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Government Activity Report on Geothermal Energy in Japan

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ABSTRACT

The move to make effective use of geothermal energy in Japan is being accelerated as a reflection of the world oil crisis. Japan's energy consumption increased fourfold between 1960 and 1974, and Japan is the second largest user of energy in the non-Communist world. She now fills 73.5% of her current energy needs through imported oil. To keep pace with expanding uses of energy, and to reduce dependence on imports, the government of Japan has launched a long-term research and development effort, Project Sunshine, which aims to develop several indigenous energy sources including the geothermal. Approximately $9 million (US) has been appropriated for the total Project Sunshine budget for fiscal year 1974, and $16 million for fiscal year 1975.

The research and development interests of Project Sunshine include development of direct exploration methods for geothermal energy (to replace the current petroleum-experience methods); development of drilling and measuring systems appropriate for the heat, pressure, corrosion, and other conditions of geothermal work; development of binary-cycle and combined-cycle equipment for power generation from low-enthalpy sources; investigation of techniques for extracting energy from hot dry rocks, including fracturing techniques and artificial hot-water systems; experiments with the use of volcanoes as energy sources for power generation; multipurpose uses; and protection of the environment from deleterious effects.

Project Sunshine is scheduled through the year 2000, and its schedule is divided into terms of 5 to 7 years each, during which it is expected that various phases of the development work will be completed. It is hoped that the program will culminate in such things as 100-MW dry-rock or volcanic power plants.

INTRODUCTION

Energy is the power source of all the activities of mankind; it is indispensable to the improvement of his living standards and industrial progress. Japan's energy consumption increased fourfold, from 100 million kiloliters in oil equivalent (on the basis of primary energy supply) in 1960 to 400 million kiloliters in 1974. This represents an annual increase of 11%, a growth rate twice as fast as the world's average annual increase in energy consumption during the same period. As a result, Japan's energy consumption grew by 1970 to the second largest volume in the non-Communist world next to the United States. At present, Japan fills 73.5% of her primary energy requirements with petroleum, for which she is almost totally dependent on imports.

Japan has, until recently, been blessed with an abundant supply of readily accessible oil. However, in the face of the world energy crisis she must make the development of new energy technology a national project.

PROJECT SUNSHINE

Project Sunshine is an ambitious national technological development program which was started in 1974 and is planned to be completed by the year 2000. The Ministry of International Trade and Industry (MITI) is responsible for all the program.

Through the utilization of inexhaustible, pollution-free solar energy, geothermal energy, and so on, Project Sunshine is expected to alleviate the energy crisis resulting from the exhaustion of petroleum resources, and to restore to the earth its fresh green character and its life-giving sunshine. To expedite the project, research and development is to be carried out on a long-term timetable, planned as far as the year 2000 and, at the same time, a medium-term schedule.

Energy sources to be treated as the objects of the project from the year 1974 are as follows:

1. Solar Energy
2. Geothermal Energy
3. Coal Gasification and Liquefaction
4. Hydrogen Energy

Project Sunshine is to be promoted on a national scale with full cooperation from national research institute organizations, universities, and private enterprise, as well as through international cooperation.

Approximately $9 million has been appropriated in the total budget for Project Sunshine for fiscal year 1974 and $16 million for the fiscal year 1975. We are planning to expand this budget by a factor of 2 or 3 every year. But this will be difficult to achieve, because the Ministry of Finance is keeping strong control on increases in the national budget.

GEOTHERMAL ENERGY

Characteristics of the Resource

Various estimates have been made in the past concerning the amounts of geothermal energy resources available in Japan. With respect to natural steam power generation including utilization of hot water, it is believed that there

are resources corresponding to several tens of millions of kilowatts. A comparable amount may be added by exploiting geothermal heat sources deeper than about 1.5 km which has thus far been regarded as a potential resource for development.

Furthermore, if the thermal energy of volcanoes and hot dry rocks were to be extracted and utilized, through development of artificial hot water systems, it is believed that this would yield power equivalent to 100 million kilowatts. It is believed that these resources will probably increase as progress is made in exploration of and extraction from geothermal reservoirs.

Thus, geothermal energy may become an important resource with quite a promising future from the long-range viewpoint. Geothermal energy is highly valued because it not only has immense reserves but also is a purely domestic source of clean energy.

TECHNOLOGICAL DEVELOPMENT

Exploration for Geothermal Energy

The current explorations largely depend upon techniques used for petroleum resources exploration, both in methods and equipment. However, in order to attain adequate precision in the future, it is necessary that new exploring techniques, directly suited to geothermal prospecting, be developed. The orientation in the future will be towards utilization of volcanoes and hot dry rocks without involvement of natural hot-water systems; consequently, the main emphasis should be placed on developing techniques of direct thermal exploration. Together with improvements in geothermal exploring techniques, studies also ought to be made to elucidate the conditions under which geothermal reservoirs are formed, so that they will enable the application of the most appropriate exploring methods.

Geothermal Well Drilling Techniques

With regard to geothermal well drilling techniques, progress is being made in applying the air-drilling method as well as the conventional mud-drilling method. In the future, drilling will be made into rocks with even higher temperatures (300 to 400°C), therefore, the development of materials resistant to high temperatures and corrosion is mandatory. Together with the drilling machine, much more severe conditions will be imposed on the well logging instruments, with respect to their heat resistance, pressure resistance, and corrosion resistance; consequently, efforts must be made to improve their performance capabilities. In the interests of preventing environmental disruption, enclosed drilling may also be widely adopted.

The development of hot-dry-rock fracturing techniques and artificial hot-water-evolving systems for extracting and utilizing thermal energy possessed by hot dry rocks is very important and a challenging theme. Furthermore, when techniques for drilling "ultra-deep" hot wells are established, it will be possible to extract ultra-deep geothermal fluids from the 3000 to 4000 m depth, which have higher temperatures and pressures, and better conditions, than the fluids in reservoirs down to a depth of about 1500 m. In such an event, it would be possible to increase the capacities of power generating plants. There is also a high potential for the development of power generation by extracting thermal energy from volcanoes, by use of the aforementioned techniques of forming artificial hot water systems.

Hot-Water Power Generating

Geothermal power generating systems today are limited to the use of natural steam, but the effective use of hot water associated with natural steam must be developed. For this purpose, the development of binary-cycle generating systems using low-enthalpy fluids, such as Freon or isobutane, as the carriers of heat energy is expected. Small binary-cycle generating systems have been built thus far in the USSR and in the USA, but large-capacity plants seem to be in the conceptual design stage. The binary system aims at complete utilization of all the thermal energy discharged from the geothermal well; it will make a great contribution towards improving the economy of geothermal power generation.

For power generation utilizing hot water, it is also necessary to establish, at the same time, transport techniques for mixed fluids consisting of both steam and hot water.

Multipurpose Use and Environmental Protection

Effective use of hot water associated with geothermal power generation is important in view of reducing generating costs by allocation and contribution to regional development. The power generating plant in multipurpose use of geothermal energy may be called a local-welfare type of power plant. The multipurpose use of geothermal energy will also be highly effective in preventing environmental pollution caused by the discharge of hot waste water.

Environmental hazards brought on by geothermal fluids must be fully controlled. These include corrosive gases and chemical components discharged from geothermal fluids, as well as hot water and solids. It is imperative that comprehensive techniques for environmental protection be established.

RESEARCH AND DEVELOPMENT

Outline of Program

The research and development program has several parallel efforts, which we shall outline briefly before presenting details. The time schedule is given in Figure 1.

Exploration and extraction. The goal is to establish methods for confirming the magnitude of geothermal deposits, to develop technology for exploring and assessing resources, and to develop technology for excavating high-temperature rock in order to reduce the risks involved in development. To this end, we plan to develop high-temperature drilling systems, and also high-temperature measuring systems.

Technology for utilizing hot water. The goal is to develop the technology for corrosion-resistant materials and for high-efficiency heat exchange, and so on, and to develop a high-efficiency, binary-cycle power generating system by the late 1980s. In this effort, we shall develop and construct two kinds of 1-MW plants, which will be completed in 1977. Then we shall select one system, and develop a 10-to-30 MW plant by 1982, and a 50-MW plant by 1985.

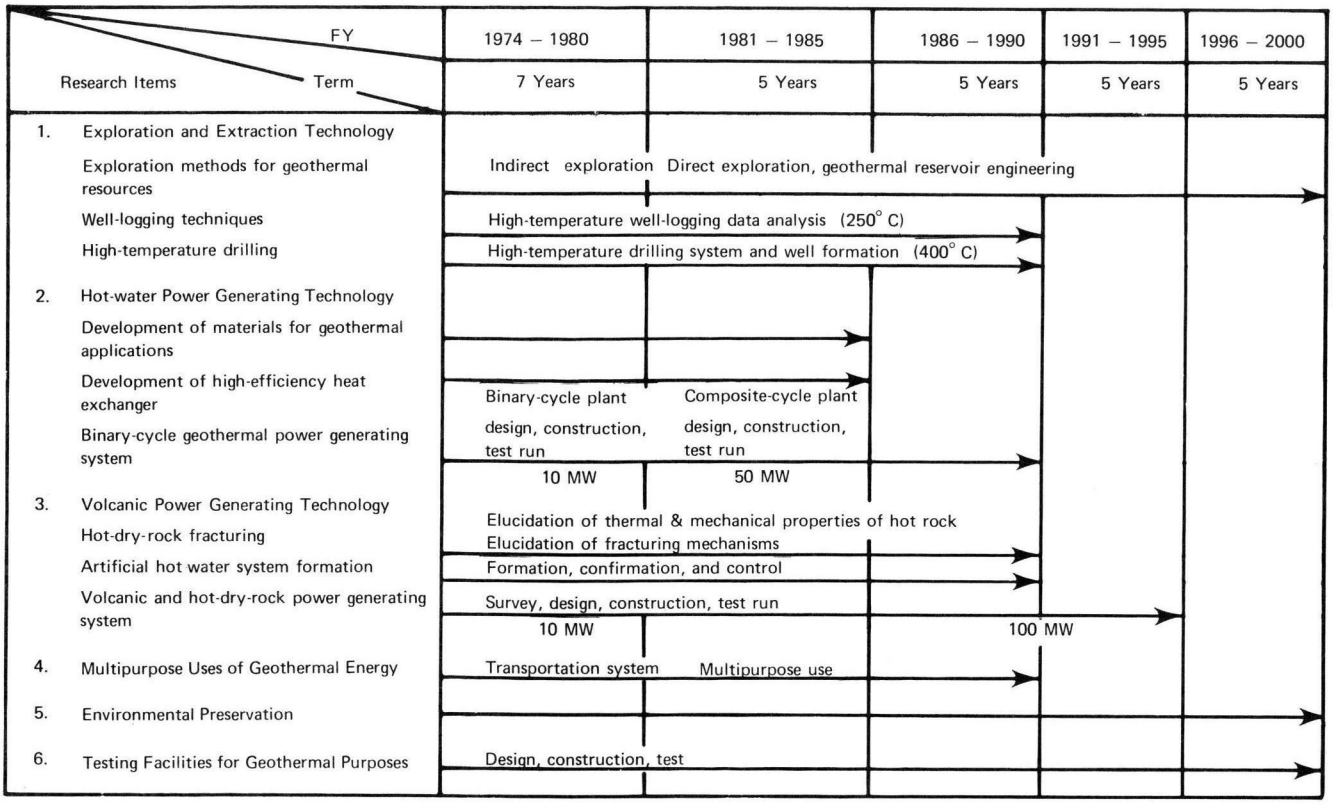

Figure 1. Geothermal energy research and development program, 1974 to 2000.

Volcanic power generating. To develop the technology for fracturing hot dry rock, and for forming man-made hot water systems; and to develop high-efficiency, large-capacity hot-dry-rock and volcanic power-generating systems by the mid-1990s, a feasibility study is now under way for a plant on the island of Iwo Zima, located at the southern end of Japan; on this island or at another suitable site we expect to develop and install a 10-MW plant by 1983 and a 100-MW plant by 1995.

Multipurpose uses. To develop the technology for transporting geothermal fluids, and to develop geothermal energy systems for regional heating, agriculture, and other non-power purposes.

Environmental preservation. To develop technology for environmental preservation in order to prevent adverse effects on the natural environment and ecosystem due to the extraction and utilization of geothermal fluids. In this program, we shall develop efficient methods for reinjecting hot water into the Earth, and will monitor the process for any damaging effects on the total environment as a result of this injection. We are also developing methods for removing poisonous substances, such as arsenic, from the water; a pilot plant that will process 5 ton/hr will be completed in 1976.

The first three of the parallel efforts sketched above were under way in 1974; all have schedules and operating budgets for 1975, and all have targets for the first seven-year program term ending in 1980. Costs will be given in the slightly more detailed descriptions of each effort below. Costs are expressed in $US; the conversion formula is $1 = ¥300.

Exploration and Extraction Technology

The research and development (R&D) subitems for fiscal year (FY) 1975 for exploration and extraction technology are:

1. Basic research of geothermal areas of Japan.
2. Study of the conditions under which geothermal reservoirs are formed, and their working dynamics.
3. Development of direct techniques for geothermal exploration.
4. Development of drilling fluids which can resist high temperatures.
5. Development of well cements for high-temperature conditions.
6. Development of a high-temperature drilling system.
7. Development of a high-temperature, high-pressure, corrosive-environment measuring system.

The targets for the first seven-year program (1974–1980 inclusive) include the achievement of methods for ascertaining reserves of geothermal resources; at the same time, efforts will be made to raise the level of technology for exploration and extraction. Research will be pursued on the technology of high-accuracy research and exploration, in the expectation that the new types of equipment will be produced. It is expected that success will be had in this period with new drilling systems for use in the deep geothermal environment.

For FY 1974, $1 300 000 was budgeted for this effort; the FY 1975 budget is $2 060 000.

Hot Water Power Technology

For FY 1975, just two R&D items are budgeted for hot-water power technology development. These are:

1. Development of materials for the hot-water well.
2. Development of binary-cycle power generating systems.

The targets for the seven-year program (1974 to 1980, inclusive) include development of a 10-MW binary power system, to be manufactured, installed, and operated shortly after the end of the period. Concomitantly, the necessary corrosion-resistant materials, high-efficiency heat exchangers, and so on will be developed. Based on the results of this work, development will begin on a 50-MW natural steam, low-enthalpy, combined-cycle system for later installation.

For FY 1974, $266 000 was budgeted; for FY 1975, the budget is $958 000.

Volcanic Power Technology

Two R&D items in this effort are being pursued in 1975. These items are:

1. Feasibility study of power generation using a volcano as the heat reservoir.
2. Development of fracturing methods for hot dry rock.

The targets for the seven-year program (1974 to 1980, inclusive) include development of a 10-MW volcanic power-generating system. This will require development of technology for fracturing hot dry rock, and techniques for extracting heat from such rock or from magma, probably through man-made hot water systems. This will be the first step in the later development of a 100-MW volcanic power generating system.

In FY 1974, $270 000 was budgeted for these lines of research; their budget for FY 1975 is $370 000.

Multipurpose Use, Environmental Protection

In 1975, study has begun on multipurpose uses and environmental protection in two areas:

1. Study of the mechanisms and effects of reinjection of hot water.
2. Development of methods for removing arsenic from the geothermal waste water.

In the long-term or seven-year program (1974 to 1980, inclusive) the goals shift and broaden. Research will be undertaken on technology for long-distance transportation of geothermal fluids, including steam-and-water mixtures, for the sake of multipurpose uses including non-power uses. Also, research and investigation will be conducted on the effects of all aspects of use and disposal of geothermal fluids on the natural environment, with an aim to protecting the ecosystem.

No funds were budgeted for these purposes in FY 1974, but their FY 1975 budget is $370 000.

Total budget appropriations for geothermal work are $1 836 000 for FY 1974 and $3 758 000 for FY 1975, out of the entire Project Sunshine budget for $9 million and $16 million for the respective years.