ATLAS OF GEOTHERMAL RESOURCES IN EUROPE

Suzanne Hurter, Ernst Huenges, Christoph Clauser & Ralph Hanel

NLfB-GGA, 30631 Hannover

Key words: geothermal resources, atlas, Europe

Abstract

A new edition of the Atlas of Geothermal Resources in Europe is being prepared. The characteristics and status of this project are reported here. At present 26 countries are contributing maps of temperature, depth, thickness and geothermal resources for relevant aquifers besides other ancillary information. Resources for porous aquifers are estimated according to an uniform procedure described herein ensuring that different areas may be compared to each other.

Introduction

The 1988 Atlas of Geothermal Resources in the European Community, Austria and Switzerland presented maps of that part of the geothermal energy resource base which could be exploited now or in the near future. The participants were European Union (EU) member states Belgium, Denmark, the former Federal Republic of Germany, France, Greece, Ireland, Italy, The Netherlands, Portugal, the United Kingdom and non EU countries Austria and Switzerland.

The recent changes in Europe permit the presentation, for the first time, of resources for almost all European countries in an uniform format. Moreover, the increase of interest in long term use of renewable energies, particularly those contributing with minimal stress to the environment, makes this re-assessment of geothermal resources a timely undertaking. An updated and extended Atlas of Geothermal Resources in Europe will provide government agencies and decision makers at various levels with the information needed for planning in the energy supply domain. Within its "JOULE II" program the European Union has approved means to:

- revise the contributions of the 1988 Atlas, extend the scope, and incorporate new data were available;
- prepare existing data in the Western Europe member states of the EU and countries, which are not membes of the European Union;
- incorporate results from a parallel project in Eastern Europe (also funded by the European Union); and
- prepare the collected data and maps for publication.

The EU funds support directly 14 partners of 11 EU member countries (Belgium, Denmark, France, Germany, Greece, Ireland, Italy, The Netherlands, Portugal, Spain, the United Kingdom) and 8 Eastern and Central European countries (Bulgaria, Czechia, Hungary, Latvia, Lithuania, Poland, Romania and Slowakia). The remaining partners find support from their own funding agencies for preparing their contributions. EU funds will then take over the publishing costs of the complete atlas.

Project organisation

Prof. Hanel (**NLfB,** Niedersachsen Geological Survey, Hannover Germany) co-ordinates the project. The Camborne School of Mines Associates Limited in Cornwall, United Kingdom, handles the administrative aspects of Eastern Europe, funded by EU. The contributions are prepared specifically for each country generally by geothermal experts of universities, geological surveys, and a few specialised private companies. Individual work programmes are set up by each partner together with the NLfB.

Project activities initiated on 01/02/94. Until December 1994 working programmes for contributions of the following countries had been defined:

> Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, The Netherlands, Poland, Portugal (including the Azores), Romania, Russia, Slovakia, Spain, Sweden, Switzerland, Ukraine and the United Kingdom.

Work programmes are in discussion for the following countries:

> Albania, Austria, Belarus, Bosnia-Herzegowina, Iceland, Macedonia, Norway, Serbia, Slowenia and Turkey.

Project duration is planned to extend over 32 months.

Resource estimation of the aquifers

Considerable efforts are being made to make data of different countries comparable for mapping, particularly across boundaries. Hence a common procedure for the thermal resource estimation was established for all participants. Parameters used in these calculations include temperature-depth distribution, hydrogeological, and structural factors.

Under conditions found in sedimentary structures, fluid extraction is governed by hydraulic conductivity or transmissivity. Unfortunately, it is not usually possible to determine hydraulic conductivity during regional exploration because borehole and expensive pumping tests are necessary. However, it is relatively easy to estimate the effective porosity. Therefore, the assessment of resources is based on the effective porosity.

The main data necessary for resource assessment of a particular aquifer are the thickness Az, the temperature T_t and the effective porosity P. The depth of the aquifer is also an important parameter because it determines the drilling cost. Data which can be generally readily obtained are the densities ρ_m, and ρ_w and the specific heat capacities c_m and c_w of the rock matrix and water, the aquifer area A, and the mean annual surface temperature T_0. Other parameters, such as permeability, transmissibility, salinity and others are of value in refining the assessment of the resource, and their knowledge is essential to an evaluation of reserves.

In order to obtain an estimate of the total heat content of an area at a depth that can be economically drilled, the accessible resource base down to 7 km (ARB,) is determined from the following simple equation:

$$ARB_7 = V \rho c \frac{(T_7 - T_0)}{2} \quad (1)$$

where

ARB_7 = Accessible Resource Base down to 7 km depth, J
V = volume from the Earth's surface to 7 km depth, m^3
ρ = mean density of the rock column, kg/m^3
c = mean specific heat capacity, $J\,kg^{-1}\,K^{-1}$
T_7 = temperature at 7 km depth, °C
T_0 = surface temperature, °C.

The heat in place (H_0 in Joule) contained within a given aquifer can be determined using a volume model of heat extraction:

$$H_0 = [(1-P)\rho_m c_m + P\rho_w c_w][T_t - T_0] A\,\Delta z \quad (2)$$

where :

P = effective porosity, dimensionless
T_t = temperature at the top of the aquifer, °C
Az = net thickness or thickness of the aquifer, m
A = surface area under consideration, m^2.
ρ_m = mean density of the rock matrix column, kg/m^3
c_m = mean specific heat capacity of the rock matrix, $J\,kg^{-1}\,K^{-1}$
ρ_w = mean density of the aquifer fluid, kg/m^3
c_w = mean specific heat capacity of the aquifer fluid, $J\,kg^{-1}\,K^{-1}$

Obviously only a fraction of H_0 can be recovered. This is expressed by a term called the "recovery factor" R_0. The identified resource H_1 is given by the product of R_0 and H_0, commonly abbreviated to "resources". In most cases, the water has to be reinjected after use, either because it is highly saline or because there is a need to maintain pressure in the aquifer. The empirical expression for the identified resource at the wellhead for a doublet (i.e. a related pair of extraction and injection wells) is:

$$H_1 = R_0 H_0 \quad (3)$$

with:

$$R_0 = 0.33 \frac{(T_t - T_r)}{(T_t - T_0)} \quad (4)$$

where :

T, = temperature of the reinjected water, °C.

For reasons of comparison the EU expert group recommends that a value of T, = *25* °C be used in these calculations. If a single production well (without reinjection), i.e. a singlet, is considered, the recovery factor is defined as:

$$R_0 \approx 0.1 \quad (5)$$

Only part of the geothermal energy resources can be exploited economically at present. A specific recovery factor R_1 is introduced to account for this. The proven reserves at wellhead, H_2, commonly abbreviated to "reserves", are:

$$H_2 = R_1 H_1 \quad (6)$$

The recovery factor R_1 is difficult to determine. It depends on site-specific geological conditions as well as on the cost of the installation of a singlet or doublet, which could vary from country to country. The recovery factors defined in (4) and *(5)* are recommended as guideline values. In special cases, however, each country's expert group is free to specify a suitable recovery factor R.

Although this project smves for uniformity of procedures and representation, some diversity has to be accommodated due to particular geological or technical conditions. All procedures that differ from the general recommendations will be described in the accompanying text of the atlas. One such situation occurs where geothermal resources are associated to volcanic systems, i.e. aquifers in fractured media, e.g. Island and the Azores (Portugal). Here structural factors play an important role defining not only the geometry and extent of the aquifer itself, but also its porosity and permeability. At present there are no uniform procedures for estimating resources and reserves in these cases. A discussion of this problem is being held with the countries possessing geothermal resources under such conditions.

Expected contributions

Although the format of the previous edition of the Atlas will be maintained, no previous maps will be repeated. Focus is upon new information and significantly improved resolution of the data especially for those partners included in the previous atlas. Each partner in this project is providing a set of maps depicting depth, thickness, temperature at the top of the aquifers of interest and the resources calculated as recommended. Furthermore this information is enriched by cross-sections of the potential aquifers. A general map of each country containing some of the major geological and tectonic features and potential areas, as well as maps of temperatures at different depths set the context for the regional aquifer maps. The accompanying text explains the maps, elucidates procedures that differ from the recommended ones and describes the present status and future perspectives of geothermal energy utilisation. Tables of heat flow density and geothermal springs and installations constitute complementary information.

The following number of sets of aquifer maps are expected for the update of the Geothermal Resource Atlas in Europe:

scale:	number:
< 1 : *250* 000	35
1 : *250* 000 - 1 : *500* 000	40
> 1 : 500 000	*5*

Conclusion

The increase of information and the shifting of a few political boundaries since the completion of the 1988 Atlas of Geothermal Resources in Europe makes an update of this atlas a timely project. It will provide basic planning information on the availability of geothermal energy in most of Europe to government and industry. The new edition will be much extended in scope, including almost twice the number of counmes (26) as in the previous version. Geothermal resources are calculated according to a uniform procedure for potential areas in porous media. For the fust time, also potential areas associated with volcanic systems will be represented, for which there is yet no uniform procedure for assessing geothermal resources.

REFERENCES:

Hänel R.and Staroste, E. (1988) *Atlas of Geothermal Resources in the European Community Austria and Switzerland,* Verlag Th. Schafer, Hannover, 110 plates.