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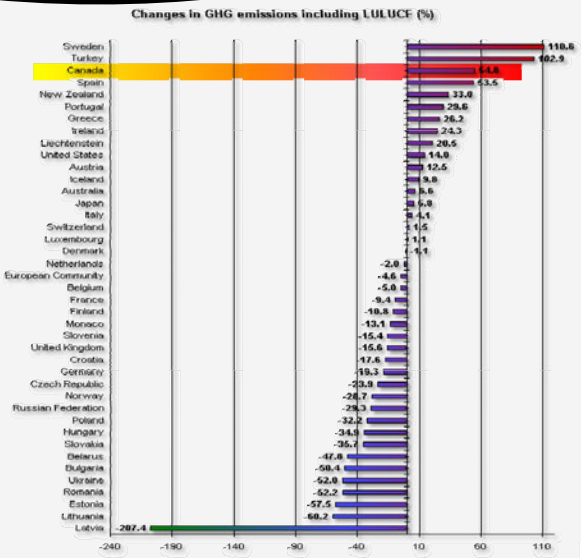
Prof. Dr. Christian Wolkersdorfer
Chair in Mine Water Remediation & Management

# Geothermal Energy

## A term with plentiful meanings

## Why Geothermal Energy?




UNFCCC 1990 – 2006

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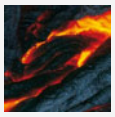
## What is Geothermal Energy?

GEO-  EARTH'S



THERMAL HEAT

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## What is Geothermal Energy?

Tuzla Springs, Anatolia, Turkey

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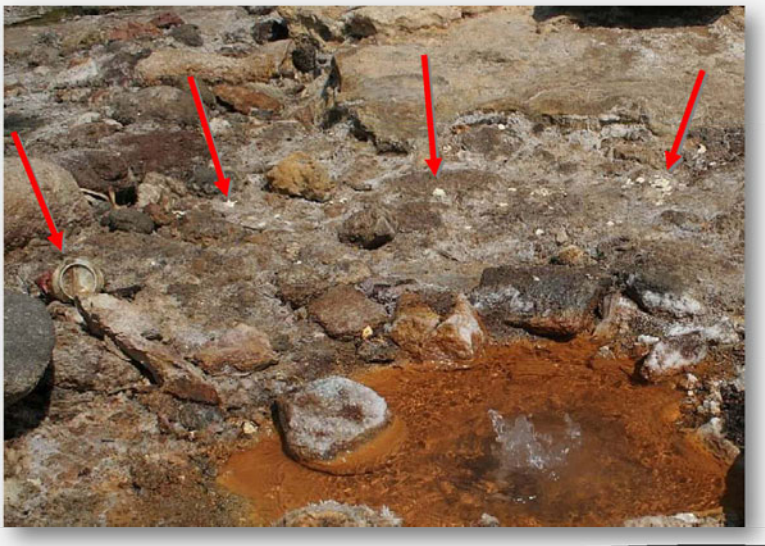
## What is Geothermal Energy?



Tuzla Springs, Anatolia, Turkey

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## What is Geothermal Energy?

- The **Nesjavellir Geothermal** plant produces about 120 $MWh_e$ and 400 $MWh_t$
- Island`s Largest geothermal power and heat plant

Agust Gudmundsson & Sonja L. Philipp

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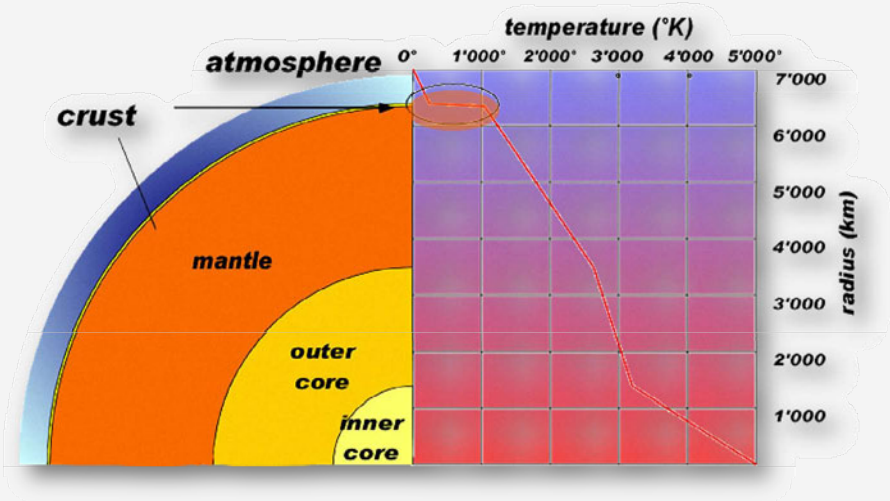
## Geothermal gradient




Geothermal Explorers Ltd

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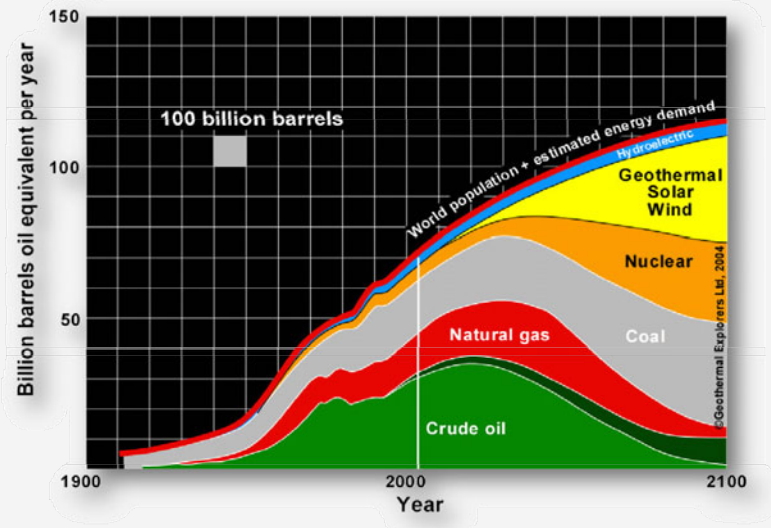
## Why Geothermal Energy?

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## What is Geothermal Energy?

- Also called Earth's Heat
- Energy stored as heat under the Earth's surface
- Source mainly from the decay of natural radiogenic nuclides ($^{232}$Th, $^{238}$U, $^{40}$K)
- In the earth's core temperatures above 6000 °C
- In the upper earth's mantle around 1300 °C
- Annual global geothermal heat flow: more than 40 Billion kW
  annual US energy consumption 0.4 Billion kW

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## What is Geothermal Energy?

- Starting at the earth surface, the temperature increases by 3 °K each 100 m of depth
  - Geothermal gradient
- heat anomalies with a higher gradient can be found in many places
  - Island, Italy, Indonesia or New Zealand
- 99 % of the Earth are hotter than 1000 °C
- Only 0.1 % are cooler than 100 °C

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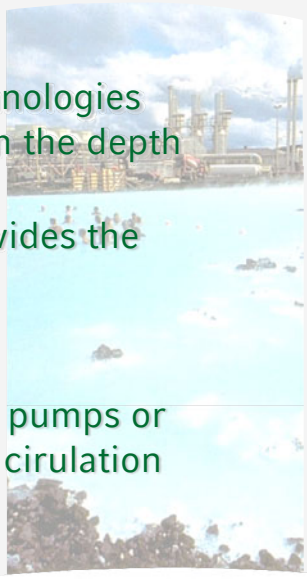
## Use of Geothermal Energy

- by means of appropriate technologies heat must be transportet from the depth to the surface
- Occasionally, natur itself provides the necessary loop system
  - Thermal springs
  - Fault zones as such in Island
- Usually, bore holes with feed pumps or geothermal probes with with cirulation pumps have to be used



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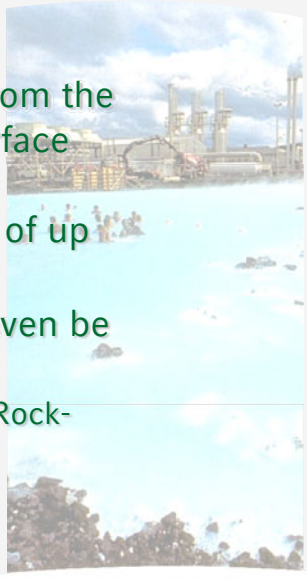
## Use of Geothermal Energy

- Integral use of heat energy from the subsurface starting at the surface down to technologically and economically feasible depths of up to 5000 m
- Heat from great depths can even be used to produce electricity
  - Deep Heat Mining or Hot-Dry-Rock-Technology



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## Use of Geothermal Energy

„In the later future, this high temperature, which is already of immeasurable importance for humans and the conditions of its existence, possibly could play still another new important role under the aids of the human life. Should once, on the more and more populated earth, all the forests be cleared and the coal reserves be exhausted then it is probably conceivable that one takes advantage of the interior warmth of the earth; that one directs it to the surface by means of special devices in shafts or boreholes and uses it for the heating of dwellings or even for the heating of machines. One will certainly not broadly and with advantage access this heat source, which probably will be expensive in their application, until a severe lack of fuel material forces to do so; then however the warmth of the mother earth remains a safe last refuge."

Bernhard von Cotta | Bergakademie Freiberg 1853

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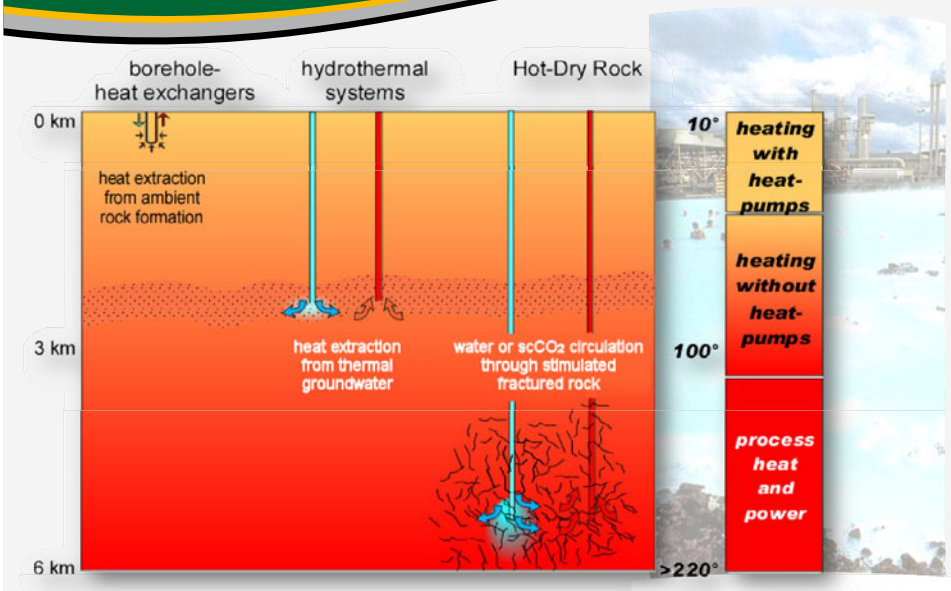
## Technological depths for Geothermal Applications

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## Types of Geothermal Energy

- Near Surface Geothermal (down to ≈ 400 m)
  - Vertical geothermal probes
  - Horizontal closed loop field
  - Geothermal use of ground water
  - Engineering constructions (loops for heating or cooling in concrete)
  - Warm tunnel or mine water for heating purposes
- Deap Geothermal (from ≈ 400 m)
  - Deep Geothermal probes
  - Geothermal use of hot springs or hot water in single or double borehole systems
  - Deep Heat Mining to produce heat or energy (e.g. HDR, EGS, HWR)

According to VDI-guideline 4640

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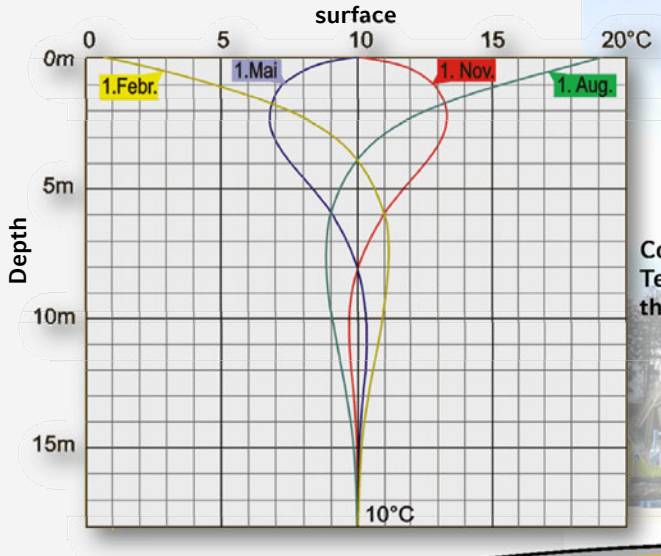
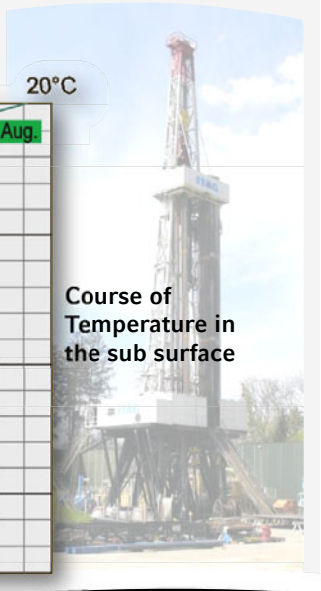
## Near Surface Geothermal: Seasonal Temperature Fluctuation




Course of Temperature in the sub surface



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## Vertical Geothermal Probes

- Boreholes between several meters and up to some hundreds of meters
- Closed loops or pipes
- Circulating fluid (e.g. water, alcohol, super critical $CO_2$) withdraws heat from subsurface
- Heat pumps extract the heat from the water
- Elevated temperature will be used for heating of buildings

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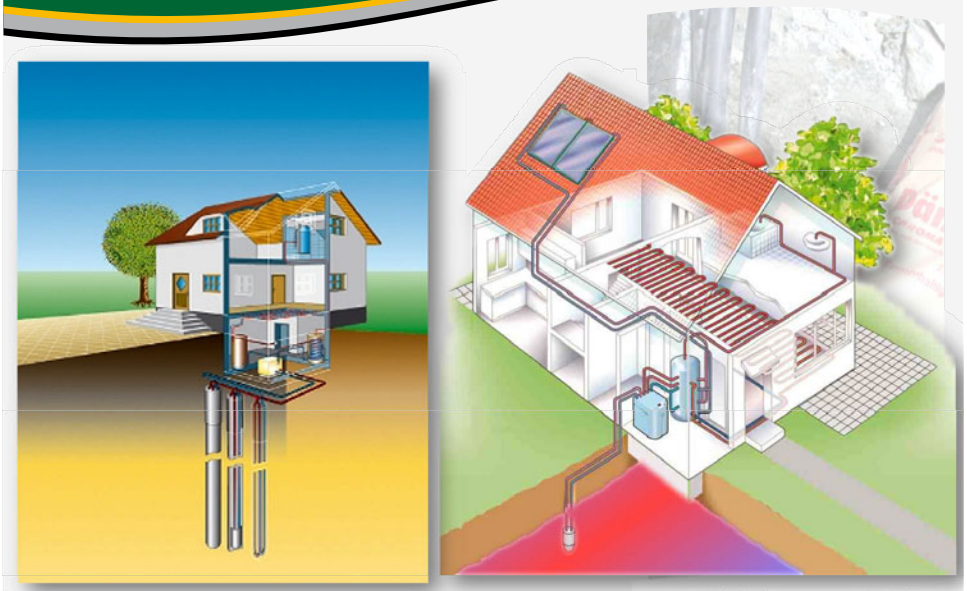
## Vertical Geothermal Probes



Bundesverband WärmePumpe e.V.

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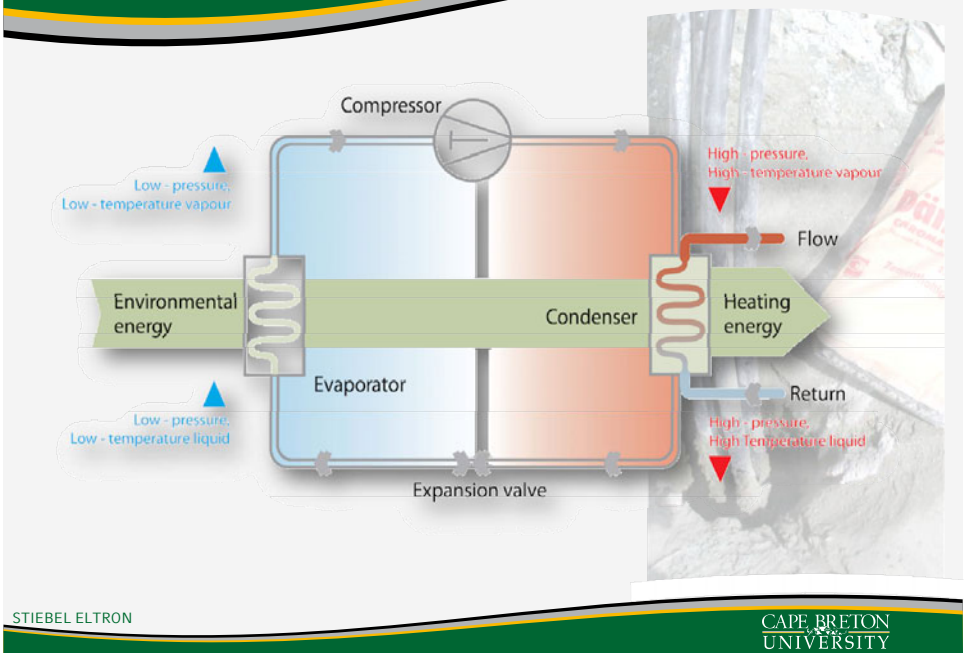
## Heat Pump




STIEBEL ELTRON

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## Vertical geothermal probes: Rough cost calculation

**Necessary heat for a house**

| | |
|---|---|
| up to 100 m² | ca. 5 kW |
| up to 150 m² | ca. 8 kW |

This equals 50 to 60 Watt per m² living space (without warm water).
Calculation base are 1.800 hours of operation without warm water.

**power consumption:**

| | |
|---|---|
| heat pump 1,5 kW | thermal output ca. 6,0 kW |
| heat pump 2,0 kW | thermal output ca. 8,3 kW |

Calculation Examples

1.800 annual hours of operation
80 m depth
10 m distance between probes

| | |
|---|---|
| capacity of one probe | 4,123 kW |
| capacity of two probes | 8,278 kW |

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## Vertical geothermal probes: Rough cost calculation

**Rough cost calculation**

between **ca. 1.200,– CAD to 1.500,– CAD** net per kW cooling costs and **900,– CAD to 1200,– CAD** net per kW heat of the heat pump

Depending on the buildings insulation this results in the following heating costs **47,– €** (good thermal insulation) to **53,– €** (bad thermal insulation) of m² heated living space.

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## Horizontal Heat Collectors

- Panel collectors | Earth register
  - PE loops in small depth and 2-dimensional layot
    - Garden of a single family house
    - Roads
  - sufficiently large surface necessary
  - horizontal in a depth of 80–160 centimetres
  - more strongly affected by the climate than by the heat flow from the underground
- Foundations Plates
  - Heat exchanger lines, which are integrated into the blinding layer, can also be used for geothermal heating

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## Horizontal Heat Collectors

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## Geothermal use of ground water

- Most common method used
- If beneficial ground water conditions exist
- Geothermal heat from wells
- Two wells are advisable
  - Production and injection wells
- Constant temperature between 8 and 11 °C
- Heat Pump
- insignificant loss at heat exchanging device

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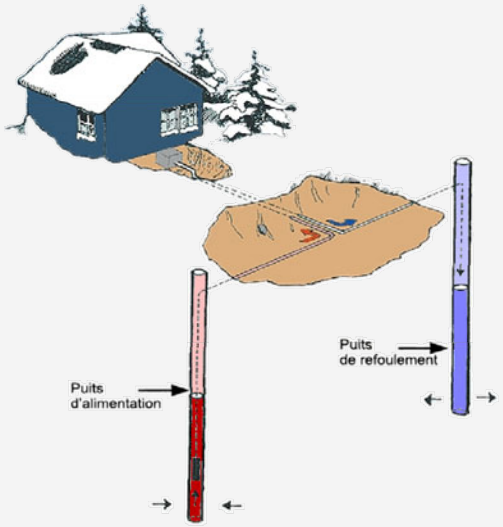
## Geothermal use of ground water




www.lysairmecanic.ca

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## Geothermal use of ground water

Viessmann Vitocal Heat Pump (outgoing temperature up to 65 degrees Celsius: old buildings/rehabilitation)

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## Energy stakes and diaphragm walls for heating or cooling

- Concrete piles or - would wind for building foundation
  - No additional drilling measure necessary
- Up to 50 meters deep and a diameter of 1.5 meters
- Single pipe or pipeline inside the pile
- Completely surrounded by concrete
- Heat transfer liquid
  - Summer: Cooling | Winter: Heating
- Almost 400 installations in Germany and Austria with 10–800 $kW_t$ achieved

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## Energy stakes and diaphragm walls for heating or cooling

Klimahaus (climate house) Bremerhafen, Germany:
http://www.klimahaus-bremerhaven.de

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## Energy stakes and diaphragm walls for heating or cooling

Klimahaus (climate house) Bremerhafen, Germany

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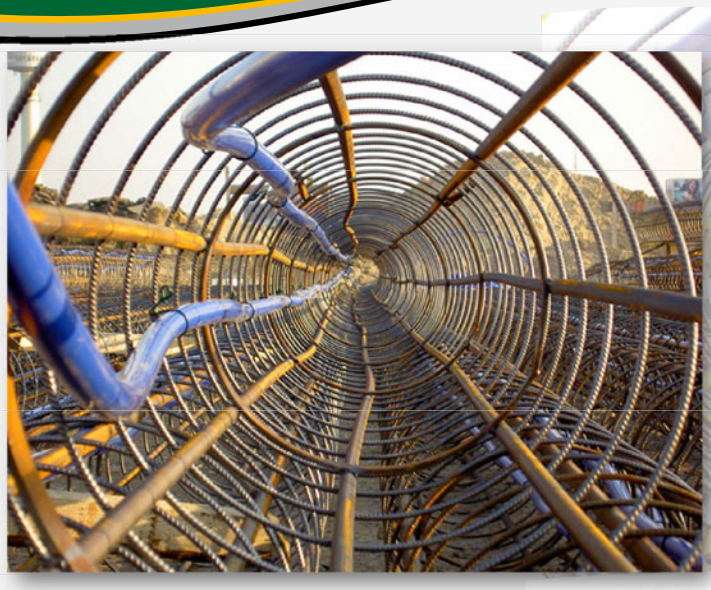

Klimahaus (climate house) Bremerhafen, Germany

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## Mine or Tunnel Geothermal:

- Use of warm tunnel or mine water for geothermal heating
- Examples
  - Gotthart-Tunnel/Switzerland (1979): 17 °C; 1,8 $MW_t$
  - Furka-Tunnel/Switzerland: 16 °C; 0,9 $MW_t$
  - Ricken-Tunnel/Switzerland: 12 °C; 0,2 $MW_t$
  - Mappo-Morettina-Tunnel/Switzerland: 16 °C; 0,7 $MW_t$
  - Springhill, Nova Scotia/Canada: 18 °C; 250 $MW_t$
  - Ehrenfriedersdorf/Saxony: 11–14 °C; 0,12 $MW_t$

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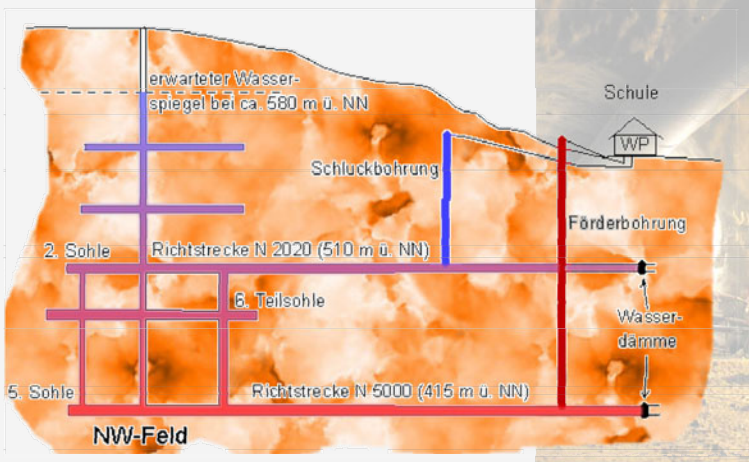
## Mine or Tunnel Geothermal: Ehrenfriedersdorf/Saxony, Germany




Modified after Burkhard Sanner

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## „Deep“ Geothermal Probes

- Most expensive part is the bore hole
- After use of unused bore holes, e.g.
  - coal
  - oil
  - gas
- Has to be equipped with geothermal probes
- Since 1994 in Prenzlau/Germany
  - 108 °C temperature
  - 2800 m deep bore hole
  - Deed into district heating system
- planning: RWTH Aachen
- water park Arnsberg/Sauerland

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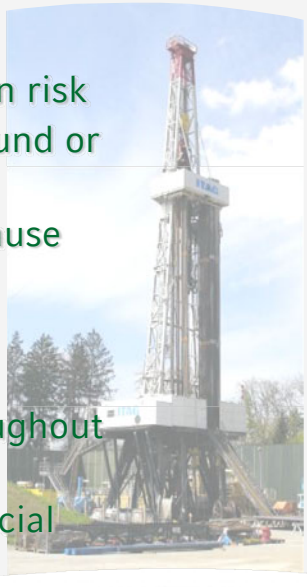
## „Deep“ Geothermal Probes

- No drilling risk, no exploration risk
- No interaction with underground or fluids in the underground
- High economic life-time, because practically no wear and tear
- Simple, safe operation
- High reliability
- Available as heat source throughout the year
- Not necessarily related to special geological conditions



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## Hydro-Geothermal

- Permeable rocks necessary
  - If needed with Frac process
- At least 100 °C
  - Unterhaching 122 °C
  - South Meager Geothermal Project, BC ≈ 200 °C
- Production and injection well needed
  - Some to several thousand meters deep
  - Distance between bore holes some 100 up to 1000 meters
- Heat or electricity with CHP (combined heat and power generation)
- KALINA or ORC-(Organic RANKINE Cycle)-plants in use

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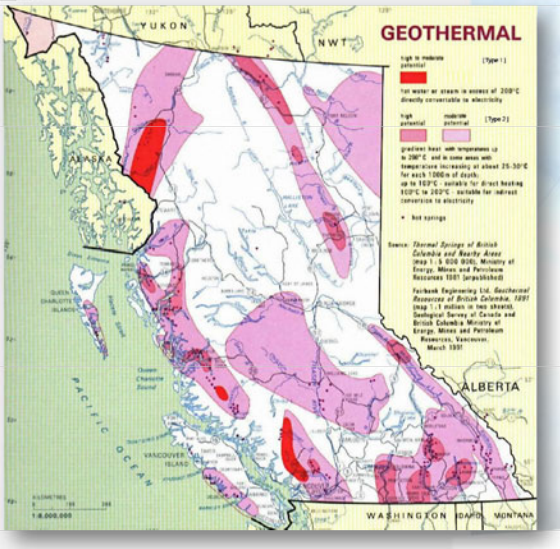
## Hydro-Geothermal in British Columbia




Ministry of Energy and Mines, British Columbia, Canada

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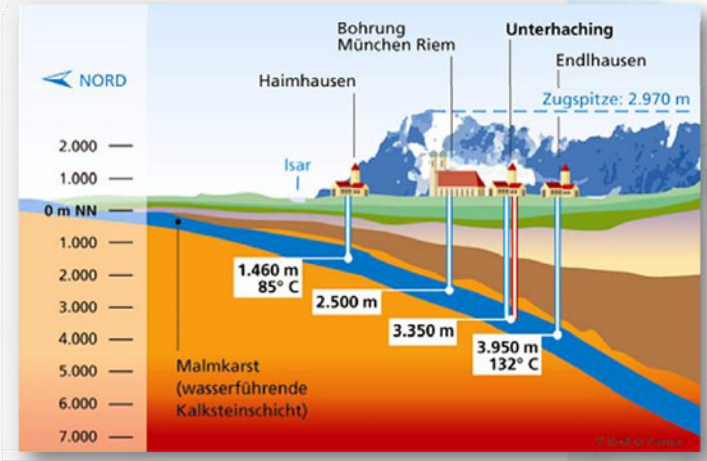
## Hydro-Geothermal in Bavaria

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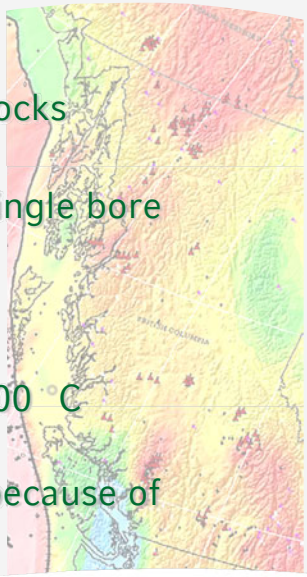
## Deep Heat Mining to produce heat and electricity: Hot Dry Rock (HDR, EGS)

- Dry, hot, nearly fractureless rocks
- 2 or more boreholes
- Frac Process to connect the single bore holes with each other
- Granites, Gneisses
- Medium: Water or $scCO_2$
- Temperatures of more than 200 °C possible
- problem: drilling technique (because of high temperatures)



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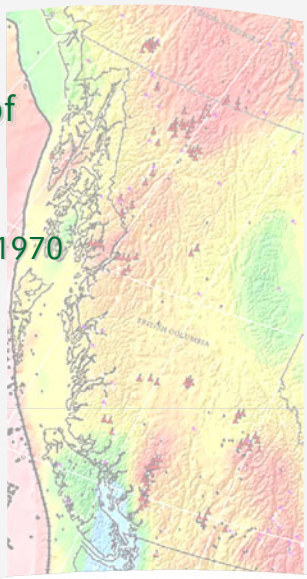
## Deep Heat Mining to produce heat and electricity: Hot Dry Rock (HDR, EGS)

- Production of energy by use of KALINA or ORC technology
- Examples
  - Los Alamos: USA (pilot project 1970 until ca. 1980)
  - Soultz-sous-Forêts: F / D (pilot project)
  - Bad Urach: D (project stopped)
  - Groß Schönebeck: D (working)
  - Another name is: Enhanced Geothermal Systems (EGS)



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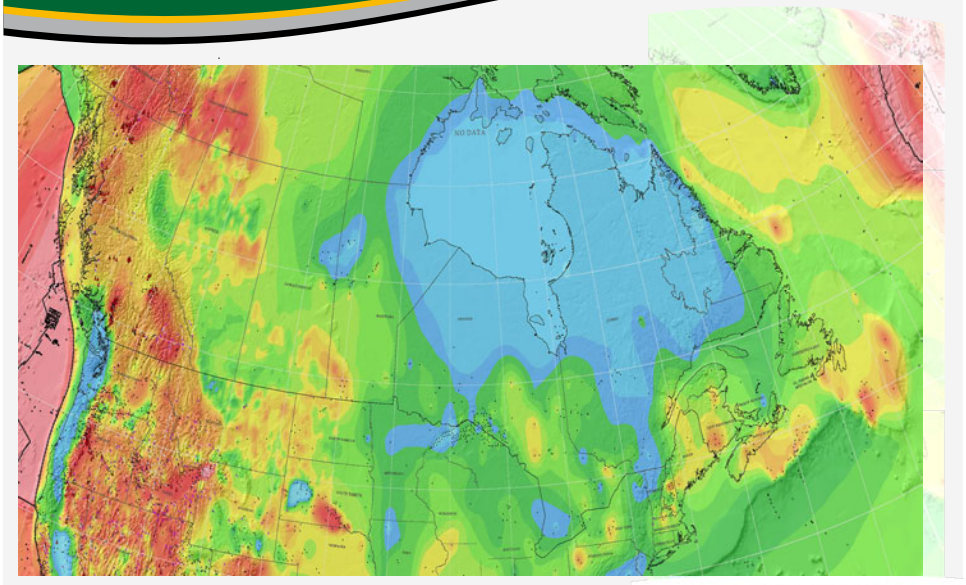
## Deep Heat Mining for Electricity and Heat: Hot Dry Rock (HDR, EGS)



Geothermal Map of North America, 2004: Terrestrial Heat Flow

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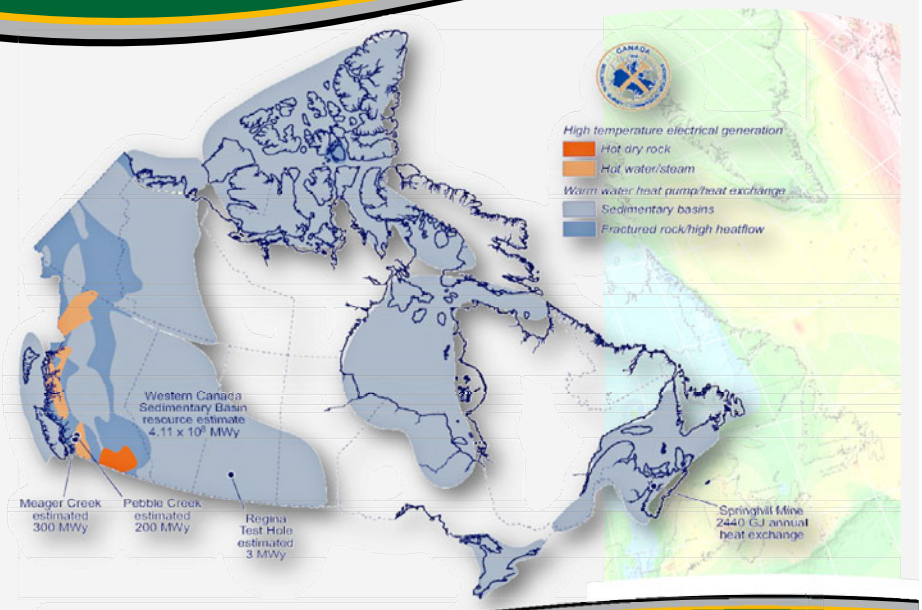
## Deep Heat Mining for Electricity and Heat: Hot Dry Rock (HDR, EGS)

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## … wouldn't that be nice if we had it …

New Zealand: Wairakei Geothermal Power Station (Richard Seaman)

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