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GEOTHERMY AND ITS FUTURE IN INDONESIA

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R I N G K A S A N

Konsep dasar dari suatu medan uap alam komersil diperbincangkan dan didefinisikan. Berdasarkan pada diskusi tersebut daerah-daerah dengan potensi geothermy dicantumkan ke dalam peta. Ternyata bahwa tak kurang dari 24 medan hyperthermal tersebar di seluruh wilayah Indonesia yang berkemungkinan untuk dapat dieksplorasikan lebih lanjut. Sayang sekali bahwa sangat sedikit yang diketahui mengenai potensi Indonesia sesungguhnya dalam bidang ini.

Menghadapi permintaan tenaga listrik yang semakin menanjak dalam rangka pengembangan program industrialisasi Indonesia dan terbatasnya persediaan bahan bakar fossil, pengarang menganjurkan agar semua segi dan kemungkinan pemanfaatan segala macam sumber energi, termasuk geothermy, dijajaki sejauh mungkin.

A B S T R A C T

The basic concept of a commercial steamfield is discussed and defined in this paper. Based on this discussion potential areas are indicated in a map. It is found that not less 24 geothermal areas are prospectable. However, it is found that very little is known about the exact potential of Indonesia in the field of geothermy.

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Anticipating the rising demand in electricity within the context of the broader industrialisation program of Indonesia and the limitation of its fossil fuel reserve, it is suggested that all possibilities for utilising different kinds of energy, including geothermy, should be explored as far as possible.

INTRODUCTION

This paper is an attempt to expose the basic principle of geothermy and the possible potential of Indonesia in this field. Its further implication to the future industrial development program is also mentioned.

The basic principle of geothermy exposed in this paper is partly built on the concept of Facca and Tonani (1961, 1964) and also based on the author's own findings in the Dieng Mountains, in the Kamodjang Solfataric fields and the thermal fields in Sumatra.

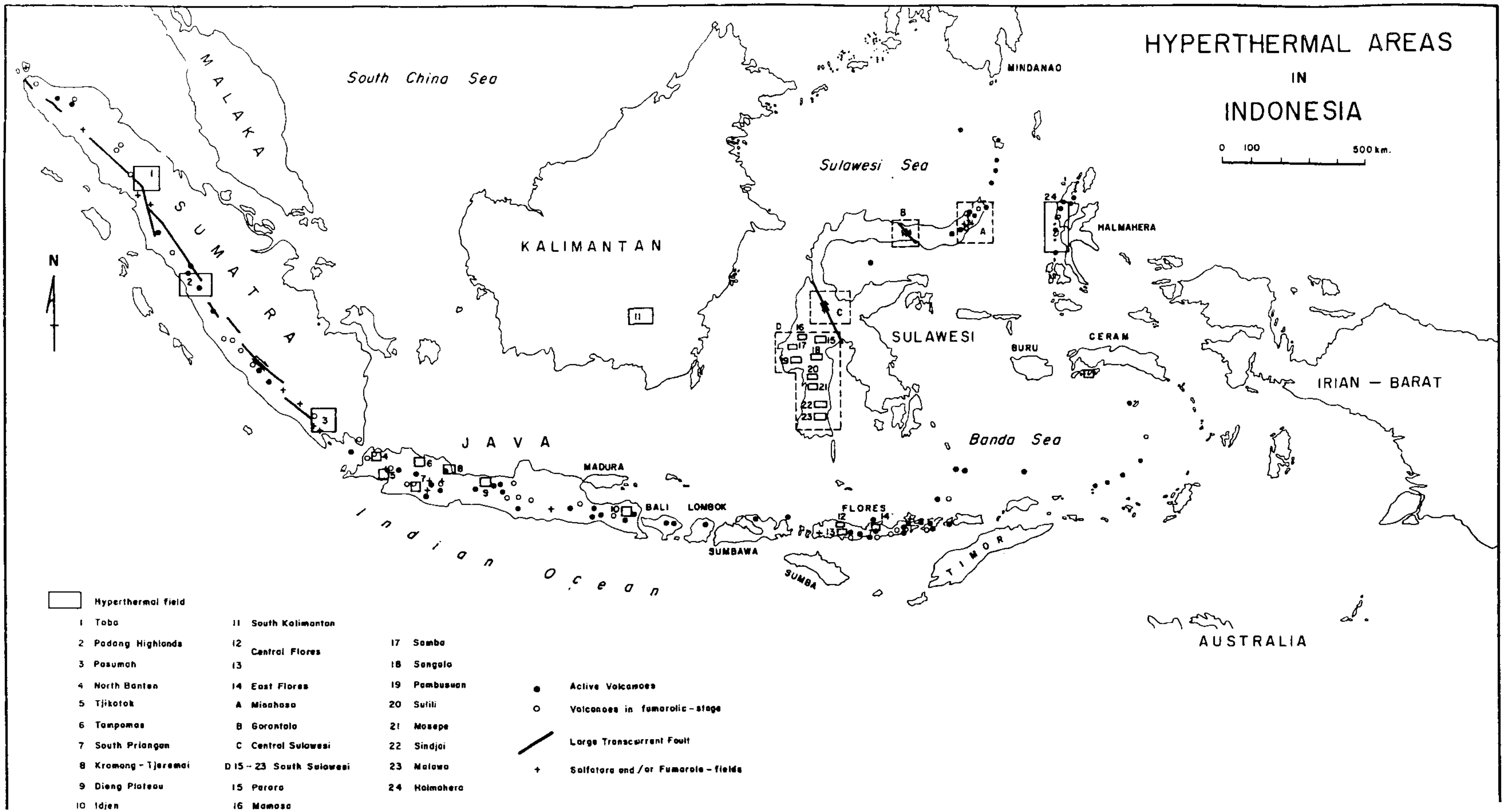
Though several geothermal surveys were made and the Dieng Geothermal Project has started the author is of the opinion that not enough attention has been paid to geothermy. Indonesia is endowed with so many volcanic areas. At least Indonesia should start to find out what benefit she can get from it.

The map in Plate I is based on the information collected by the author during his recent visit to Irian and Sulawesi. The thermal fields of Northern Sumatra, the Padang Highlands, and Southern Sumatra were visited in early 1972, Kalimantan in 1971, Flores in 1969 (through the aid of the Institute of Power Research in Jacarta), whereas the thermal fields of Java have been visited for the so many times.

CONCEPT AND DEFINITION OF A COMMERCIAL STEAMFIELD

General Statement

Before a lengthy discussion of the potential areas in Indonesia is attempted the author think it is fruitful to discuss the fundamental concept of a commercial steamfield since this concept has changed so much with the development of modern geothermy. The history and development of the attempt to utilise natural steamfield for commercial purposes in Indonesia has been discussed by the author in his previous papers (Zen, 1968, 1970, 1971).


HYPERTHERMAL AREAS
IN
INDONESIA
0 100 500 km.
South China Sea
Sulawesi Sea
Banda Sea
Indian Ocean
MALAKA
SUMATRA
KALIMANTAN
JAVA
MADURA
BALI
LOMBOK
SUMBAWA
SUMBA
FLORES
TIMOR
SULAWESI
BURU
CERAM
HALMAHERA
MINDANAO
IRIAN — BARAT
AUSTRALIA
N
Hyperthermal field
1 Toba
2 Padang Highlands
3 Pasumah
4 North Banten
5 Tjikotok
6 Tampomas
7 South Priangan
8 Kromong - Tjeremai
9 Dieng Plateau
10 Idjen
11 South Kalimantan
12, 13 Central Flores
14 East Flores
A Minahasa
B Gorontalo
C Central Sulawesi
D 15 – 23 South Sulawesi
15 Parara
16 Mamasa
17 Samba
18 Sangala
19 Pambusuan
20 Sulili
21 Masepe
22 Sindjai
23 Malawa
24 Halmahera
Active Volcanoes
Volcanoes in fumarolic - stage
Large Transcurrent Fault
Solfatara and / or Fumarole - fields

Definition and Description of a Commercial Field

Definition. By definition energy is that entity that enables man or machine to perform some work. It may change through a wide variety of forms, but it can not be destroyed. When it disappears in one form it reappears in another. Heat, light, electricity, forces of motion and sound waves are all different manifestations of that one fundamental entity called energy.

Most of the energy used by man on the surface of the earth originates as solar energy or radiant energy of sunlight whereas *all sources of subsurface natural heat that can be utilised for practical purposes produce geothermal energy.*

However, the definition just given has a very wide meaning. It covers not only the actual but also the future possibilities of practical use of natural heat. It is very likely that in the future every kind of geothermal energy will be of practical value. At present, however, only the natural steam can be utilised economically for industrial development.

First of all we have to define what a natural steamfield is; the next step is to define the physical requirements which a natural steamfield should have in order to be able to support an industrial development commercially. In other words, a commercial steamfield should be defined first.

In this paper a natural steamfield is defined as an area in the earth crust where sufficient natural steam can be produced by drilling to support an industrial development.

This implies that the interest of geothermy is limited to the steamfield that can produce large quantities of energy commercially. Since exploration costs are high a lower limit should be set for the commercial interest and this means that a field producing less energy than the certain quantity set up by the limit is not classified as a commercial natural steamfield.

Many economic and technological factors are involved in defining this lower limit. With the conditions prevailing at present and the technological progress we are in, *it can be safely stated that a steamfield which has the capacity of producing half a billion of Kwh per year is a field which can produce 5 million of tons of steam at a pressure of 5 atmosphere or more, and with a minimum temperature of 150°C* (Facca and Tonani, 1961). This definition is important since it provides a base by which a geological conditions and environment can be defined which might produce steam in such a quantity.

Geologic Conditions and Environments of a Steamfield

The most essential geologic condition to produce a steamfield is a heat source. However, just a heat source is not enough. It should be in a geologic environments such that a kind of a trap can be formed to produce steam in commercial quantity.

Many geologic phenomena can act as a source of heat such as faulting and geochemical reactions. However, the quantity of heat generated in such a way usually can never reach the defined requirements of a steamfield. The most likely geologic process which is capable to provide sufficient quantities of heat is the mobilisation of subcrustal heat stored up in deep seated magma.

Upwelling of basaltic magmas, processes of magmatic evolution and the genesis of volcanoes are geologic events in which a transfer of heat from the deepest part to the upper layers of the earth crust are involved.

Based on this, the natural steamfields now in production are classified into 3 main types. These are:

1. Larderello Type) Italy
2. Mount Amiata Type)
3. Wairake Type New Zealand

1. The Larderello Type of a steamfield is one of which the heat source is a granitic pluton, seated at an unknown, but not at a very great depth. It is a magmatic body, a batholith or lacolith, which has come very close to the surface but without having any direct communication with the surface.
2. The Mount Amiata Type is a steamfield generated by a magmatic body which has reached the upper part of the crust with sufficient energy to give birth to a distinct volcanic manifestation in the form of pliocene or quaternary volcanoes which are extinct at present.
3. The Wairake Type is a steamfield which is distinctly connected with an active volcano.

Based on the three models we can define 3 favorable areas for steam exploration, and these are:

1. Areas with relatively shallow intrusions
2. Areas of recently extinct volcanoes
3. Areas around active volcanoes.

Petroleum geology a firm knowledge of the sedimentary basin is essential for an exploration program since it enables us to make a scientific, rational choice of potential areas, whereas the theory of hydraulics will help us to locate more exactly the probable single exploratory well. This is also valid in setting up a geothermal exploration.

In this way it can be stated with certainty that actual surface shows are no longer necessary condition for the choice of a drilling site. However, they are very useful from a regional point of view. This concept of course alters drastically the method and technique of a geothermal exploration program.

Conditions and Environments for Heat Accumulation

We have previously defined the heat source necessary to generate a steamfield. A heat source is a basic prerequisite. However, it is not sufficient.

The most ideal geologic condition and environment of a steamfield is such that we encounter a source's cap rock, a productive aquifer and an aquifer cap rock such as illustrated in Fig. 1.

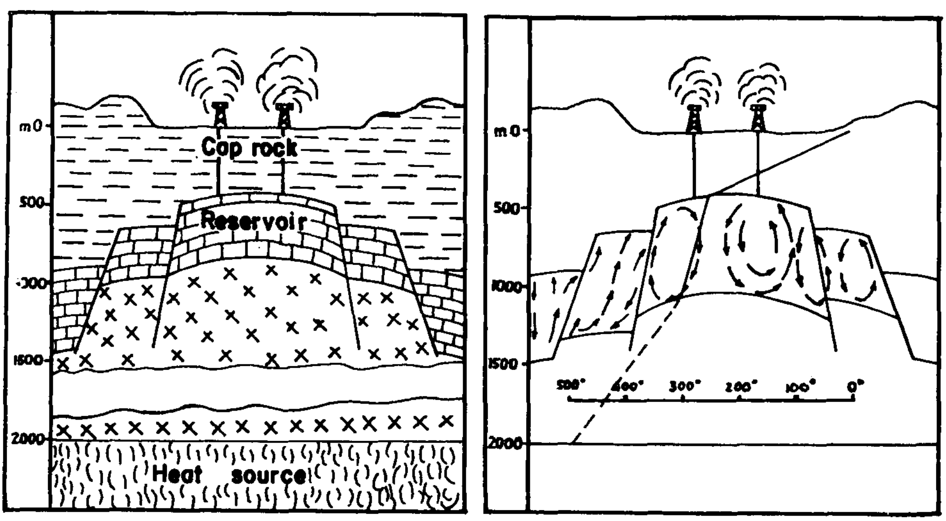


Fig. 1. Scheme of an ideal geothermal field according to Tonani et al., 1964.

Right on top of the heat source there is a source's cap rock which consists of an impervious series overlying the magmatic body. In reality it is the magmatic body and the overlying impervious body which make out the heat source.

On top of the source's cap rock there is a very pervious and porous reservoir which is called the productive aquifer. This layer again is overlain by an impervious layer which is called the aquifer cap rock. The productive aquifer is sandwiched in between two impervious sequences.

The situation must be such that in the previous horizon of the source's cap rock the thermal conductivity is raised and the thermal gradient is lowered caused by the thermal convection, and also vice versa in the impervious horizon. In this way the highest possible temperature for the top of the permeable series is assured.

The top surface of the source's cap rock should enable a steady and upward flow of heat. The water of a productive aquifer is heated at the bottom. If the permeability is high and if the thickness of the productive aquifer is sufficient, convection currents will originate and assure an upward transfer of heat (Facca and Tonani, 1961). All the water of the very pervious aquifer is heated, whereas the temperature at the top of the pervious layer is not so different from the temperature at the bottom. The heat transfer, assured by the convection currents, occurs in an entirely different way than the heat transfer in the impervious beds. In the pervious beds the strong convection aqualises the top and bottom temperature of the fluids.

Whereas in the impervious beds where no fluids movement is possible the temperature increases with depth at the high rate stated by the low conductivity of the rocks and by the total high flow of heat. Therefore the temperature at the pervious bed happens to be high in this case (Facca and Tonani, 1961). In other words, a commercial steamfield is a trap for the convection geothermal currents generated by a sufficient heat flow (Facca and Tonani, 1961).

Prospectable Areas in Geothermal Exploration

Based on the classification of present day operating geothermal fields, the prospectable areas of natural steamfields are:

(i) fields connected with shallow intrusions
(ii) fields linked to present day active volcanoes
(iii) fields linked to recently extinct volcanoes.

Areas of active and extinct volcanoes are very easy to locate. However, there are so many areas of recently extinct volcanoes so that something more elaborate has to be said. In this respect, all areas of extinct volcanoes with some signs of post volcanic activity (Kamodjang solfatara field in western Java) are considered prospectable; without such signs all quaternary and pliocene volcanic areas are prospectable. Nothing can be said at this state about pre-pliocene volcanoes, however, if there is some evidence of actual thermal activity, this area deserves further investigation.

A geologic environment with a high probability for finding a steam trap is when a thick sedimentary series are being pierced by a volcano. In this case the subsurface geological sequence with its pervious and impervious layers can be forecasted better. The geological as well as the geophysical information are more reliable so that the choice of a rational location for the exploratory well will be not so difficult. In an entirely volcanic series, like in the Dieng volcanic mountains (Central Java), the pervious and impervious strata can only be ascertained by drilling (Zen, 1971). In this case neither can there information be obtained about the lateral extend of the different volcanic facies.

Like in petroleum exploration geologic and geophysical methods can be applied such as gravimetry, magnetometry, geoelectricity and seismometry. The most successful method in delineating hot water reservoir is the geoelectric method (Zen, 1971) aided by a geochemical investigation. The most recommended geophysical procedure to be used in delineating a hot-water reservoir up till now would be profiling with direct current resistivity method, combined with direct current resistivity soundings to depths of the order of 3 Km (Banwell, 1970).

POTENTIAL AREAS IN INDONESIA

The Volcanic Geology of Indonesia

After the basic concept of geothermy has been explained we can now attempt to define potential geothermal areas in Indonesia. However, some understanding of the volcanic evolution in Indonesia will be a very valuable aid in this attempt.

In Indonesia, not less than 128 active eruption centers are found, of which 78 have erupted since 1600, 29 are in solfataric stage and about 21 are solfataric fields which are not obviously connected with a volcano, whereas the number of volcanoes which are in a more or less advanced stage of exhaustion and disintegration is much greater; it exceeds 500. However, the volcanic activity we witness taking place around us now is part of a phase which commenced in the Quaternary. Before, several phases were known. However, phases of volcanism did not start at the same time all over the islands (Table 1 - 2).

In Java, the latest and third cycle of volcanism started in the Quaternary and lasted until the present time. It is very interesting to note that some Quaternary volcanic activity in Java with leucite-bearing ejecta occurred along the north coast of the island, namely in the sedimentary basin of the island, where the volcanic channels pierced through the thick young sedimentary strata. However, no potential areas have been found as yet along this zone.

The volcanoes in the Indonesian Archipellago are arranged in a number of zones. The zones form generally the inner arc of mountain systems; their outer arcs are non volcanics. One typical example is the Sunda Mountain System. Its volcanoes are situated on the axis of a large anticline which stretches from the Barisan Mountains in Sumatra through Java to the Lasser Sunda Islands. The non-volcanic outer arc runs through the islands west of Sumatra and the submarine ridge which cuts the trough south of Java into two. In northern Moluccas, two zones of active volcanism are found, whose complex sides face each other with one non-volcanic outer arc in common.

Potential Areas

Areas of greatest potentials in Indonesia are the area along the Semangko Rift Zone in Sumatra, Java, Central Flores, South and Northern Sulawesi, Halmahera and several others (see Plate I). Very little is known about the thermal springs in Kalimantan; Bali has recently been investigated (not indicated in Plate I) and nothing is known about West Irian.

Though several geothermal surveys have been made (Zen, 1967) the real and exact potential of Indonesia in the field of geothermy is not known. One United Nation expert put the geothermal potential of Java as high as several thousands of Megawatts (Meidav, 1972).

Of the so many potential areas only the Volcanic Complex of Dieng in Central Java has reached its exploratory drilling state, whereas the Kamodjang Solfatara field in West Java might be explored and investigated more in detail by a combined New Zealand - Indonesian team.

As of now quite a lot of attention is paid to several areas in Java. However, the potentials of Sumatra and Sulawesi remain practically unknown. It is the author's opinion that inventarisation of data of those respective areas should be done as quickly as possible. A fair geologic map on a scale of at least 1:250.000, with a more detailed information on geothermy should be available in order to make these areas attractive for future investment in this field.

Table 1. Evolution of the Meratus Mountains in south-eastern Borneo (according to Van Bemmelen, 1954, p. 70)

Orogenesis	Volcanism and plutonism
3rd impulse of uplift in Plio-Pleistocene times.	No external volcanism. The erosion has not yet sufficiently far progressed to establish the presence or absence of concomittan granite intrusions.
Quiet subsidence in Tertiary times	External volcanism persists into Eocene times.
2nd impulse of uplift at the end of Cretaceous times	External volcanism of the Pacific suite. The quartz dioritic fillings of vents are at present exposed.
Quite subsidence in Middle and Late Cretaceous times	No external volcanism.
1 st impulse of uplift in Early Cretaceous times	No external volcanism. Granites intruded into the basic plutonites of the ophiolitic suite.
Subsidence in Jurassic times.	Formation of ophiolitic intrusions and extrusions.

Table 2. Evolution of the Barisan Mountains in Sumatra (according to Van Bemmelen, 1954, p. 71).

Orogenesis	Volcanism and plutonism
3rd impulse of uplift in Plio-Pleistocene times	Revival of the external basalto-andesitic volcanism. Intruding granites (3rd generation) caused violent eruptions of dacitic and rhyolitic pumice, e.g. those of Ranau and Toba.
Quiet subsidence in Mio-Pliocene times	External volcanism, mainly of basaltic and andesitic composition.
2nd impulse of uplift in Middle Miocene times	Violent eruptions of dacitic and rhyolitic pumice, especially along the Semangko fault zone on the top of the geanticline, are associated with the intrusion of granites (2nd generation).
Quiet subsidence in Oligo-Miocene times	Strong volcanic activity, mainly of basaltic and andesitic, but sometimes dacitic composition. Produced the "Old Andesite formation".
1st impulse of uplift in Late Cretaceous and Early Eocene times	No external volcanism. Intrusion of granites (1st generation).
Geosynclinal subsidence, especially in Late Mesozoic times (geosynclinal foredeep of a mountain chain N.E. of the Barisan Zone.	Ophiolitic rocks intrude the geosynclinal sediments, e.g. in the Garba and the Gumai Mountains in southern Sumatra.

GEOTHERMY AND ITS IMPLICATION TO THE FURTHER INDUSTRIAL DEVELOPMENT IN INDONESIA

Complete data on the resource of energy of Indonesia and its consumption pattern is not available. At this stage it can be said that the lignite reserve is estimated at roughly 6 billion metric tons, coal at 500 millions tons (recent exploration not included), natural gas at 43 billion cubic meters (Arismunandar, 1972). Anticipated oil production before 1980 will be around 3 million barrels a day. Total Hydropower capacity is estimated at 28.000 M W, whereas the geothermal potential of Java only is estimated as high as several thousands of megawatts. It is further estimated that the demand for electric power will reach 5100 M W in the year 1990 (Hoesni, et al, 1971).

Because of its relatively low cost geothermal power is competitive as a source of energy. However, geothermal energy is not free energy. Capital as well as coordinated efforts should be invested in this field in order to obtain a clear picture as to what extent it can play a role in the industrial development planning in Indonesia. The idea of saving petroleum as an export commodity as much as possible and use geothermal energy together with hydropower and other kinds of energy, except oil, for domestic use is quite attractive. Besides, it is predicted that within a couple of decades all fossil fuels will be consumed. It is within this frame of reference that the author feels the urgent need of exploring all kind of possibilities of developing new kinds of energy, geothermal energy included.

Last but not least, how far will the utilization of geothermal energy be damaging to the environments? This is one prime question to be solved far in advance.

The current most debated energy crisis and the long term projected finiteness of fuel resources on one hand and the increasing success of environmentalist in stalling the building of new generating plants in many developed countries make developments of geothermal power plants more attractive. As of now no indications have been cited about pollution caused by geothermal plants. Gilluly (1970) stated that tapping these naturally occurring pools of hot water beneath the earth crust would cause few of the pollution problems created by conventional or nuclear power plants.

Magma power Co (Gilluly, 1970) which has a geothermal power pilot plant in Brady, Nevada, is using a system of heat transfer that eliminates some of the possible disadvantages of geothermal power. The system brings hot water and steam from a geothermal reservoir to the surface, but the steam itself does not actually operate the power plant. Instead the steam and hot water are used to heat isobutane-and the isobutane turns the plant's turbine. Then the hot water is pumped back into the reservoir.

Dallas Peck (op. cit. Gilluly, 1970) stated that such a heat transfer system eliminates two possible sources of environment damage: leftover brine, which in some cases might be toxic and difficult to dispose of, and possible sinking of the ground caused by removing the subsurface water. Russian engineers are experimenting with similar heat transfer system, using Freon instead of isobutane.

That geothermy could be a new source of energy, is no longer questioned. However, could geothermal energy be large enough to play a role in supporting an overall industrial development program such as planned by Indonesia?

It is estimated that the Dieng Mountains in Central Java might be able to supply electric power of the order of 200 megawatts for 25 years or 100 megawatts for 50 years. The long draught of 1972 has proved clearly that Indonesia's electric power supply is far from adequate to meet the consumer's demand whereas Indonesia has not even entered its full industrialisation program. It is scheduled that the emphasis of Indonesia's second Five Year Plan will be more in the industrial sector.

In the United States, geothermy has gained considerable attention. In California, the Imperial Valley Geothermal site only is reported to be able to produce electricity of 20.000 to 30.000 megawatts. Other countries such as the Soviet Union, the Philippines, Turkey, Chile, El Salvador start a wide geothermal exploration program.

In Indonesia, many mining districts will be opened in the Eastern part of the archipellago (International Nickel Company in East Sulawesi, Aneka Tambang in Center Sulawesi, Pacific Nickel in Gag Island, Free port Sulphur in West Irian). Present day mineral exploration program in the eastern part of Indonesia might discover new areas which might develop into mining districts.

If Indonesia in the future no longer would consider exporting ores but start exporting finished or half finished mining products, a large amount of energy will be required for the process. On the other hand all the producing oil well are in the western part of Indonesia.

Finally, the author of this paper is of the opinion that Indonesia should have a clear cut policy on energy, geothermal energy included.

Once and for all the government must solve the problem whether a private enterprise (domestic or foreign) could de-

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*) Indonesia's state electric company.

velop such a geothermal power plant and sell its electricity to the public beside the PLN *).

It is the author's firm opinion that the government of Indonesia alone through the PLN would not be able to provide the gigantic demand of electricity needed for Indonesia's future industrialisation program. The power black out during the draught of 1972 is a clear proof.

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