GEOTHERMAL ENERGY OPPORTUNITIES FOR DESERT REGIONS

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ABSTRACT

Geothermal energy allows application for many demands in electric power, heat, and cold. Not all applications may be suited to desert regions, however, depending upon the geological/geothermal regime, a desert region might quite well have a good potential for geothermal energy use. Some general ideas and examples are presented:

- Power generation from high enthalpy resources
- Direct heat applications in agriculture, food industry, etc.
- Absorption cooling driven by geothermal heat
- Seawater desalination for coastal deserts and islands
- Depending upon climate zone, ground source heat pumps for cooling (and some winter heating and DHW production) can be used.

INTRODUCTION

Geothermal energy is defined in Europe as the "**energy stored in the form of heat beneath the surface of the solid earth**", first officially written down in [1]. The earth is a hot sphere, most of its interior heat coming from natural nuclear fission of radioactive isotopes in the lower crust and in the mantle of the earth, some is remaining heat from the building up of the globe.

The total thermal power which the earth releases continuosly into outer space is on the order of 38 to 43 TW. The actual energy production from geothermal sources at the beginning of the 21st century was … GWh of electricity and … GWh (… TJ) of heat [2].

The geothermal (terrestrial) heat flux varies from 0.03-0.20 W/m^2, on average about 0,06-0,07 W/m^2. The highest heat flux, and, in consequence, the most important high-enthalpy geothermal ressources, can be found around the Pacific ocean, on the Mid-Atlantic ridge, the East-African rift, and the Alpine-Himalayan fold belt. Some major desert areas on earth are located within these zones (fig. 1). Within the following chapters, geothermal energy opportunities will be discussed in three areas, keeping the focus on applications for desert areas:

- Geothermal Power Production
  used from a few hundred metres depth (in some high-enthalpy areas) down to a current maximum of 5000 m
- Deep Geothermal Energy for "direct use" (heating, cooling, process heat)
  typically used from 400-3000 m depth, or from some natural springs
- Shallow Geothermal Energy for heating and cooling
  in the range of 0-400 m depth, mainly in form of ground source heat pumps

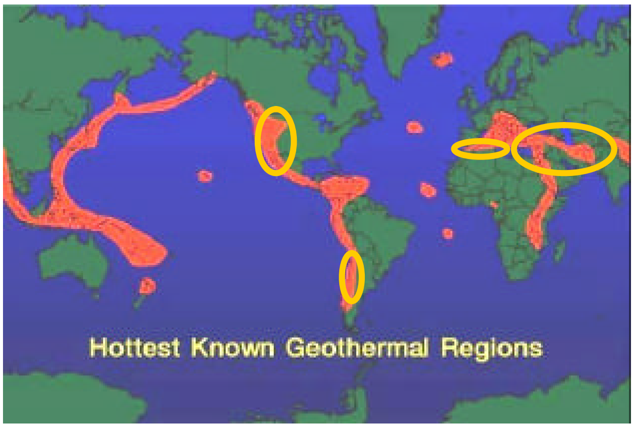

Fig.1: Some of the high temperature geothermal potential is located in arid or semi-arid zones (base map from [3])

POWER GENERATION

Geothermal power generation has a history over 100 years old (fig. 2). After the first tests in 1904, the first real powerplant became operational in 1912. Until well into the 1950s, Italy was the only country producing geothermal electricity. The main increase in installed capacity started around 1980 (fig. 3), and today the list comprises some 24 countries with geothermal power plants world-wide (fig. 4).

Fig. 2: First geothermal power production by Prince Ginori Conti at Larderello, Italy, in 1904, using a boiler heated from geothermal steam, a piston steam engine, and a dynamo (photo ENEL, Italy)

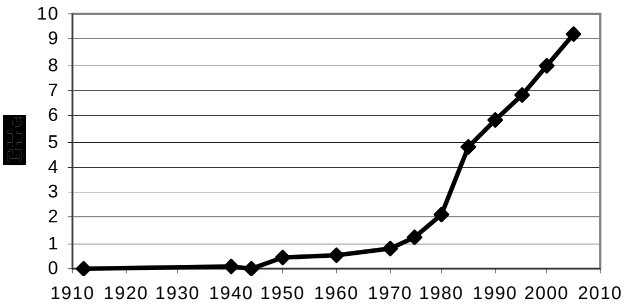

Fig. 3: Development of installed electric power capacity in geothermal plants from 1912-2005 (mainly from data in [2])

"Conventional" geothermal power plants

In some places, natural steam reservoirs allow using steam directly for turbines. However, in most cases, hot water or a water-steam-mixture under high pressure first has to be released into lower pressure for evaporating ("flashing"), and steam has to be separated from the remaining liquid phase, before it can go to a turbine. This process can be done in a single step (single-flash), or being repeated at lower pressure levels (double-flash, triple-flash) in order to fully exploit the energy of the hot water.

To maximize the efficiency of the process, and also to avoid release of the steam to the atmosphere, most geothermal power plants are built with condensation of the steam. Fig. 5 shows a generic scheme of a condensing single-flash geothermal power plant. A problem for desert areas may be the water need for a wet cooling tower re-cooling the condensor. In this case, dry coolers can be used; the efficiency of a dry cooler, however, can be up to 30% lower in summer due to high dry-bulb temperature (fig. 6).

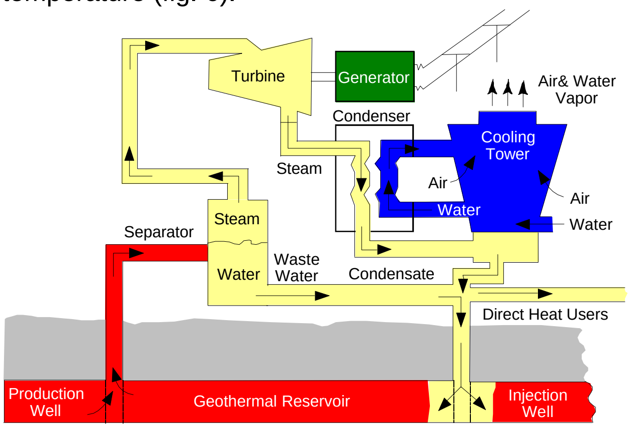

Fig. 5: Generic schematic of a single-flash geothermal power plant with condensation [4]

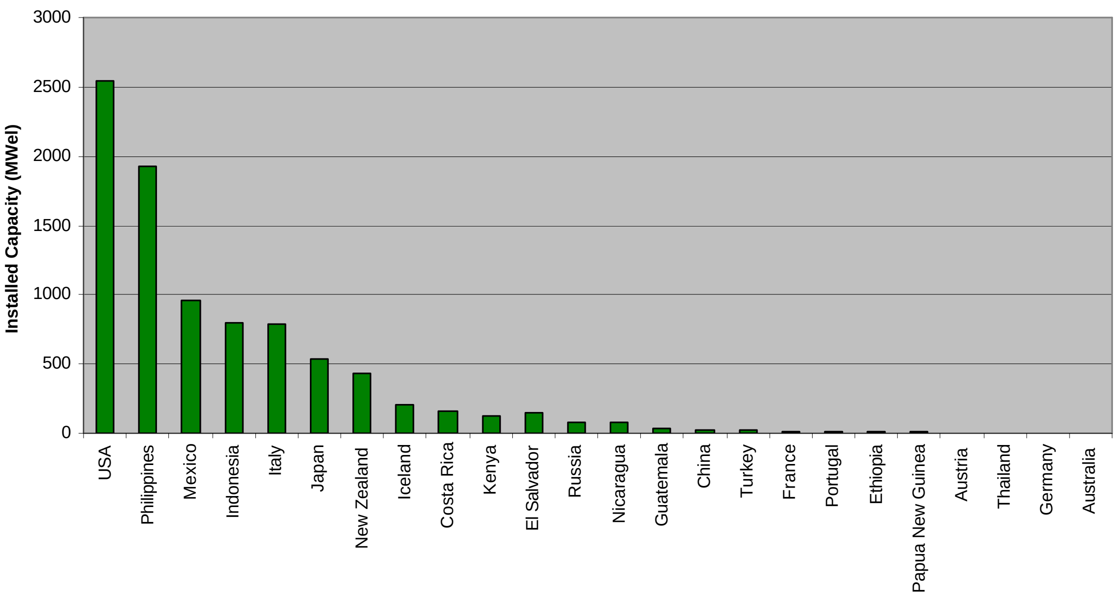

Fig. 4: Geothermal electric power production in the world 2004, after data from [2]

Fig. 6: Wet cooling tower (above) and dry coolers (below) for geothermal power plants [4]

Binary geothermal power plants

For geothermal reservoirs with temperatures from <100 °C to about 200 °C, or those containing plenty of noxious ar corrosive gases, binary power plants are a solution (fig. 7).

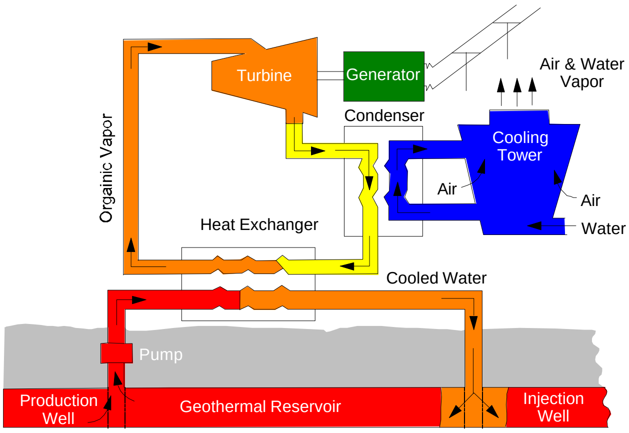

Fig. 7: Generic schematic of a binary geothermal power plant (ORC-principle) [4]

The geothermal fluid is used to heat the process only, while the energy conversion in the turbine is done in a separate, closed circuit. This can either be built using the Organic Rankine Cycle (ORC), with working fluids like Isopentane, Fluorohydrocarbons, etc., or using a Kalina Cycle with a water/ammonia mixture. While a large number of geothermal ORC power plants is operational world-wide today, only one Kalina plant exists yet, in Husavik in Northern Iceland.

Binary plants need condensation in any case. Typically the coolers are the most prominent feature of an ORC unit. Fig. 8 shows an example of a small, packaged unit that can be transported on a truck and installed at the wellhead in short time. The individual components can clearly be seen here.

Fig. 8: ORC unit in Bad Blumau, Austria (250 kW el. Output): Evaporator, turbine, condensor and controls in the frame to the lower right, air coolers for re-cooling the condensor in two parallel racks to the upper left (cf. fig. 7) (Photo ORMAT, Israel)

Operational examples

Large geothermal power plants (about 20 MW electric or more) are supplied with steam or hot water from various wells, by insulated pipelines. These pipelines are expensive and need protection. With the advancement in automatisation and remote control, a trend can be seen to smaller power plants just at the wellhead, with no permanent crew on site. This feature is particularily well suited for plants in desert areas.

Both flash-type and binary plants can be found among geothermal power generation in desert areas. Data for two examples after [4] shall be given here (fig. 9):

- Geothermal power plant in Wabuska, Nevada, USA:
  Electrical output 750 kWe
  Geothermal fluid temperature 104°C
  Geothermal fluid flow rate 54 l/s (194 m^3/h)
- Geothermal power plant in Nagqu, China, Tibet:
  Electrical output 1300 kWe
  Geothermal fluid temperature 110 °C
  Geothermal fluid flow rate 69 l/s (248 m^3/h)
  A special feature of this plant is the elevation of 4526 m above sea level.

Enhanced Geothermal Systems (EGS)

At places where no natural geothermal resources in form of steam or hot water exist, the heat of the rock can be used by creating artificial permeability for fluids extracting that heat. Known as “Hot Dry Rock” technology (HDR), this method is under development since the 1970s. Meanwhile the crucial break-throughs have been made, the most remarkable the first long-term circulation in the European test site in Soultz-sous-Forêts in France, generating hot water from ca. 3500 m depth over several months (fig. 10).

Fig. 9: Frame with evaporator, turbine, and condensor of ORC-plant in Wabuska, Nevada, USA (above) and complete view with air coolers of plant in Nagqu, Tibet, China (below) [4]

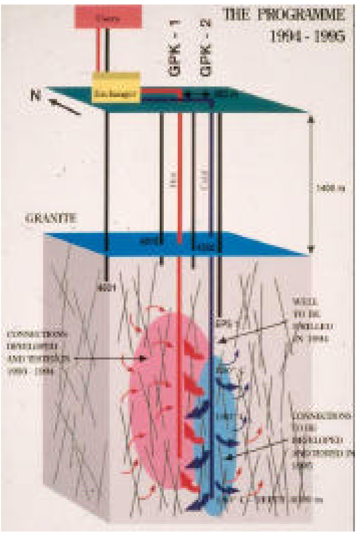

Fig. 10: Schematic of the EGS-project in Soultz-sous-Forêts, status until 1997 (graphic from Soultz project group)

In 2006, in Soultz-sous-Forêts 3 boreholes exist each 5000 m deep, 1 for injection of water, and 2 for production of hot water. Start of power production from that source is imminent. Because in most of the current projects of that type the ground is not "dry" in the strict sense, and the aim is more on opening pre-exisiting fractures and fissures for permeability, than to create completey new ones, the technology today is called Enhanced Geothermal Systems (EGS), and comprises everything from a stimulation of already existing sites with insufficient permeability, to the classical HDR idea. EGS will allow geothermal power production almost everywhere. The economy will be best, of course, in areas with a geothermal heat flux above average (cf. fig. 1).

GEOTHERMAL DIRECT USE

Geothermal heating and cooling

Beside conversion to electric power, geothermal energy can favourably be used directly as heat. The classic application of that type is geothermal district heating, and the typical way of tapping the geothermal resource is a deep well doublet (fig. 11).

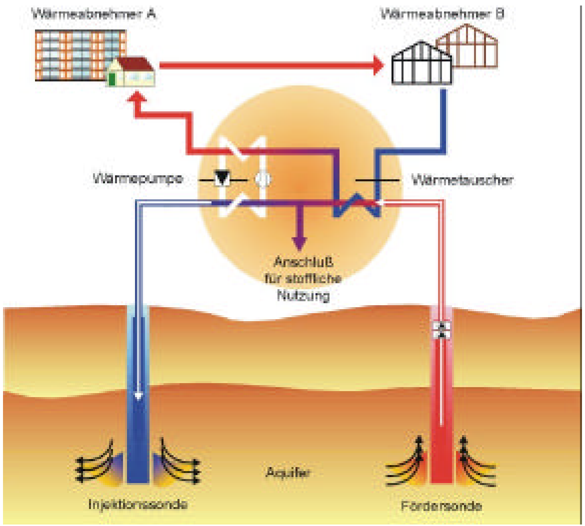

Fig. 11: Hydrogeothermal doublet for district heating; production well (right) and re-injection well (left), both between 500 m and 3500 m deep (graphic: GTN)

In areas with deep, warm aquifers, geothermal energy is well suited for district heating; however, it typically needs some investment support, reduced interest loans, etc. to become economic, as the first cost of the wells are considerable. In desert climates, there can be a considerable heating demand e.g. in high altitude deserts.

Geothermal energy also can be used for greenhouse heating, industrial processes (e.g. fruit drying), absorption cooling, etc. Cascade uses with subsequently decreasing temperature levels (e.g. district heating => industry / thermal spa => agriculture => aquaculture) improve economy, but it is not often to find all demands on one site.

The option of absorption cooling driven by geothermal heat (fig. 12) is of particular interest for desert areas. The first demonstration of this technology operates in Zakopane, Poland, in the local geothermal district heating office, generating 45 kW of cold for air conditioning. A much larger project is under development for a hospital in Izmir, Turkey. Absorption cooling can complement a geothermal district heating system in an ideal way, by making use in summertime of the heat available year-round. The minimum geothermal source temperature to operate an absorption chiller is ca. 80 °C, with better efficieny at 100-110 °C.

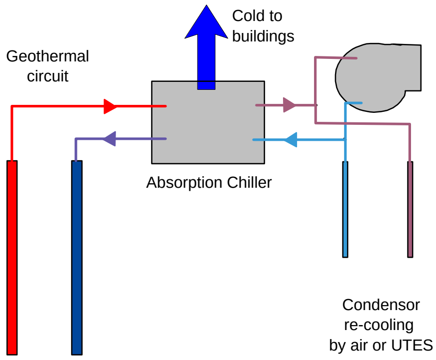

Fig. 12: Schematic of a geothermal absorption cooling system

Geothermal water desalination

Geothermal heat can also be used for desalination purposes. A demonstration is underway on the Greek island of Kimolos, coordinated by the Centre for Renewable Energy Sources in Athens. The main objective of this project is to exploit part of the geothermal potential of Kimolos island for the production of drinking and irrigation water through sea-water or geothermal water desalination, with the intent of achieving water sufficiency for Kimolos island inducing further agricultural, industrial and tourist development on the island.

The desalination method applied is the Multiple-effect Distillation (MED) method with distillation under vacuum in vertical tubes. The unit (fig. 13) will use geothermal heat as the heating and geothermal brine as feed-water medium.

Fig. 13: The geothermal desalination unit for Kimolos island (photo: CRES)

The intention in this project is to demonstrate the technology of producing clear fresh desalinated water from geothermal water on Kimolos island. In parallel investigations on the technical and financial feasibility for further applications in other regions of Greece, the EU and the world are made; next targets are other islands which face significant water scarcity problems, such as Milos, Santorini, Nisyros, Kos, Chios etc.

SHALLOW GEOTHERMAL SYSTEMS

Shallow geothermal installations do not make use of higher temperatures in the underground, but of the steady temperature level throughout the year, and of the thermal storage capacity. Two approaches can be distinguished:

Ground Source Heat Pumps (GSHP):
The low temperature from the ground is transformed into useful energy for heating and cooling by the heat pump

Underground Thermal Energy Storage (UTES):
The temperature in the ground is changed by injecting heat or cold, and this heat or cold can be retreived later; usually seasonal storage (e.g. cold from winter to summer)

The various ways to access the shallow geothermal realm comprise (fig. 14):

- horizontal loops 1.2 - 2.0 m
  depthborehole heat exchangers 10 - 250 m depth
  (vertical loops)
- energy piles 8 - 45 m depth
- ground water wells 4 - 50 m depth
- water from mines and tunnels
- other (standing column wells, etc.)

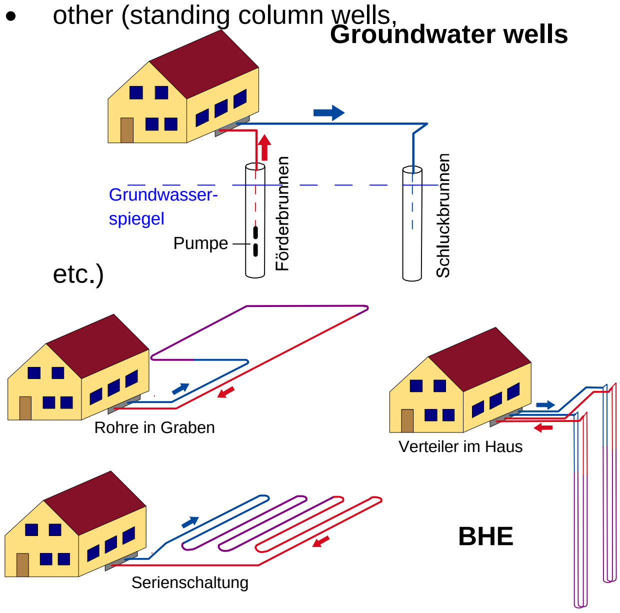

Fig. 14: Various shallow geothermal methods

The basic principle is to extract heat in wintertime from the underground, and to inject heat from cooling in summertime into the underground. Heat pumps (in summer operating as chillers) can transform this low-temperature heat of the ground in both useful heat and cold.
Many residential and commercial buildings (offices, workshops, hotels, etc.) in Europe, North America and East Asia already make use of this technology (in the USA also known as "Geoexchange"). Some, like in Las Vegas or Phoenix, are actually located in desert regions. In Europe, examples can be found from Northern Sweden all the way to Greece, through all climatic zones. An example from Germany is shown in fig. 15, to explain the layout. The system, in the city of Aachen just at the Belgian border, consists of 28 borehole heat exchangers each 43 m deep. Heating and cooling mainly is done through slab heating and cooling (pipes in the concrete floor slabs), adding substantially to a low auxiliary energy input for the heat pump. Ground Source Heat Pumps (GSHP) meanwhile are firmly placed on the markets in many countries.

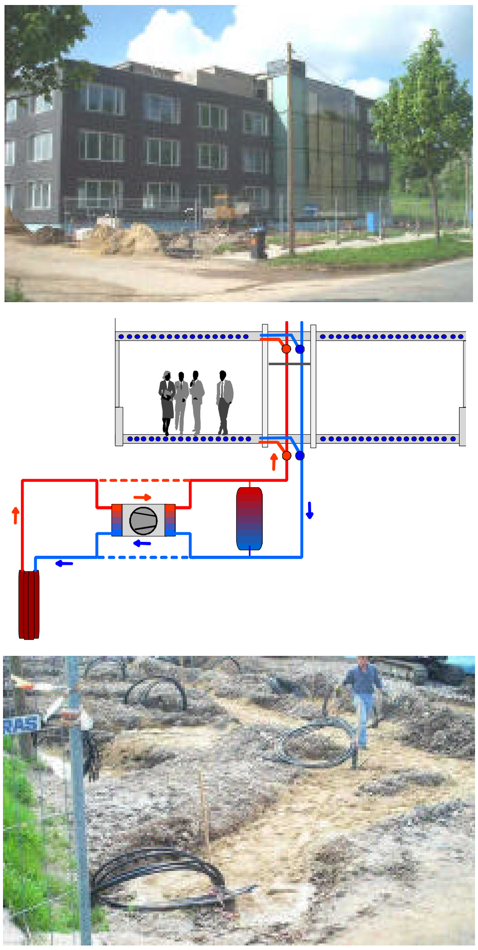

Fig. 15: Office in Aachen, Germany, with ground source heat pump for heating and cooling, and finished borehole heat exchanger field before connections (graphic and photos: EWS)

GSHP are well suited for any climate with substantial temperature changes from summer to winter, from day to night. This is often found in desert regions. It should be noted that GSHP make no sense in tropical regions, and they can have problems and require large layout in very cold areas.
An example for Egypt, in Gizeh, had been investigated by [5]. The temperature distribution (fig. 16) shows the days with average temperatures above and below 20-22 °C.

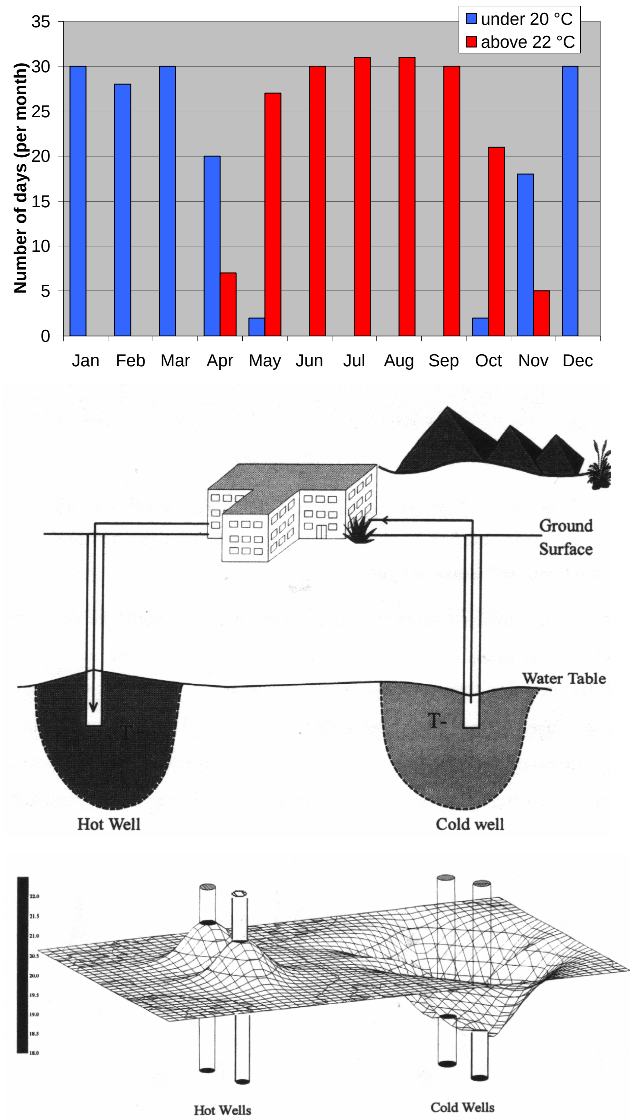

Fig. 16: Feasibility study in Gizeh, Egypt: Days colder than 20 °C (and warmer than 22 °C), suggested system with groundwater wells in delta sediments, and a result from the numerical simulation of the area

SITUATION IN JORDAN

Some words on the existing possibilities in Jordan (mainly from [6]):
Hot springs from 30-60 °C are known since ancient times in the Dead Sea region; the water is found in

lower Cretaceous sandstones, but is uprising from deeper layers along fault zones. In the Eastern desert, near the border to Syria and Iraq, drillings in upper Cretaceous limestones revealed another geothermal reservoir. The highest temperatures proven geochemically are up to 115 °C at reservoir depth (not yet accessed by drilling).

Best explored is the Zarqa Ma'in - Zara thermal area at the Eastern Dead Sea escarpment. Current use of geothermal energy in Jordan is for spas only, however, plans exist already to use the resources for greenhouses and other agricultural applications (incl. fish farming and absorption cooling for cooled warehouses), and for water desalination.

Recent interest concerns shallow geothermal technologies for heating and cooling of buildings (offices, hotels, etc.). The experiences from Europe and USA in that field could help to develop applications adapted to the climatic and geological conditions prevailing e.g. in the Greater Amman or Zarqa areas. Two papers at this conference deal with shallow geothermal ideas in Jordan (Al-Sarkhi et al., Akash et al.).

CONCLUSIONS

Geothermal Energy is widely used in the world, for power production, direct heating (and cooling), and shallow geothermal for heat and cold. In desert climates, all sectors can exist, and owners might make use of this renewable energy.
However, the most interesting applications for most desert regions are the generation of electric power, desalination (mainly if water from sea or deeper aquifers is used), and shallow systems for heating and cooling.

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