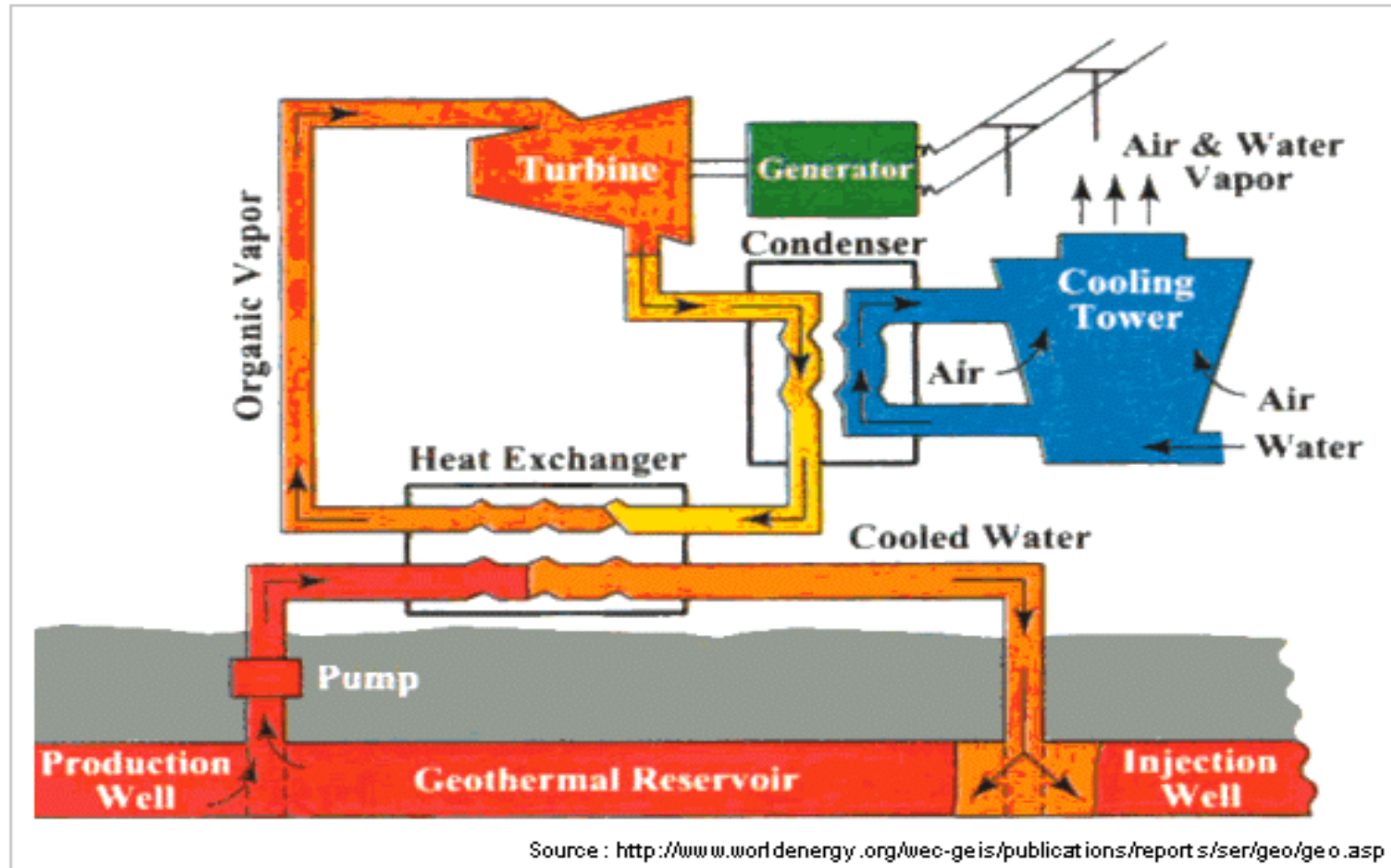
- Direct use
- Electricity generation
- Geothermal heat pumps



# Electricity Generation

- Geothermal electric power generation generally uses higher-temperature geothermal resources (above 110°C)
  - Vapor dominated sources – direct steam conversion
  - Liquid dominated sources – to separate steam from the geothermal fluid
  - Low quality resources – using binary power plant

Schematic of binary cycle geothermal power plant



# Electricity Generation (contd.)

- Electricity generation requires high temperature resources that can only come from deep underground. The heat must be carried to the surface by fluid circulation, either through magma conduits, hot springs, hydrothermal circulation, oil wells, drilled water wells, or a combination of these.
- Away from tectonic plate boundaries the geothermal gradient is 25-30°C per km of depth in most of the world, and wells would have to be several kilometers deep to permit electricity generation.
- The quantity and quality of recoverable resources improves with drilling depth and proximity to tectonic plate boundaries.

# Electricity Generation (contd.)

- The thermal efficiency of geothermal electric plants is low, around 10-23%, because geothermal fluids do not reach the high temperatures of steam from boilers.
- Because geothermal power does not rely on variable sources of energy, unlike, for example, wind or solar, its capacity factor can be quite large – up to 96% has been demonstrated. The global average was 73% in 2005.

# Geothermal Heat Pump

- The GHP energy-conversion process works much like a refrigerator, except that it is reversible, that is, the GHP can move heat either into the earth for cooling or out of the earth for heating, depending on whether it is summer or winter.
- GHP can be used instead of or in addition to direct uses of geothermal energy for space or industrial process heating (or cooling), but the shallow resource used by
- GHP is available essentially anywhere, constrained principally by land use and economics, especially initial installation costs.

# Geothermal Energy - Status

- The largest group of geothermal power plants in the world is located at The Geysers, a geothermal field in California, United States.
- As of 2004, five countries (El Salvador, Kenya, Philippines, Iceland, and Costa Rica) generate more than 15% of their electricity from geothermal sources.
- Worldwide, geothermal plants have the capacity to generate about 10 GW as of 2007, growing annually by 3%
- More than half of the geothermal energy is used for space heating, and another for one third for heated pools. The remainder supports industrial and agricultural applications.
- India has a geothermal potential of 10 GW

# Location of Geothermal Power Sites, 2005



TOTALS Installed 2000: 7,974 MWe, and 2004: 8,912 MWe (Generated 56,798 GWh/y)

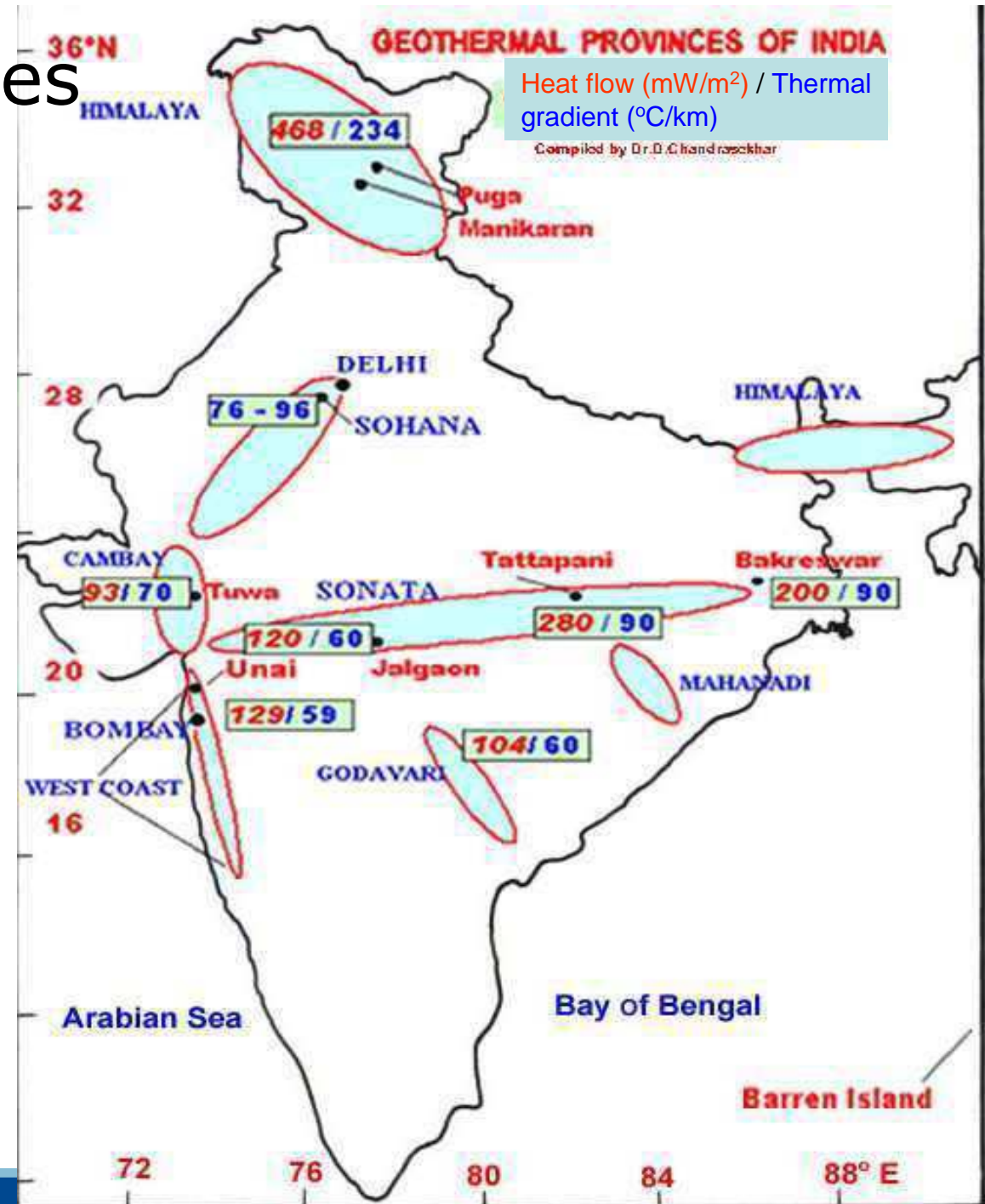
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MWe – Megawatt electrical energy



# Geothermal Provinces of India

- Indian has 400 medium to high enthalpy geothermal springs, clustered in seven province as shown in Figure.
- The most promising provinces are
  - i) Himalaya,
  - ii) Sohana,
  - iii) Cambay,
  - iv) Son-Narmada-Tapi (SONATA)
  - v) Godavari.
- With the recent volcanic eruption, the Barren island, a part of the Andaman-Nicobar chain of islands, is added to the above list.
- Most of them are liquid dominated systems with one or two having both liquid and gas dominated systems.



# Manikaran Geothermal Plant in Himalaya

- The first and the last (!) pilot binary 5 kW power plant using R113 binary fluid was successfully operated by the Geological Survey of India at Manikaran which proved the power producing capability of this province.

# Environmental Impacts

- Fluids drawn from the deep earth carry a mixture of gases, notably carbon dioxide (CO<sub>2</sub>) and hydrogen sulfide (H<sub>2</sub>S). These pollutants contribute to global warming, acid rain, and noxious smells.
- Existing geothermal electric plants emit an average of 122 kg of CO<sub>2</sub> per megawatt-hour (MWh) of electricity, a small fraction of the emission intensity of conventional fossil fuel plants
- In addition to dissolved gases, hot water from geothermal sources may contain trace amounts of dangerous elements such as mercury, arsenic, and antimony which, if dumped into rivers, is hazardous.
- Plant construction can adversely affect land stability. (subsidence and earthquake)

# Sustainability

- Geothermal power is considered to be sustainable because the heat extraction is small compared to the Earth's heat content, but extraction must still be monitored to avoid local depletion.
- Although geothermal sites are capable of providing heat for many decades, individual wells may cool down or run out of water.