

## A FUTURE FOR INDUCED GEOTHERMAL ENERGY?

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### ABSTRACT

The possibility of using geothermal energy in non-volcanic, normal areas is discussed. An attempt is made to apply this concept to the Netherlands, where the geothermal gradient is in general above the world's average.

If geothermal heat production from non-volcanic areas will ever be feasible, technologically or economically, is still very uncertain.

### INTRODUCTION

The energy crisis, real or imaginary, has become a prominent economic and political issue. Up till now this has mainly been treated in terms of proven and non-proven (probable and possible) reserves in relation to the trends of energy consumption, but recently the emphasis is shifting. The oil-producing countries are arriving at the conclusion that the rate of inflow of foreign exchange is faster than their economies can reasonably absorb. They may well decide to keep their oil-production at a more or less constant level, which is optimal for their economic development, instead of trying to meet the growing energy demands of our technological society by adjusting their production to these demands. This way the income from oil can be stretched over a longer period, and be more profitable to their national economies.

Secondly several major oil-producing countries are using their oil potential and production as a means to exert political pressure. In addition most of the means of energy production cause considerable pollution, chemical as well as thermal. In the light of such considerations it is understandable that a search is made for alternative sources of energy.

### GEOTHERMAL ENERGY

Although the heat production within the earth is only a small fraction of the energy the earth receives from the sun, still very large amounts of energy are involved. The annual

global heat-generation by the decay of naturally occurring radioactive elements, mainly <sup>40</sup>K, Th, and U, is of the order of  $2 \times 10^{20}$  cal, which exceeds the annual world consumption of energy, estimated at some  $7 \times 10^{19}$  cal for 1975, according to S e l d e n r a t h, 1972.

In view of the fact that rocks are very poor conductors of heat, and that the density of heat-production is very small, geothermal energy must be treated as a non-renewable heat source. Even a fairly radioactive rock like granite, containing 4 g/ton uranium, and 15 g/ton thorium, yields only  $6 \times 10^6$  cal/g.yr. This means that if we extract energy from a hot rock-body at some depth by cooling it, we cannot repeat the same procedure for the same body within any reasonable time.

In addition to the use of "active" geothermal energy in volcanic areas, as practiced a.o. in Iceland, Italy and New Zealand, there is now a report (New Scientist, 1973) that Soviet scientists have made studies to tap the Earth's subterranean heat in non-thermal areas. Essentially this will involve pumping down cold water in one well, having it pass a zone of hot rocks at depth, and pumping it up through another well as hot water.

It is still very doubtful if such a method is technologically and economically feasible. In order to see if feasibility studies should be undertaken at all, it is worthwhile to find out first what the order of magnitude of extractable geothermal heat would be. Purely as a hypothetical approach, let us try to do so for the Netherlands. The surface of the Netherlands is 31.500 km<sup>2</sup>, of which we will assume that about 5% exhibits the right geological conditions to permit induced geothermal heat production. In these favourable areas a temperature drop of 20°C will be permitted in a rock column of 1 km thickness. With geothermal gradients between 35° and 40°/km, as encountered in parts of the Netherlands, geothermal heat production would center around 3 km depth, and involve temperatures between 100° and 150°C.

Rocks have on the average a specific heat of 0.5 cal/cm<sup>3</sup>. This means that for the Netherlands the extractable geothermal energy would be of the order of

$$1.500 \times 10^{15} \text{ cm}^3 \times 20^\circ\text{C} \times 0.5 \text{ cal/cm}^3 \cdot ^\circ\text{C} = \\ = 1.5 \times 10^{19} \text{ cal.}$$

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This figure is of an interesting order of magnitude, as the annual energy consumption for the Netherlands for 1975 has been estimated at  $7 \times 10^{17}$  cal (S e l d e n r a t h, 1972).

The induced geothermal energy can certainly not be extracted in a very short time. Even if all technological and economical difficulties prove surmountable, the energy production is likely to be a matter of several tens or even hundreds of years. Exploitation must take place in extraction units (of  $\sim 1 \text{ km}^3$  ?), the Russian estimate for the lifetime of one extraction unit being 10-15 years.

Even if spread out over several hundred years, an extra energy supply of  $1.5 \times 10^{19}$  cal. would constitute a sizable contribution to our pattern of energy consumption.

Especially if we can use this energy directly in the form as it is supplied, i.e. as hot water, or steam under low pressure (a few atm. at most) for heating purposes (greenhouses, central heating systems for complete towns), we would of course increase the efficiency of the energy extraction. Energy consumption for heating purposes makes up slightly less than 20% of the Dutch energy consumption at present. It should be noted here, however, that even now the thermal waste water of our electricity plants are hardly used yet for such purposes, although this would conceivably be cheaper (S e l d e n r a t h, written comm., 1973). If the heat of thermal waters must be converted into other forms of energy, the efficiency will be low, because we are dealing with low-level energy sources.

#### SOME ADDITIONAL SPECULATIONS

The geothermal gradient in the Netherlands is not low, contrary to what one might expect from a region which is broadly speaking a region of subsidence and sedimentation. Only in the northeastern part of the country the geothermal gradients are systematically somewhat below  $30^\circ/\text{km}$ , which is the world average. This may be due to the presence of anhydrite and rocksalt which have fairly high thermal conductivities.

Gradients in other parts of the country, and on the Dutch part of the North Sea shelf are generally in excess of  $30^\circ/\text{km}$ , locally reaching values as high as  $44^\circ/\text{km}$  (written communication NAM, and T h i a d e n s, 1963). This means that a well may reach rock-temperatures of  $100^\circ\text{C}$  already at a depth of 2 km, assuming the average surface temperature to be  $12^\circ\text{C}$ . It is not excluded that a careful directed search for

thermal anomalies will reveal even higher gradients in some part of the Netherlands. If ever the Dutch government would decide to undertake, in conjunction with Dutch oil interests, a feasibility study of induced geothermal energy extraction, a detailed study of the thermal structure of the Netherlands will be one necessary prerequisite.

Subsidence as a result of cooling is relatively small; a rock column of 1 km length will shrink about 1 cm for every  $^\circ\text{C}$  of cooling. Taking the approximate figures used above of a  $20^\circ\text{C}$  temperature drop in extraction units of  $1 \text{ km}^3$ , this would involve a maximum subsidence of 20 cm.

#### CONCLUSIONS

It is yet impossible to say if induced geothermal heat extraction is technologically or economically feasible. Its possibilities should be explored, because also from an environmental point of view the technique would be almost ideal. It will offer no solution to the energy crisis, but may help to alleviate the energy problems with which the world will be faced. Technological feasibility studies will need detailed data on the hydrogeological properties of the deep subsurface, as well as a knowledge of geochemical interactions at depth. The most important technological problems will probably center around the artificial increase of permeability in the extraction units.

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