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Comprehensive Development of New Sunshine Plan—Reference Material

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[Text]

Industrial Technology Council, MITI

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	Koichi Yamanashi	Managing Director, New Energy Foundation
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Reference

1. Scenario for the Development and Introduction of Key Technologies
   Solar energy utilization
   Photovoltaic power generation
   Fuel cell power generation
   Super heat pump/energy accumulation system
   Geothermal
   Distributed battery power storage technology
   Ceramic gas turbine engines
   Superconductor power applications technology
   Coal liquefaction
   Coal gasification
   Wind power generation
   Marine energy (Ocean thermal energy power generation)
   Biomass energy
   Magma power generation

2. Analysis of Achievements Contributing to the Simultaneous Resolution of Sustained Economic Growth and Energy/Environmental Problems via the Sunshine/Moonlight Plans

3. R&D Trends in Energy/Environmental Technology in the United States and Europe

4. Overview of the Global Regeneration Plan

(Reference 1) Scenario for the Development and Introduction of Key Technologies [by technology field]

1. Solar Energy Utilization

R&D Overview

Development of solar systems capable of being applied to the various processes in industrial and non-industrial fields that require high levels of heat control. The following technology development programs are currently underway—From FY1979 on—Total funds of roughly ¥8.7 billion

[1] Development of component technologies

Development of the high performance adiabatic technology required for high-performance solar systems (FY1990-93)

[2] Development of advanced heat processing systems

Development of high-efficiency solar energy refrigeration technology that makes use of the heat of reaction between hydrogen and hydrogen absorbing alloys to attain via solar energy low temperatures of -20°C and under, a feat that has proved difficult for conventional heat-driven systems (FY1984-93).

[3] Passive solar systems

Development of passive devices with new functions such as transparent heat insulators and modulated light materials required in passive solar systems that regulate the intake and emission of solar light and energy using adiabators and building construction (FY1991-93).

Major R&D Results

1. Solar energy systems for private consumers

Research on this technology was completed in FY 1981, and we are currently implementing programs such as low-interest loans and subsidies designed to foster the widespread use of these systems. As of the end of 1991, 350,000 solar energy systems for private consumer use had been installed in Japan as a result of these propagation efforts.

2. Solar energy systems for industrial use

Air heat collector-style drying (fixed heat processing type) systems and refrigerated warehouse (advanced heat processing type) systems have been developed and have succeeded in attaining a solar energy dependency ratio of 50% and long-term continuous operation.

Current State of Utilization

As of the end of FY 1990, there were 1) approximately 370,000 solar energy systems, and 2) roughly 4.6 million solar energy water heaters in use in Japan, furnishing the equivalent of roughly 1.4 million kiloliters of petroleum-generated energy. This worked out to a utilization ratio of roughly 12% (out of a total of 40 million households).

Current State of R&D in the Private Sector

Private industry is currently developing technology for commercializing solar energy equipment for private consumers. Industrial solar energy equipment is rapidly approaching full-scale practicalization, and all-out research projects are no longer being carried out. Research is being carried out now on passive solar systems as part of R&D efforts aimed at developing building materials for family housing.

Anticipated Supply Potential

[1] Since solar energy systems for private consumers have already been commercialized, their utilization should continue to increase steadily.

[2] The results of R&D on industrial solar energy systems will lead to practicalization.

[3] The latent utilization potential for solar energy systems for private and industrial use is about 17 million kiloliters [kl] (in terms of petroleum-generated energy).

—25.2 million private homes, or roughly 5.9 million kl

—1.1 million private offices and workplaces, or roughly 5.7 million kl

—1.1 million industrial facilities, or roughly 5.7 million kl (Based on data obtained from NEDO's New Energy Utilization Vision)

Potential 15 million kl

Remarks Calculated based on the assumption that 100% of the 25 million private homes, 100% of the 1.1 million private offices and workplaces and 60% of the 1.1 million industrial facilities will install solar energy systems.

Future Development/Utilization Plans

1. Technology development tasks

(1) Industrial solar systems

[1] Component technology: for realizing higher temperatures, lower-cost heat insulators and higher efficiency.

[2] New utilization technology systems (expanded temperature zones): Technology development is necessary for industrial solar systems requiring low temperature heat control.

(2) Passive solar systems

[1] Technology for increasing the surface area and service life of modulated light materials

[2] Technology for enhancing the strength of transparent heat insulators.

2. Near-term utilization plans. The following programs are currently being implemented to promote utilization:

(1) A low-interest rate loan system for household solar energy systems Loans for FY1992 reached ¥4.8 billion

(2) Solar system installation subsidy system for specified public facilities.

—Facilities targeted: educational and medical treatment facilities.

—Budget: FY 1992 budget was ¥400 million.

2. Photovoltaic Power Generation

R&D Overview

Development of technology for the manufacture of solar batteries and photovoltaic power generation systems aimed at lowering the costs involved in achieving the early practicalization of photovoltaic power generation.

—Development period: FY1979 on

—Total development costs: approximately ¥100 billion

1. Solar battery production technology

[1] Development of thin solar batteries and laminated (layered) solar batteries as a means of lowering costs while increasing efficiency of new-types of solar batteries (poly-crystalline solar batteries) (FY1988-92). Based on results achieved thus far, research and development work will commence in FY1993 on production technology for even less costly thin polycrystalline solar batteries.

[2] Amorphous solar batteries

Development of production technology geared towards increasing the quality, reliability and surface areas of amorphous solar batteries to heighten their performance capabilities (FY1983-92). Based on results achieved thus far, research and development work will commence in FY1993 on production technology for even higher performancethin amorphous solar batteries.

[3] Ultrahigh efficiency solar batteries

Development of next-generation solar batteries that are ultrahigh efficiency batteries (single crystal silicon solar batteries and/or compound semiconductor solar batteries) that are expected to double the conversion efficiency (30-40%) of current solar batteries (FY1990-?).

2. Photovoltaic power generation system

Development of low-cost, high-efficiency auxiliary equipment, such as invertors, storage batteries and racks as a means of lowering the costs and increasing the stability of photovoltaic power supply equipment, plus the development of various evaluation methods and research on system interconnection for the construction of optimum systems.

Major R&D Results

1. Succeeded in lowering the cost of manufacturing solar batteries to just slightly more than 1/30 what they were at the start of research on these devices in FY1979, i.e. from ¥20,000-30,000/W to ¥650/W (See below diagram [not reproduced]).

2. Succeeded in lowering the cost of producing power with photovoltaic power generating systems to just over one-tenth what they were originally, i.e. from roughly ¥2,000/kWh to about ¥120/kWh.

3. Achieved amorphous solar batteries with the highest conversion efficiency in the world (conversion efficiency of 11.1% with a 10 cm^2 battery) and increased their surface area by 9.7% to 30x40 cm.

Current State of Utilization

1. Solar battery output

Production output of solar batteries is steadily increasing, with Japan producing one-third of the world supply.

World 1986-26MW, 1991-55MW

Japan: 1986-13MW, 1991-20MW

2. Utilization of photovoltaic power generation systems

There were roughly 3,000 kW of power being generated in Japan as of the end of FY1991 by photovoltaic power generation systems, the majority of which were being used for R&D purposes.

3. Principal utilization examples (NEDO)

—200kW for testing system interconnectability (Rokko [phonetic] Island)

—750 kW for validation testing (Seiben-cho [phonetic], Okinawa)

Current State of R&D in the Private Sector

Power companies are currently carrying out operation-based research to validate their respective photovoltaic power generation systems.

[1] Tokyo Electric Power Corporation is conducting system interconnection validation testing on a 50kW system at Urawa.

[2] Kansai Electric Power Corporation is test operating a 50kW light-converging type photovoltaic power generation system.

Anticipated Supply Potential

[1] Utilization ratio will rise in line with lowering of photovoltaic power costs to private households and outlying islands and/or other remote areas where conventional power generation costs are still high.

[2] Over the long run, the photovoltaic power supply per user will improve in line with the enhancement of power generation efficiency.

[3] Latent utilization potential is calculated as 340 million kW (According to data compiled by the Photovoltaic Power Generation Technology Research Consortium).

—104 million kW for power plants

—71 million kW for private homes

—69 million kW for plants/factories

—35 million kW for outlying islands and other remote areas

—23 million kW for power sources for public facilities

—17 million kW for power sources for industrial facilities

—10 million kW for power sources for the forestry, agriculture and marine industries

—9 million kW other uses Total: 338 million kW

Note: Photovoltaic power generation systems have an operation rate of 12%, compared to the operation rate of 70% for conventional power plants. This means that actual system capacity is one-sixth that of conventional power plants. Example: 30 million kW of photovoltaic power generated for industrial use, for instance, would be equivalent to 5 million kW generated by a large-scale thermal power generation plant.

Potential

—70 million kW (18 million kl)

Remarks 25% of the 40 million households in Japan are expected to install personal photovoltaic power generation systems (4kW x 1,000 households), and roughly 30 million kW of photovoltaic power is expected to be generated for industrial use (See note above).

Future Development/Utilization Plans

1. Technology development tasks

In addition to promoting technological development aimed at achieving photovoltaic power generation costs of ¥20/kWh by the first part of the year 2000, plans also call for promoting the development of revolutionary solar batteries capable of large-scale power generation in and after the year 2000.

(1) Solar batteries

[1] Polycrystalline solar batteries

Development of technology aimed at lowering the cost of the continuous casting of silicon for use as solar battery substrates, of increasing substrate processing times and of simplifying processing methods. Employ modular structures capable of frameless (integral) construction and batch wiring to lower costs and achieve 15% modular efficiency.

[2] Amorphous solar batteries

Development of technology for employing film substrates and lowering costs, stabilizing quality and increasing production speed via high-speed laser patterning techniques. Development of light deterioration prevention technology and the achievement of 10% modular efficiency after initial deterioration.

(2) Systems development

[1] Enhance efficiency of the overall system

Research and develop evaluation technology for the system as a whole, and establish uniform evaluation methods for auxiliary equipment such as invertors, storage batteries and interconnection devices.

[2] Simplification of auxiliary equipment

Development and standardization of devices and subsystems that surpass conventional auxiliary equipment in shape, structure and functions, and the development of high-performance, low-capacity storage batteries capable of handling power demand peaks for use on outlying islands and in times of disaster.

[3] Expanded utilization formats

Analysis and grasp of characteristics of output fluctuations caused by fluctuating solar radiation when multiple photovoltaic power generation systems are installed over a wide area, certification of optimum installation formats and studies on policies for interconnecting with other energy systems.

[4] Lower cost systems

Lower costs by enhancing the efficiency of photovoltaic power generationsystems as a whole, simplifying auxiliary equipment, enhancing storage battery capabilities and optimizing each utilization format.

2. Near-term utilization plans

   All the power companies are promoting plans to introduce photovoltaic power generation systems in the several kW-500 kW class (total expected utilization equivalent to 2400 kW).

   —Field testing business for new energy power generation.

   —Subsidize expenses required for on-site testing of photovoltaic power generation systems.

   —Budget for FY1992: ¥845 million

   —Subsidy ratio: 2/3

3. Other Preparation of system interconnection guidelines. Presentation of surplus power purchasing menus by the power companies.

3. Fuel Cell Power Generation

R&D Overview Development of technology that generates power directly from the electrochemical reaction of oxygen in the atmosphere with hydrogen obtained by reforming natural gas, methanol and coal gas fuels. Currently carrying out research and development by matching up the [Illegible] of the four systems for generating power directly from electrochemical reactions described below, which differ as to type of electrolyte (a substance which, when dissolved in a suitable liquid, dissociates into ions (hydrogen ions), thus rendering the liquid electrically conducting) employed.

—Development period: FY1981-97

—Total funding: Approximately ¥70 billion

1. Phosphoric acid fuel cells

   Promoted development of a centralized fuel cell power generation system (1,000 kW class), as well as an on-site system (200 kW class for industrial and outlying island use) (FY1981-90).

2. Fused carbonate fuel cell

   Currently engaged in research and development work aimed at developing a 1,000 kW class fused carbonate fuel cell pilot plant that will feature higher power generation efficiency (45-50%) than phosphoric acid type fuel cells and be capable of using coal gas and a variety of other fuels (FY1981-97).

3. Solid electrolyte fuel cells Currently developing a several kW class solid electrolyte (ceramics, etc) fuel cell that is expected to yield even higher power generation efficiency (50-60%) than fused carbonate fuel cells (FY1981-97).

Major R&D Results

1. Phosphoric acid fuel cells

   [1] Achieved power generation efficiency of 39.7%, the highest in the world, under normal pressure operating conditions.

   [2] Achieved a high integrated efficiency rate of 80.2% with a co- generation phosphoric acid fuel cell system.

   [3] First in the world to succeed in recovering heat in the form of 170°C steam (Up until now, heat recovery had only been achieved in the form of hot water.). Based on these achievements, small-scale phosphoric acid fuel cells in the 200 kW class are now ready to be commercialized. (The Agency of Natural Resources and Energy is currently undertaking research and development aimed at practicalizing large-scale phosphoric acid fuel cells in the 1,000 kW and over class).

2. Fused carbonate fuel cells

   Succeeded in achieving rated output operation in each of the 1 kW, 10 kW, 25 kW and 50 kW classes.

3. Solid electrolyte fuel cells Developed fuel cell production technology for the several hundred watt class of solid electrolyte fuel cells.

Current State of Utilization

As of FY 1991, fuel cells in Japan, primarily for R&D purposes, were turning out roughly 13,000 kW of power. Principal utilization examples.

(1) Examples of fuel cell use related to the Moonlight Plan.

   [1] 1,000 kW class fuel cell used as an alternative to thermal power generation (FY1987-89).

   [2] 1,000 kW class dispersed fuel cell (FY1988).

   [3] 200 kW class fuel cell for operating use (FY1989-91).

   [4] 200 kW class fuel cell for generating power on outlying islands (FY1989-91).

(2) Examples of non-Moonlight Plan-related fuel cells.

   [1] 4,500 kW fuel cell operated by Tokyo Electric Power Corporation (FY1983-85).

   [2] 11,000 kW fuel cell operated by Tokyo Electric Power Corporation (FY1990-92).

Current State of R&D in the Private Sector

Research efforts in the private sector are the closest to commercializing phosphoric acid fuel cells.

[1] Electric power industry—Tokyo Electric Power Corporation is researching the feasibility of operating an 11 MW phosphoric acid fuel cell plant (at its Satsui [sic] thermal power plant).

—10 electric power companies plan to introduce and operate 30 fuel cells in the 50-200 kW class.

—The Agency for Natural Resources and Energy is taking part in the development of a 5 MW fuel cell power plant for local power supply purposes as part of the "City Energy Center Fuel Cell Technology Development" program.

[2] Gas industry

—The Tokyo Gas Company, Osaka Gas Company and others have plans for commercializing 50 kW and 100 kW fuel cell power plants.

—The Agency for Natural Resources and Energy is taking part in the development of a 1 MW fuel cell power plant for on-site use as part of the "City Energy Center Fuel Cell Technology Development" program.

Anticipated Supply Potential

[1] For the time being, promote the accelerated introduction of phosphoric acid fuel cells.

[2] Commence introduction of fused carbonic fuel cells beginning around the year 2005.

[3] Commence introduction of solid electrolyte fuel cells beginning around the year 2015.

[4] Of a total capacity for thermal power plants in the year 2010 of 133.2 million kW, co-generation via fuel cells is expected to account for 24.3 million kW.

[5] If we calculate the percentage of energy conserved via the enhancement of fuel cell efficiency and the utilization of heat resulting from co-generation operations, we see that:

—Phosphoric acid fuel cells: efficiency enhanced from 38% to 40%, and heat usage of 40%.

—Fused carbonic fuel cells: efficiency enhanced from 38% to 50%, and heat usage of 10% on average.

—Solid electrolyte fuel cells: efficiency enhanced from 38% to 60%, and heat usage of 10% on average.

Potential 54 million kW (70.4 million kl)

Remarks

—Phosphoric acid fuel cells: 500 kW x 40,000 units, 50,000 kW x 80 units;

—Fused carbonic fuel cells: 300,000 kW x 70 units;

—Solid electrolyte fuel cells: 300,000 kW x 30 units.

Future Development/Utilization Plans

1. Technology development tasks

(1) Reduction of costs

—By making the fuel cells themselves capable of higher output and higher [Illegible]

—By increasing fuel cell surface area

—By increasing fuel cell lamination

—By developing higher performance catalysts

(2) Development of more compact, lower-cost technologies

—By combining reformers and fuel converters and making them more compact.

—By developing higher performance, longer lasting catalysts for use in fuel reformers.

(3) Develop large-scale fuel cells and validate their long-term operation. Carry out research aimed at validating operation from the standpoint of confirming reliability in line with commercialization.

2. Near-term utilization plans

(1) Electric power companies and gas companies are planning to utilize fuel cells to conduct research aimed at validating their operation.

—The utilization outlook for electric power companies is roughly 20,000 kW.

(2) Field testing business for new energy power generation.

—Subsidize expenses required for onsite testing of fuel cell systems.

—Total budget for FY1992: ¥635 million

—Subsidy ratio: 1/3.

4. Super Heat Pump/Energy Accumulation Systems

R&D Overview

Development of high-performance, compression-type heat pumps and chemical heat accumulators required to enhance energy utilization efficiency and level power demand load by recovering and storing with high efficiency and in a high density form low grade energy not used during night-time power generation operations and supplying this recovered energy to large-scale air conditioners and industrial processes during the afternoon hours.

—Development period: FY1984-92.

—Total funding: ¥10 billion

1. High-performance heat pumps

Development of heat pumps with the following performance capabilities:

[1] High efficiency—Heat pumps that possess the capabilities to double the coefficient of performance (heat output/required power) from the 3-4 achieved with conventional heat pumps to 6-8.

[2] High temperature output—Heat pumps capable of outputting 150-300°C of heat as their maximum output temperatures at a coefficient of performance of around three (conventional heat pumps can only generate 110°C.

2. Chemical heat storage—By developing heat storage technology that uses chemical reactions to store heat, it will be possible to construct compact heat storage equipment that is roughly one-fifth the size of conventional water heat storage equipment.

Major R&D Results

Research and development work in this field is in its final stages, and results achieved thusfar are outlined below.

1. Achieved the sought after coefficient of performance of 6-8.

2. Alternative CFC heat pump

—First in the world to apply this technology to an alternative CFC heat pump.

3. Affects on component technologies

—Approximately 400 stainless plate fin heat exchangers developed as component technology for the super heat pumps are being utilized for waste heat recovery in fuel cells and gas engine co-generation systems. (Utilization examples)

—Heat exchangers in operational phosphoric acid fuel cells (Hotel Plaza: Kansai Electric Company)

—Heat exchangers in a gas engine co-generation system in operation in Kawasaki.

Current State of Utilization

1. Conventional heat pumps

Conventional heat pumps come in a variety of sizes and are put to various applications, to include large-scale regional heating and cooling businesses and as refrigerators in plants and factories. (Examples of regional heating and cooling businesses)

—Hakozaki (Tokyo Electric Power Corporation): utilizes heat from river water (from 1989).

—The Tokyo subcenter of [Illegible] (Tokyo Electric Power Company): utilizes waste heat generated during sewerage processing (from 1990).

—Hikarigaoka apartment complex (Tokyo Heat Supply Company [sic]): utilizes waste heat from underground power transmission facilities and garbage incineration operations (from 1983).

2. Super heat pumps

As of this time, the only utilization of super heat pumps is in connection with research activities related to the Moonlight Plan, but studies are underway to introduce a super heat pump into the heating and cooling system for the Tokyo subcenter of Rinkai [sic].

Current State of R&D in the Private Sector

1. Private firms are engaged in research aimed primarily at developing conventional heat pumps for commercial purposes.

2. High-performance heat pumps Members of the private sector are currently making use of the Agency for Natural Resources and Energy's system of "Subsidies for Developing Technologies for the Utilization of Unused Energy" to develop high-performance heat pumps.

—Budget for FY 1992: hundreds of million yen [Exact amount not given].

—Subsidy ratio: 1/2.

Anticipated Supply Potential

[1] If we calculate the amount of conserved energy by usubtracting the amount of driving energy from the amount of supplied energy ((supplied energy) - (driving energy)), the amount of energy conservation achieved with super heat pumps works out to 50% of supplied energy based on a coefficient of performance of six (6) (If required power is equal to one (1) and supplied energy equals six (6), then the actual driving energy is 2.7 with an average power generation efficiency of 38%, i.e. (6-2.7)/6 x 100 = 50 (%)). (Note: coefficient of performance = heat output/required power).

[2] The latent utilization potential for heat pumps by volume of energy consumed is ultimately 20%; primarily in the fields of heating, hot water supply and the utilization of heat in industrial processes (Based on FY1985 figures, ultimate energy consumption volume = 2706 x 1012 kcal, and total latent supply potential by volume is 550 x 1012 kcal).

Potential 40.6 million kl

Remarks Figures derived from the results of the Echo Energy City System.

Future Development/Utilization Plans Technology development Development work on basic technologies is in its final stages. In the future, development work will focus on achieving low-cost commercial super heat pumps with the goal of recovering investments within three (3) year's time (at present, investment recovery takes between 5-6 years).

5. Geothermal Energy

R&D Overview

Development of technologies for exploring for, evaluating, drilling for, recovering and effectively utilizing the geothermal resources estimated to be so abundant in Japan.

—Development period: FY1974 on

—Total funding: ¥100 billion

1. Exploration/evaluation technologies

[1] Comprehensive survey of geothermal resources nationwide

Development of technology for efficiently and accurately sampling likely geothermal locales in an attempt to systematically grasp the extent of the geothermal resources present in Japan and to promote the development of this geothermal energy in a rational manner.

[2] Study aimed at certifying technologies designed to explore for geothermal energy

Development of optimum methods for exploring the fractured reservoir structure of the earth's crust, where the majority of Japan's geothermal reservoir exists.

[3] Development of hydrothermal power generation system

Development of binary cycle power generation technology for the effective use of unused medium- and high-temperature hydrothermal energy in an attempt to promote the development and utilization of geothermal energy.

[4] Development of high-temperature solid rock power generation system

Development of a high-temperature solid rock power generation system that extracts by means of man-made hydrothermal systems the tremendous heat energy present in high-temperature rock, and then uses this heat energy to generate power.

[5] Development of technologies designed to study the extent of deep geothermal resources that exist below shallow geothermal resources, and efficiently recover these deep geothermal resources to increase the power-generation capacity of geothermal power plants.

Major R&D Results

1. Comprehensive survey of geothermal resources nationwide

[1] Conducted a nationwide geothermal resources survey (FY1980-83) and prepared a sampling map of likely geothermal locations throughout the country.

[2] Based on the results of a detailed study started in FY1984, determined the potential for geothermal resources in locations other than those pinpointed via the comprehensive survey described in (1) above, and developed optimum exploration techniques for focusing in on the most likely locations.

2. Study to certify geothermal exploration technologies

Beginning in FY1980, carried out surface exploration and hole investigations in the well-known geothermal regions of Sengan [phonetic] and Kurikoma [phonetic], and compiled basic data required for correlation analysis of geothermal structures and exploration technology data. Used the development of a high-precision MT method to significantly enhance the economics involved in the exploration of deep geothermal resources.

3. Hydrothermal power generation

Succeeded for the first time in the world test operating a down hole pump (50t/h, 170°C), which forms the nucleus of a binary cycle power generation system.

4. High-temperature solid rock power generation

[1] In 1986, in a joint research effort with the United States and then West Germany, successfully completed tests on the heat extraction cycle.

[2] In FY1991, successfully tested a long-term (90 days) heat extraction cycle in the Hijiori [phonetic] region of Yamagata Prefecture.

Current State of Utilization

There are presently nine conventional geothermal power plants (steam power generation method) in Japan producing 270,000 kW of power. Power plant name: Output (Business use)—Mori: 50,000 kW—Kuzuneda [phonetic]: 50,000 kW—Onikubi [phonetic]: 12,500 kW—Otake: 12,500 kW—Hatchobara [phonetic]: 110,000 kW (Private power generation)—Onuma: 9,500 kW—Matsugawa: 22,000 kW—Suginoi [phonetic]: 3,000 kW—Kirishima: 450 kW—Takenoyu: 105 kW Total: 270,055 kW

Current State of R&D in the Private Sector

Central Research Institute of Electric Power Industry (CRIEPI)

Currently engaged in the development of component technologies for high- temperature solid rock power generation at Osukatsucho [phonetic] in Akita Prefecture.

Anticipated Supply Potential

[1] Introduction of the results of the development of deep geothermal resources will double the volume of supply energy in the near future.

[2] Results of development efforts in the areas of binary cycle and high-temperature solid rock power generation will be gradually introduced.

[3] The latent supply potential of geothermal energy is approximately 66 million kW (Deep geothermal energy = 43 million kW; binary cycle power generation = 15 million kW; and high-temperature solid rock power generation = 7.5 million kW).

[4] Add the additional energy volume indicated in the Long-term Energy Supply/Demand Outlook under the heading "Geothermal."

Potential 21 million kW (32 million kl)

Remarks Deep geothermal energy expected to account for 40% of overall geothermal supply potential, while binary cycle power development accounts for 20% and high-temperature rock power generation for 10%.

Future Development/Utilization Plans

1. Technology development tasks

   (1) Reduce costs

   —Lower drilling costs

   —Increase drilling efficiency by developing new drilling technology (High-efficiency drilling technology capable of withstanding high temperatures and high pressures.)

   (2) Lower development risks

   —Promote the development of high-precision exploration techniques

   —Develop technology that will enable the effective utilization of geothermal wells (holes) that have been drilled. (Countermeasures against the attenuation of productive steam)

   (3) Increase geothermal power generation capacity

   —Develop unused geothermal resources Medium- and high-temperature hydrothermal resources (binary cycle power): develop technology to validate reliability and economic feasibility. High-temperature solid rock: develop practical technology Magma, etc.: develop basic technology for feasibility studies.

   —Increase the capacity of existing geothermal development locations Deep geothermal resources: Develop exploration, drilling and recovery technologies.

   (4) Validation tests

   —Long-term continuous operation tests to validate the economical efficiency of binary cycle power generation and the reliability of the DHP and volume heat exchange systems in binary cycle power generation systems.

   —Long-term continuous operation tests to validate the economic efficiency of high-temperature solid rock power generation and the heat supply capabilities of artificial reservoirs.

2. Near-term utilization plans Power plants currently scheduled to come on line. (Power plant name): (Output capacity)

   —Kaminotake [phonetic]: 27,500 kW—Yamakawa: 30,000 kW—Kuzuneda [phonetic] No. 2: 30,000 kW—Ogasumi [phonetic]: 30,000 kW—Sumigawa: 50,000 kW—Yanagitsunishiyama [phonetic]: 60,000 kW—Takinoue [phonetic]: 25,000 kW—Oguni: As yet unknown Total: 232,500 kW

6. Distributed Battery Power Storage Technology

R&D Overview

Development of high-efficiency futuristic batteries and related auxiliary technologies to level user power loads as a means of relieving the day-night demand differential as well as increases in peak demand during the summer months.

—Development period: 1992-2001—Total funding: ¥14 billion

1. Development of high-efficiency futuristic batteries

   Development of lithium secondary batteries possessing energy densities several times higher than those of lead batteries for use as distributed power sources and batteries for use in electric vehicles, etc.

2. Total system research R&D on the optimum capacity, environmental safety and economic efficiency of distributed battery power storage systems.

Major R&D Results

1. Large-capacity centralized systems

   Research was completed in FY1991 on large-scale battery power storage systems for leveling demand loads placed on power suppliers (electric power companies). (Principal Results)—Sodium sulphur batteries—Conducted research on a 1,000 kW class pilot-plant and achieved an overall efficiency level of 76%.

2. Distributed systems—Commenced R&D on lithium secondary batteries in FY1992.

Current State of Utilization

Roughly 1,000 distributed battery power storage systems are now in use primarily in electric vehicles used as company cars by electric power companies.

Current State of R&D in the Private Sector

R&D is being pushed ahead on a variety of new types of batteries primarily for use in electric vehicles.

—Nickel hydrogen batteries

Small-size nickel hydrogen batteries have already been commercialized, but Matsushita Electric is currently developing this type of battery for use in electric vehicles.

—Sodium sulphur batteries

Yuasa Battery Co. is currently continuing development work on this type of battery started as part of the Moonlight Plan's "New Battery Power Storage Technology" project.

—Zinc-bromine batteries

Meidensha [phonetic] Co. is continuing development work on this type of battery started as part of the Moonlight Plan's "New Battery Power Storage Technology" project.

—Lithium batteries

The world's leading battery manufacturers are carrying out basic research on lithium batteries as the ultimate battery ever made.

Anticipated Supply Potential

[1] Calculate the amount of energy conserved via these new battery power storage systems by the effects of their utilization in electric vehicles

(Assuming annual mileage of 20,000 kilometers, average gasoline consumption (gas mileage) of 10 kilometers/liter and an energy conservation ratio for electric vehicles of 42%, then electric vehicle utilization will save 0.84 kiloliters of gasoline per car per year.).

[2] Of the 7.2 million automobiles expected to be operating on Japanese highways by the year 2000, a latent utilization potential of 4 million exists for electric vehicles. (Figures derived form MITI's "Electric Vehicle Popularization Plan"

Potential—1.2 million cars (10 million kl)

Remarks—Three (3) times the latent utilization potential for the year 2000.

Future Development/Utilization Plans

1. Technology development tasks

[1] Enhance battery performance

Component and prototype research is needed to achieve long-life batteries with high energy density and high output density.

[2] Utilization technology

Develop equipment necessary for the stable utilization of new types of batteries, such as optimum charging systems and residual capacity systems.

[3] Evaluation technology

Establish test evaluation methods for comprehensively evaluating battery characteristics.

2. Near-term utilization plans

[1] "Electric Vehicle Popularization Plan" (prepared by MITI)

Strive to introduce onto the market 200,000 electric vehicles primarily for business use by the year 2000 (prepared in 1991).

[2] Put together a system for promoting the widespread use of electric vehicles.

Develop battery charging stands that make effective use of night-time power, and implement a fleet testing service for electric vehicles operated by specified businesses.

—Time period: FY1992-96

—Total funding: Approximately ¥2.3 billion (Reference data)

—Steps for introducing the "Electric Vehicles Popularization Plan"

1. Basic thinking behind plan

Implement in stages policies aimed at fields targeted for popularization each period to steadily increase user groups and numbers of electric vehicles in use.

2. Overview of policies to be implemented at each step of plan.

[1] Step One (1991-93)

—Fields: Public organs and agencies at the national and local levels

—Objective: Enhance related technologies (National government will also provide assistance)

—Policy: Economic assistance (subsidies, tax breaks) and infrastructure development.

[2] Step Two (1994-97)

—Fields: Public utilities (electric power companies), transportation and retail industries

—Objectives: Expand user groups and lower price of electric vehicles

—Policy: Economic assistance (tax breaks, loans) and the introduction of various incentive programs

[3] Step Three (1998-2000)

—Field: Ordinary users

—Objectives: Lower electric vehicle prices further and develop production and service technologies.

—Policy: Introduction of incentive programs and completion of infrastructure.

[4] Step Four (2001 on)

—Objective: Self-sustaining popularization that matches user demand with the supply level.

7. Ceramic Gas Turbine Engines

R&D Overview

Development of ceramic gas turbine engines using ceramic materials with outstanding heat and corrosion resistance to drastically enhance the heat efficiency (currently about 35%) of the small- and medium-sized engines employed in co-generation systems, decrease the burden on the environment and diversify the kinds of fuel used in these engines. Ceramic gas turbine engines will feature:

—Output: 300 kW

—Turbine inlet temperature: 1,350 degrees centigrade

—Heat efficiency: better then 42%

—Overall efficiency: better than 80%

—Development period: FY1988-96—Total funding: ¥16 billion

1. Development of heat-resistant ceramic members

Development of high-precision, high-efficiency processing and parts technologies for key heat-resistant ceramic members to enhance the durability and reliability of the various component parts used in the high-temperature portions of gas turbine engines.

2. Research and development of component technologies

Development of high-performance, low-polluting/high-load combustion component parts to enable the construction of a more compact gas turbine with all of its high-temperature component parts made of ceramics.

3. Design, prototype and operation research

Development of a 300 kW-class ceramic gas turbine engine that features a three-stage turbine inlet temperature (900, 1,200 and 1,350°C)

Major R&D Results

1. Development of heat-resistant ceramic members

Developed know-how related to molding methods for making heat-resistant ceramic parts that conform to the intricate shapes required for use in gas turbine engines, uniform sintering methods for thick ceramic parts and nondestructive inspection methods for ceramic parts.

2. R&D of component technologies. Carried out prototype studies for all component parts based on analysis of material and aerodynamic characteristics.

3. Design, prototype and operational research Completed prototype operational research on the primary basic model (900°C metal gas turbine engine)

Current State of Utilization

Co-generation systems are currently producing roughly 10 million kW of power using diesel engines for the most part.

Current State of R&D in the Private Sector

1. Ceramic gas turbine engines for automobiles

The Petroleum Industry Action Center, with grants from MITI, is currently developing a 100 kW-class ceramic gas turbine engine for use in automobiles (FY1990-96).

Anticipated Supply Potential

[1] Amount of energy conserved using ceramic gas turbine engines is calculated by adding the extent to which efficiency is enhanced to the amount of heat supplied (The average power generation efficiency of existing power plants is 38%, but the overall efficiency of co-generation systems is 80%).

[2] Utilization outlook for co-generation systems (including diesel and gas turbine systems):

1988 - 10 million kW

2000 - 17.65 million kW

2010 - 24.30 million kW (Outlook of the Advisory Committee for Energy)

Potential—14 million kW (23 million kl)

Remarks—Equivalent to the increase in power generation predicted between the years 1988 and 2010.

Geological Survey of Japan (GSJ)

1-1-3 Higashi, Tsukuba City, Ibaraki Pref. 305, Japan; Telephone: (0298) 54-3576; Telex: 3652511 GSJ J; Facsimile: (0298) 54-3533, 56-4989

Established: Feb. 13, 1882

Budget for Fiscal 1992: ¥4,573 million

Outline of Institute

The Geological Survey of Japan (GSJ), established in 1882, is the only national research institute in the country concerned with the systematic investigation of geology and mineral resources. It is responsible for geological mapping and for research on earth sciences and various natural resources (including metallic and non-metallic minerals, fossil fuels, geothermal energy and groundwater) in the Japanese islands, adjoining offshore areas and the open ocean floor. The GSJ also makes substantial contributions to environmental conservation and the mitigation of damage from geological hazards such as earthquakes, volcanic eruptions and landslides.

The results of this study are published in the form of geological and thematic maps at various scales, bulletins and special publications through the Geological Information Center, as well as in major international journals. The Geological Museum is also open to the public to disseminate geological information and knowledge.

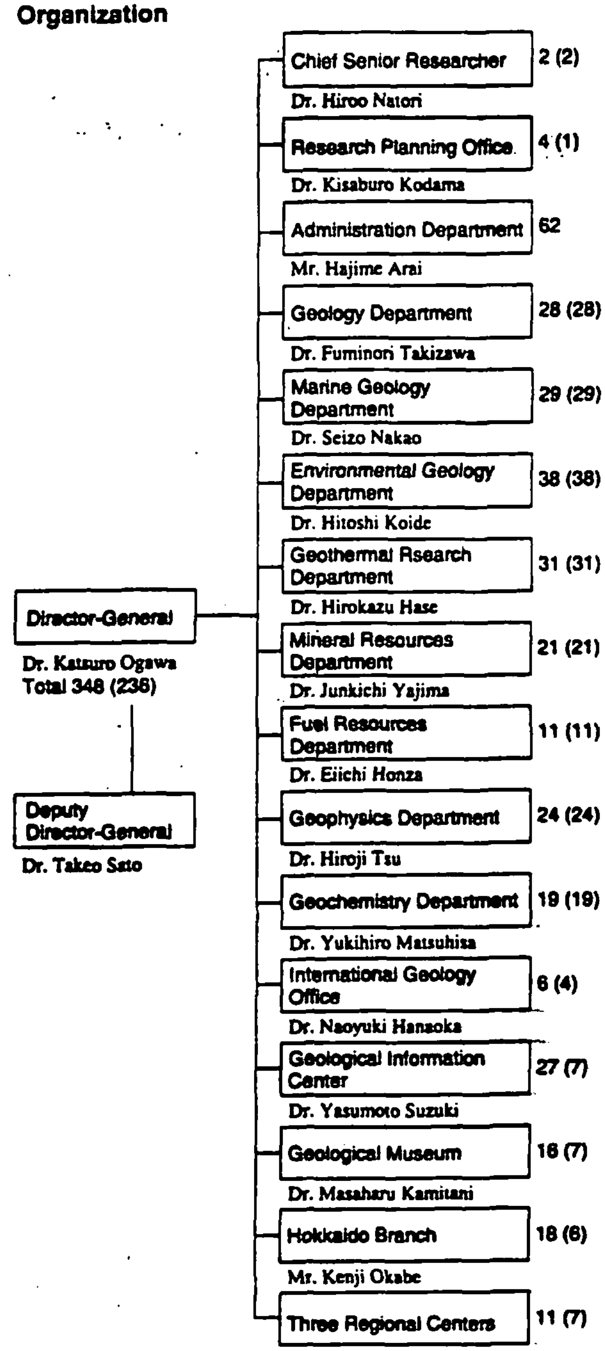
The staff of the GSJ take an active part in international research projects and technical cooperation efforts. Experts on geology and mineral resources have been dispatched abroad and foreign scientists and technicians participate in training courses in the GSJ.

Research Activities

As the world economy grows, the use of natural resources also increases. New concepts, methods and tools are therefore required to find undiscovered and new types of resources. The GSJ is now conducting research in frontier fields of the earth sciences, including study on metal and rare element transport and concentration mechanisms in magma-related systems and in the island arc crust, as well as, development of new geophysical technology, such as three-dimensional modeling and remote sensing.

Recently, in relation to increasing global environmental problems, the GSJ initiated research on the global geochemical cycles in the ocean, on coral reefs as sinks of atmospheric carbon dioxide and on mechanisms for release of methane into the atmosphere. The GSJ is considerably broadening its outlook, and is now engaged in activities related to the complete spectrum of earth sciences in order to meet the needs of national and international development and the demand of the geological community.

Organization



Note: Figs. show personnel; researchers in parentheses.

The departments listed in the chart are organized according to research objectives. However, at the same time, there are also pools of professionals with specialities that can be brought together for specific projects through the organization of multidisciplinary groups.

Main Facilities

For geological laboratory study: electron microscope, scanning electron microscope (w/wo X-ray analyzing system), fluorescence microscope, electron microprobe analyzer, automatic powder and single crystal X-ray diffractometer, photoelectron/auger electron spectrometer, γ-ray spectrometer, electron spin resonance spectrometer, image analyzer, etc.

For chemical and geochemical laboratory study: thermal ionization mass spectrometer, McKinney-type isotope ratio mass spectrometer, GC mass spectrometer, automatic X-ray fluorescence spectrometer, neutron activation analysis system, liquid scintillation counter, inductively coupled plasma emission spectrometer, ion and gas chromatograph, etc.

Experimental geoscience work systems: uni-axial testing machine, tri-axial squeezing machine, hydrothermal syntheses system, etc.

For geophysical field work: several types of gravity, magnetic, electric and seismic survey equipment, both for onshore and offshore use.

For geophysical laboratory study: multi-channel seismic data processing system, cryogenic magnetometer, Fourier transform infrared spectrometer, etc.

The GSJ also has many computer work stations connected to the supercomputer system of the AIST Tsukuba Research Center.

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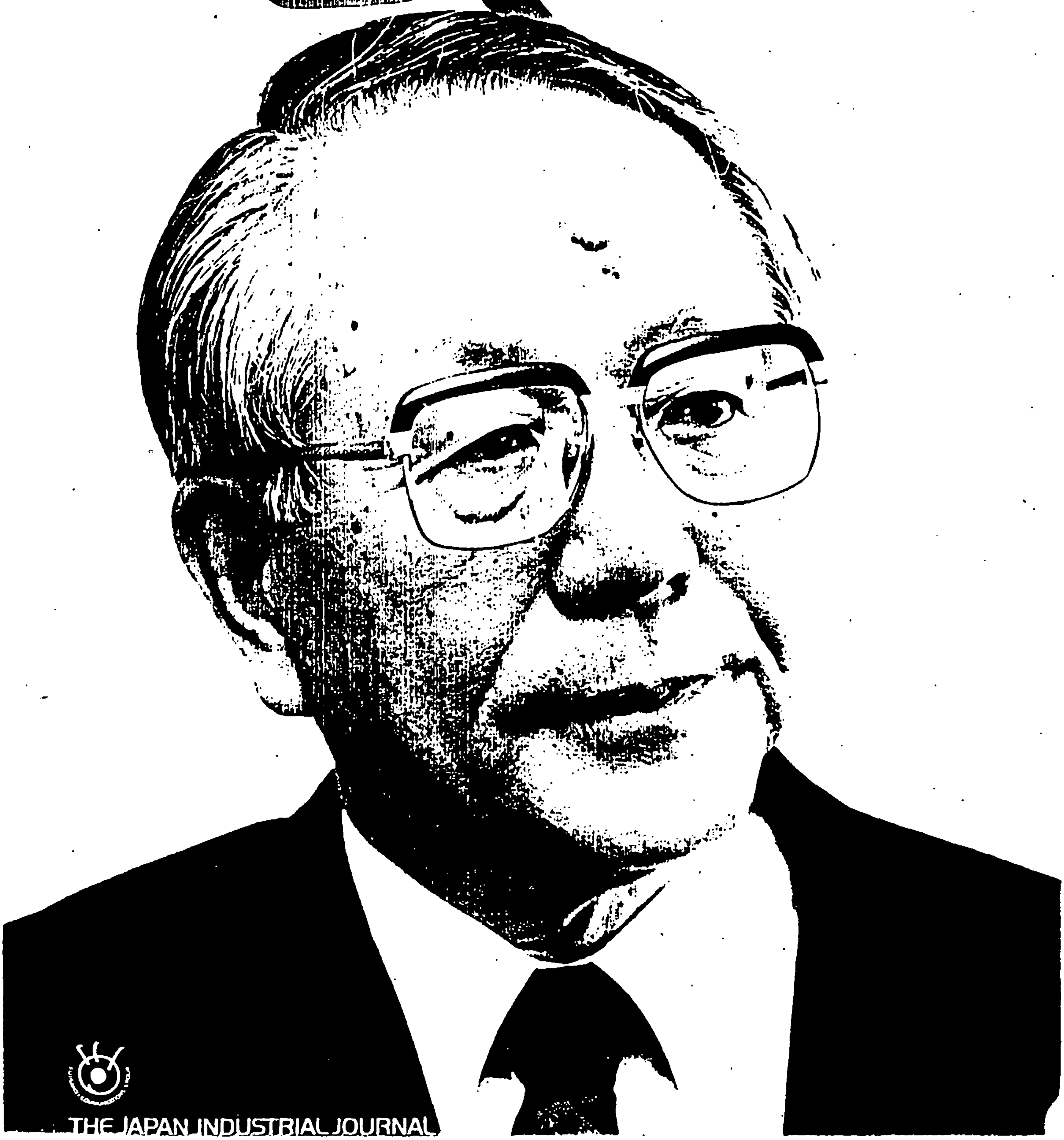


THE JAPAN INDUSTRIAL JOURNAL

Outline of Research & Development of Geothermal Energy Technologies

Nobuaki Mori,
Director for Development Program, New Sunshine Project Office, Agency of Industrial Science and Technology

Nobuaki Mori was born on Aug. 12, 1946. He graduated from a postgraduate course of Kyushu University in 1971 and joined the Ministry of International Trade and Industry (MITI) in the same year.

He went to the United States to study nuclear power in October, 1977. He was appointed general coordination section chief for the nuclear power safety administration Division, Agency of Natural Resources & Energy in 1982, director of the division in 1984 & director of General Coordination Division, Nagoya bureau of MITI in 1985. He is director of Development Program, New Sunshine Project Office, Agency of Industrial Science and Technology.

THE Sunshine Project started in 1974 to develop technologies for securing clean and petroleum-substitute energies. As Japan is one of the most volcanic countries and is abundant in geothermal resources, technological development for geothermal energy is promoted as one of the main subjects in the Sunshine Project.

Technological development is about exploration and drilling/recovering of geothermal reservoirs, and utilization of unused geothermal resources. Basic research is carried out by national research institutes and technological development for practical use by the New Energy and Industrial Technology Development Organization (NEDO). The main R&D has aimed at technologies for development of shallower geothermal resources, but will center of deeper resources. Developed technologies in the Sunshine Project are mainly used for and expected to support development of geothermal power generation by the Agency of Natural Resources and Energy.

Furthermore, in order to consistently develop technologies for energies and the global environment, the New Sunshine Project will begin in FY1993 integrating the Sunshine, the Moonlight (energy-saving technology R&D) and the Global Environmental Technology Projects.

Basic research studied in national research institutes are as follows:

1) "Research on Exploration Technology of Deep Geothermal Resources" to obtain useful data for exploration of deep-seated resources in "Technology for Exploration of Geothermal Energy".
2) "Studies on Drilling Methods for Geothermal Well and Downhole Coaxial Exchanger System" to develop a directional bit applied to a downhole motor, and downhole coaxial exchanger system used for heat extraction from high-temperature magmatic zones in "Techniques for Exploration of Geothermal Energy."
3) "Studies on Geothermal Material Development" to search for materials to be used in the geothermal environment of high temperature and corrosion/errosion.
4) "Research on Fracturing and Heat Extraction from Hot Dry Rock" to study techniques for fracturing and acoustic-emission exploration in "Technology for Hot Dry Rock Power Generation System".

Developing technologies for practical use by NEDO are as follows;

1) "Development of Comprehensive Analysis System" using information-processing highly advanced computer technology, to systematically understand the conditions of geothermal resources in Japan, and to extract promising areas by analyzing ground surface survey data.
2) "Investigation of Exploration Methods for the New Type Geothermal Resources" using ground surface survey data of geology and alteration zones, and airborne magnetic and electromagnetic surveys utilizing resource-satellites and aircraft, to build effective exploration techniques for various types of geothermal resources,
3) "Development of Exploration Techniques for Fracture-type reservoirs" consisting of techniques for seismic exploration (seismic reflection, vertical seismic profiling and seismic tomography methods), electromagnetic wave exploration (new and more efficient array-type controlled source magnetotelluric survey system) and microearthquake exploration, to make accurate exploration methods for fracture-type geothermal reservoirs, the main reservoir type in Japan.
4) "Development of the Binary Cycle Generation (10 MW-class) Plant" furnishing a downhole pump, to search for effective utilization of unused medium to high temperature thermal water.
5) "Development of Technology for Increasing Geothermal Energy Recovery" to establish basic technologies of effective fracturing and accurate prediction for a volume of energy recovery.
6) "Development of MWD (Measurement While Drilling) System for Geothermal Wells" to get various types of well-bottom information on a real time basis while well drilling, and to make possible improvement of efficiency and precision for geothermal well drilling.
7) "Development of Hot Dry Rock Power Generation Technology" consisting of the heat extraction experiments using an artificial reservoir, to utilize heat of high-temperature rocks, one of the unused geothermal resources, effectively.

Furthermore, "Deep Geothermal Resources Survey" program has started to understand conditions of deep-seated geothermal resources (4000m-class), useful to increase geothermal power generation, and to develop effective exploration methods for deeper reservoirs.

"Development of Deep Geothermal Resources Recovering Technology" program consisting of development of drilling and recovery technologies used in high-temperature environments for effective and economic recovery from deep resources, as development of a downhole motor.

For development of the technologies, a budget of ¥4.6 billion is requested for FY1993. The New Sunshine Project Office intends to promote technological development on the basis of advanced domestic and foreign technologies, and to consider joint R&D with overseas enterprises. ◘

Present Status and Future Prospects of Geothermal Power Generation

Yukio Arai was born in March 1949. After graduating from the Atomic Power Engineering Dept., Faculty of Engineering, University of Tokyo, he joined the Ministry of International Trade and Industry (MITI) in May 1972. He became the technical official in charge of industrial technology at the Sunshine Project Promotion Headquarters, the Agency of Industrial Science and Technology, MITI, in June 1976. He became Head of the No. 2 Nuclear Fuel Section, the Nuclear Energy Industry Division, Director-General's Secretariat, the Agency of Natural Resources and Energy (ANRE), in March 1978; Head of the Survey Technology Section, Nuclear Power Generation Dept., Electricity Power Generation Division, ANRE, in January 1980; and Director of the Technology Dept. of the same division in April 1982. After October 1986 he was engaged in the development and planning of advanced reactors in the Nuclear Power Generation Dept., Electricity Power Generation Division. In May 1988 he went to China as Director of the Electric and Nuclear Power Dept., Beijing Office of the Japan-China Economic Association. He was appointed Director in charge of safety management of nuclear power generation, Electricity Power Generation Division, ANRE, in July 1991. Since June 1992 he has been Director, Electricity Power Generation Division.

Yukio Arai,
Director,
Electricity Power Generation Division,
Agency of Natural Resources and Energy, MITI

1. Introduction

JAPAN has endeavored positively for the introduction of alternative energy resources to petroleum after going through two oil crises. But its energy structure is still very flimsy, depending on import from abroad for the supply of practically all energy resources. The energy demand in Japan is tending to increase steeply along with vigorous economic activities and the nation's aspiration for affluent living.

On the other hand, the rising interest of people in global environment problems, represented by global warming and acid rain, has given rise to lively discussions on the use of energy derived from fossil fuels.

The Advisory Committee for Energy, an advisory organ of the Minister of International Trade and Industry, compiled a report with a long-term projection of energy demand in June 1990 in response to these contemporary trends. The projection predicts that national energy demand will rise 1.24 times by 2000 and 1.38 times by 2010 from the level of 1988, even assuming that the nation will make maximum efforts to save energy. The energy to meet this huge demand must be procured somehow. The report points out the need for promoting comprehensive development of all sorts of alternative energy resources to petroleum, including solar energy, nuclear power, geothermal energy and hydroelectric power.

2. Position of Geothermal Power Generation in Japan

The Supply and Demand Committee of the Electricity Utility Industry Council (June 1990) recommended the energetic development of geothermal power generation as a basic power source, which, like hydroelectric power generation, is free from the environmental load of CO_2 and features a very stabilized supply as domestic energy. The following features also rank geothermal energy as a clean energy resource matching the demand of the times because of its stabilized supply and compatibility with the environment.

(1) Geothermal power is purely domestic, inexhaustible and renewable energy. As a volcanic country, it is one of the very few energy resources abundantly available in Japan.
(2) The technology for practically utilizing geothermal power has already been established and its utilization is expected to expand further along with the reduction of development risks and costs.
(3) It is accompanied by little emission of smoke, dust or CO_2.
(4) Besides power generation, hot geothermal water can be utilized for agriculture, fisheries and forestry, and multiple utilization is expected to stimulate local economies.

3. Present Situation of Geothermal Power Generation and National Policy

(1) Present Situation of Geothermal Power Generation

The development of geothermal power generation in Japan dates back to 1925 when Dr. H. Tachikawa carried out the first experimental geothermal power generation of 1.3kW using natural steam in Beppu, Oita Prefecture. Large-scale geothermal power generation started with the putting into commission of the Matsukawa Geothermal Power Plant for private power generation by Japan Metals & Chemicals Co., Ltd. The geothermal power plants operating in Japan at present number 10: five for electric utilities and five for private power generation with a total generating capacity of 270MW.

Seven geothermal power plants are in development at present with definite construction plans. These new power plants with total capacity of about 260MW are slated to start operation by 1996. However, there are only two other locations where geothermal power generation are eventually planned. Private-sector companies have no plans to carry out development surveys in other locations for the time being.

On the international scene, the overall plant generating capacity stood at 6,010MW as of December 1990. Japan boasts the sixth geothermal power generating capacity in the world.

(2) Development Form of Geothermal Power Generation

The development of geothermal power plants in operation or under planning at present can be classified into two forms. The components of the geothermal power plant consist of underground facilities for steam production and the power generation facilities for using the steam.

The first form is characterized by a single company undertaking the development of all components from steam production to power generation. The tasks are performed either by electric power companies; including power distribution, or companies engaged in only the development of power resources.

The second form is characterized by different companies performing the steam production and power generation. It constitutes the mainstream of development including the power plants now in the process of development. The power plant is naturally entrusted to electric power companies, but steam production is frequently performed by firms specializing in the development of geothermal resources, which are often mining companies or their affiliated firms.

(3) National Policy in Japan

The Japanese government is implementing various supporting measures for the survey, development and introduction of geothermal power generation.

1) Budget measures
   * The government takes the initiative in comprehensive surveys regarding geothermal resources.
   * The government conducts surveys on environmental countermeasures.
   * Cost and interest subsidies are granted to drilling enterprises for prospecting wells.
   * Subsidies for the construction of geothermal power plants.
2) Treasury investment and loans
   * Treasury investment and loans for steam production and power generation
3) Taxation
   * Partial exemption of national and local taxes for private power generation facilities

4. Future Prospect of Geothermal Power Generation

The Supply and Demand Committee of the Electricity Utility Industry Council announced the supply target of geothermal power generation according to which the present geothermal power generation capacity of 270MW is to be raised to 1,000MW by 2000 and 3,500MW by 2010.

The solution of various problems inherent in geothermal power generation is indispensable for achieving this target. Principal pending problems are enumerated as follows: (1) various development risks such as those attending survey and industrialization; (2) economic problems related to long lead time and interest load for development; (3) difficulty in harmonizing development with natural parks and hotsprings.

The regulations of national budget and treasury investment and loans are being expanded to deal with these problems. In addition, the three rules to facilitate joint geothermal development by electric power companies and geothermal developers are being worked out. The basic concept regarding pricing for steam purchases was established in April 1992. The rules for cooperation between electric power companies and geothermal developers from the initial stage of development and the standardization of methods for evaluating geothermal resources are being worked out.

The expansion of existing regulations and the improvement of rules related to geothermal development are expected to gradually raise the importance of geothermal power generation for Japan's entire energy supply. For instance, the output capacity and the output of geothermal energy, which now occupies 0.1% and 0.2%, respectively, of the total electricity supply, are projected to account for 0.4% and 1% in 2000, and 1% and 2% in 2010. ◘

Developing Hot Water Power Generation Plants

Kunio Ishibashi,
Director General,
Geothermal Energy Technology Dept.,
New Energy and Industrial Technology Development Organization (NEDO)

Kunio Ishibashi was born in September 1941. He graduated from Mechanical Engineering Department, Faculty of Engineering, Kinki University, in March 1966 and joined Kyushu Electric Power Co., Inc. in April of the same year. He was engaged in operation, maintenance and management of thermal power plants from 1967 to 1976. He was assigned the tasks related to environmental assessment and monitoring of thermal and nuclear power plants from 1976 to 1982. He was transferred to The Federation of Electric Power Companies from 1982 to 1984 and was engaged in tasks related to environmental assessment and monitoring. He took part in the management of thermal power plants from 1984 to 1988. He was assigned tasks related to environmental assessment and monitoring of thermal and nuclear power plants from 1988 to 1992. Since July 1992 he belongs to Geothermal Energy Technology Department, New Energy and Industrial Technology Development Organization (NEDO).

1. Foreword

GEOTHERMAL energy is a subterranean power source. The technologies for prospecting, drilling and exploitation are indispensable for its development and utilization. The precision and efficiency of these technologies must be improved for development promotion.

The vast volume of geothermal water of medium to high temperature and hot dry rock is left untapped underground and the technology to utilize them for electric power generation has not been established yet. It is an urgent task to develop the methods for the development and utilization of these resources.

NEDO is promoting the "Development of Power Generation Plant Utilizing Geothermal Fluid, etc." as an auxitiary project for the "Sunshine Project." Specifically, it is aimed at

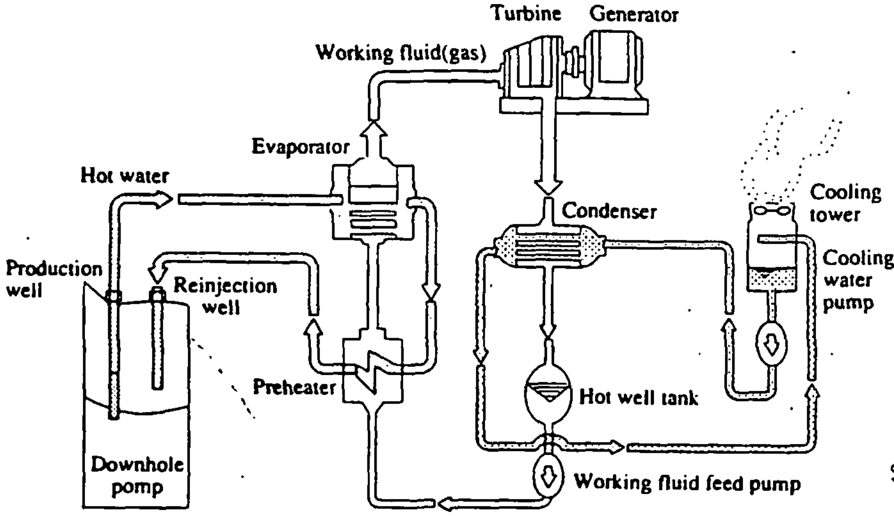


Fig. 1-a Flow Diagram of a Binary Cycle Power Plant

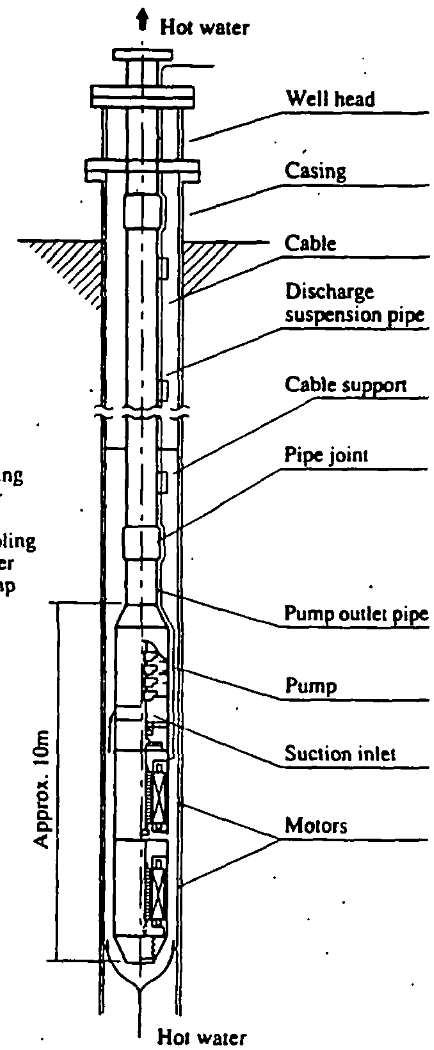


Fig. 1-b General Configuration of a Downhole Pump

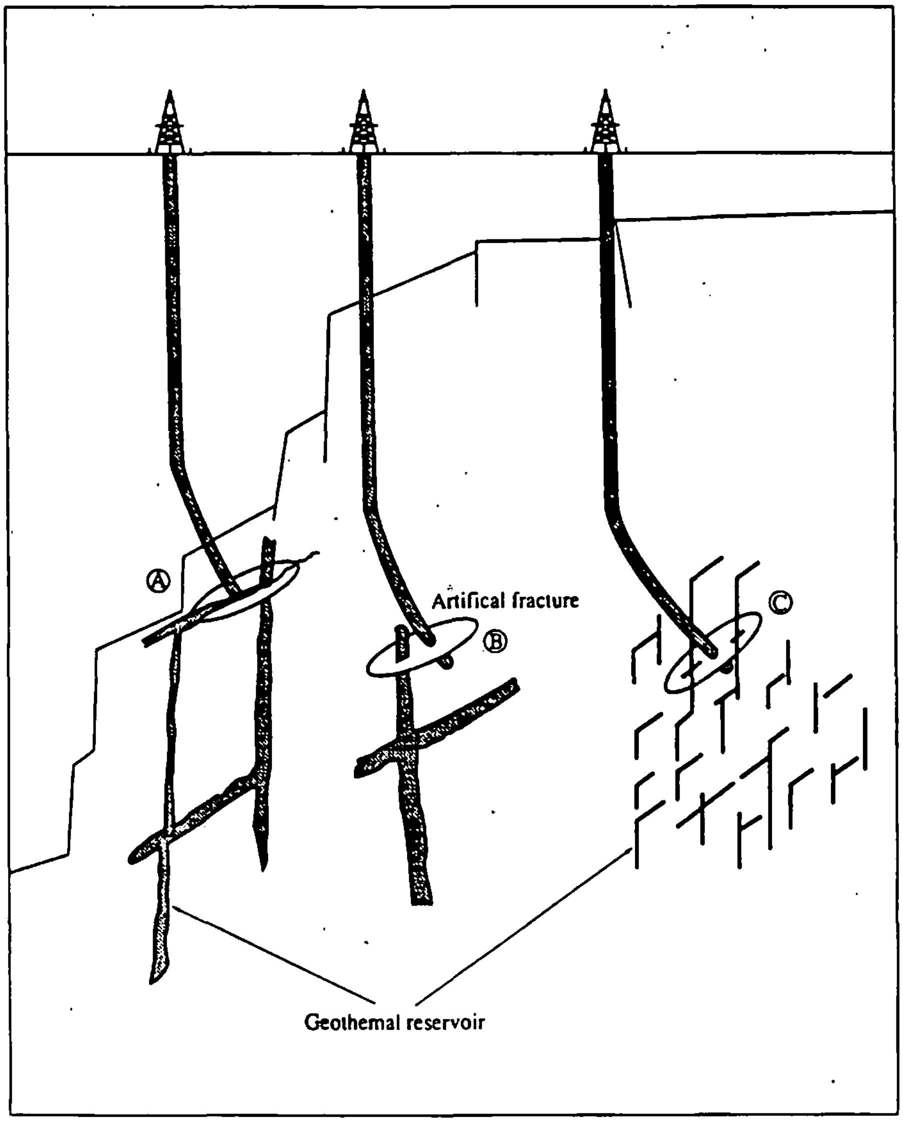


Fig. 2-a Development for Increasing Geothermal Energy Recovery

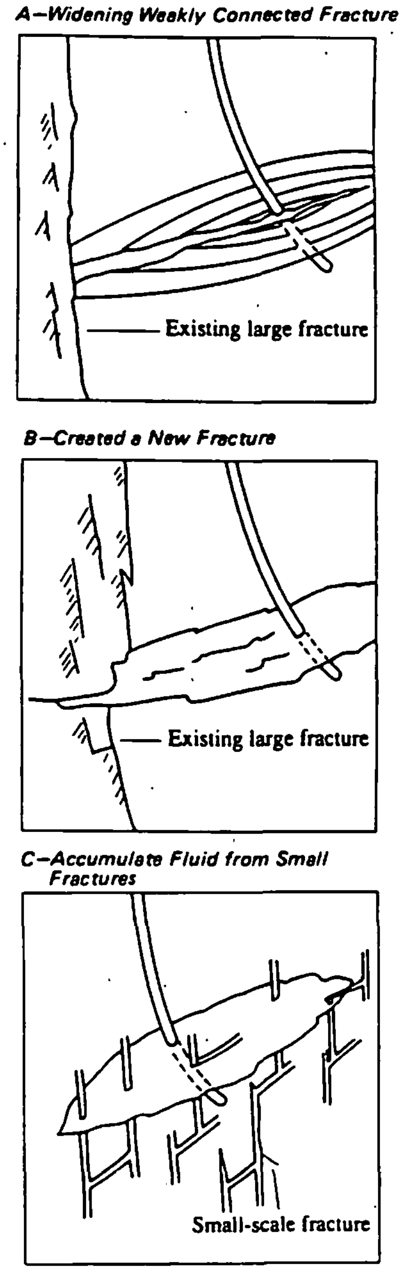


Fig. 2-b Concept of Hydraulic Stimulation for Different Types of Reservoir

the development of technology for expanded utilization of still untapped geothermal resources (hot water and hot dry rock); development of technology for cost reduction of geothermal resources development; and development of technology for exploiting deep-seated geothermal fluid such as drilling and production methods indispensable for increased geothermal power generation capacity and the development of deep-seated geothermal resources:

2. Development of Binary Cycle Power Generation Technology

NEDO is endeavoring to establish technology for binary cycle power generation permitting the utilization of geothermal fluid resources of medium to high temperature which are known to exist in vast quantities in Japan. According to this method, the downhole pump driven by a submerged motor is installed in the geothermal well to pump above ground the geothermal hot water which lacks the power to flow out by itself. Energy contained in hot water is then transferred to a working fluid of low boiling point so as to generate the vapor of the fluid, raising its pressure high enough to drive the turbine for power generation.

At the same time, NEDO is developing the technology for increasing geothermal energy recovery and of a MWD (measurement while drilling) system for geothermal wells as technologies for supporting binary cycle power generation and also for reducing the development cost of geothermal power generation.

(1) Development of a 10MW Demonstration Binary Cycle Plant

As regards the utilization of geothermal water of medium and hot temperature, NEDO is carrying out the "Development of a 10MW Demonstration Plant" based on the above-mentioned binary cycle power generation and the "Development of a

Downhole Pump" (specifications: discharge, 200t/h; lift, 380m; water temperature, 200°C). (Fig. 1).

If these technologies are established, the effective utilization of the latent-type geothermal resources at present (geothermal fluid resources of medium and high temperature of 150 - 200°C) will become possible, laying the foundation for tremendous expansion of geothermal power generation capacity in Japan.

(2) Development of Technology for Increasing Geothermal Energy Recovery

Many geothermal production wells developed so far produce steam and hot water through fractures. Their performance will not be as good as expected if drilled wells do not connect to fractures, or if connections between wells and fractures are poor.

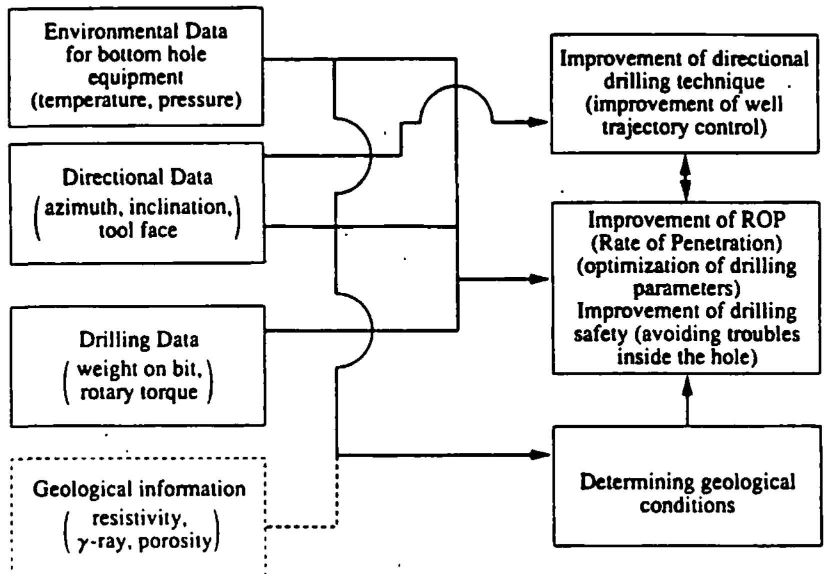
The technology for increasing energy recovery is intended to create artificial fractures by injecting pressurized water into such wells. (Fig. 2). This technology, when perfected, will revive and regenerate existing wells with low productivity, increase the power generating capacity per field unit, reduce the number of wells needed for power generation, reduce the time needed for development and thereby contribute to cost reduction of geothermal power generation.

(3) Development of a MWD (Measurement While Drilling) System for Geothermal Wells

Geothermal wells must be drilled under high temperature conditions. Furthermore, wells are located in complex formations with numerous fissures and water leakage, especially in Japan. Geothermal development areas are subject to environmental conservation regulations and therefore the technique (directional drilling technique) of many wells in many directions from one spot in high precision is increasingly required.

Hence, we started the development

Fig. 3-b Bottom hole measurements and expected effects



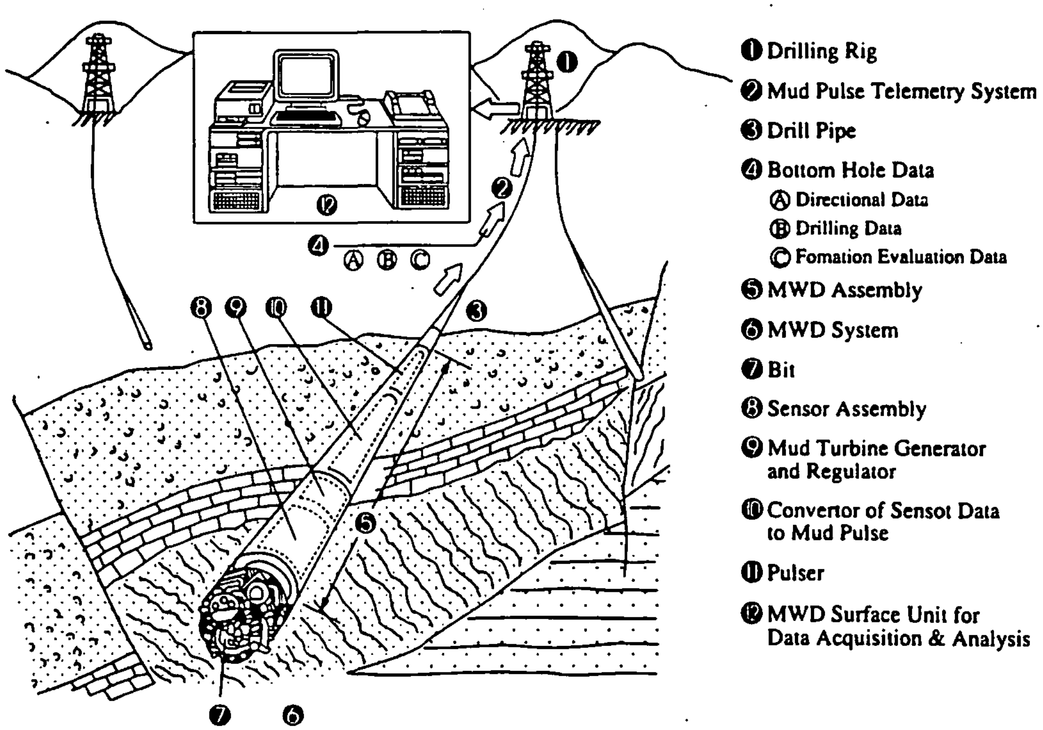


Fig. 3-a Concept of MWD system

of a MWD (Measurement While Drilling) system for geothermal wells which allows the surface personnel to acquire in real time the bottom hole measurement data (direction, inclination, temperature, pressure, etc.) for analysis. (Fig. 3).

This technology, when established, will permit early grasping of changing conditions in the bottom hole, adequate countermeasures based on that data, the improvement of drilling efficiency and precision, and further reduction of drilling cost.

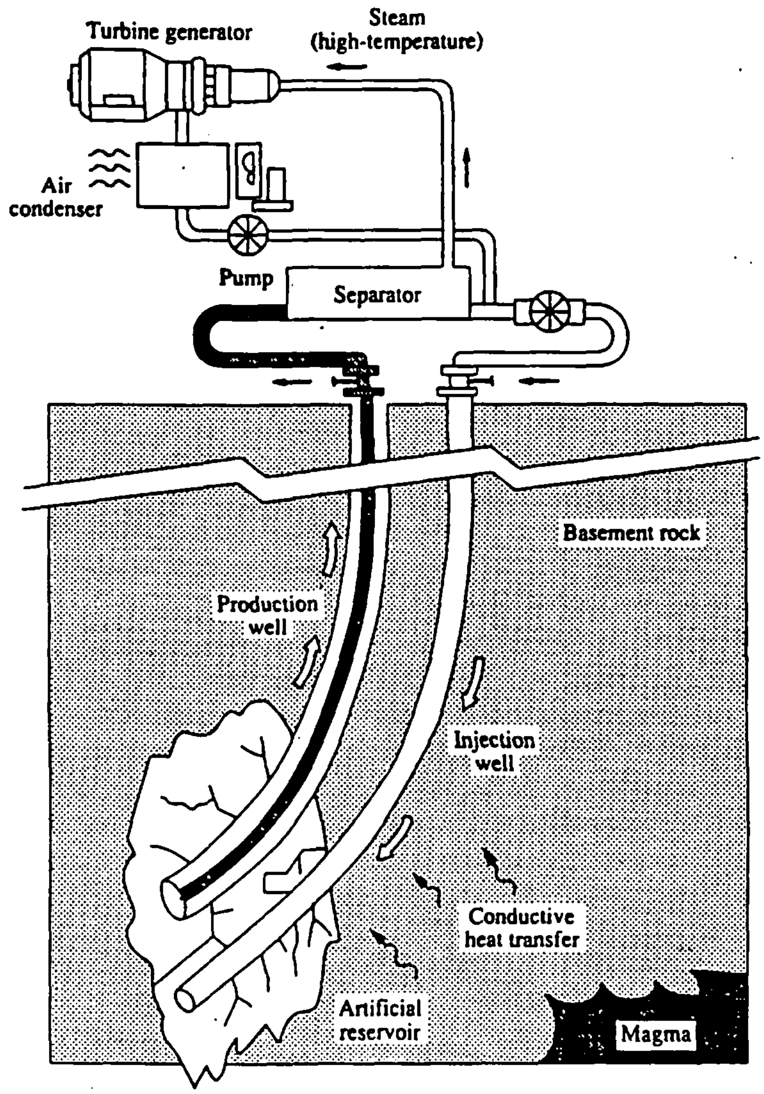
3. Development of a Hot Dry Rock Power Generation System (Elementary Technologies)

NEDO is pursuing the development of a hot dry rock power generation system, namely, the system for developing and utilizing geothermal energy in the so-called hot dry rock or natural high-temperature geothermal reservoir with little water content. Artificial fractures are made in the hot dry rock, water is injected into this artificial geothermal fracture system via a number of wells and steam or hot water is recovered on the ground as in the case of geothermal fluid reservoirs.

Feasibility studies of geothermal power generation from hot dry rock are continuing by injecting pressurized water to make fractures for the artificial geothermal reservoir, the fracture mapping technology and down-hole measurement technology for estimating the extent of the artificial reservoir and the heat extracting system of the artificial geothermal fluid reservoir. (Fig. 4).

Japan as a volcanic country is endowed with abundant hot dry resources which contain an inexhaustible quantity of thermal energy. If we can establish hot dry rock utilization technology that suits Japan's geological conditions, our reserves of recoverable geothermal energy will increase dramatically.

Fig. 4 Concept of a Hot Dry Rock Power Generating Plant



4. Development of Utilization Technology for Deep-Seated Geothermal Reservoirs

The deep-seated geothermal resources that are believed to exist beneath the geothermal reservoir (shallow geothermal resources) developed so far are regarded as very promising geothermal energy resources that lend themselves relatively easily to prospecting and production. They will undoubtedly contribute to increased geothermal power generation capacity at an early date.

NEDO has launched the "Development of Utilization Technology for Deep-Seated Geothermal Resources" as a project to develop drilling, production design technologies and other elementary technologies indispensable to prospecting for deep-seated geothermal resources.

When these technologies have been established, they can be applied to shallow geothermal areas now in operation or development and will contribute to the prevention of the depletion of steam production through adequate production control covering both shallow and deep-seated geothermal resources.

The applications of these technologies to new geothermal areas will pave the way to efficient exploitation of geothermal energy in these areas through planning and execution of a consistent development program comprising the disposition of wells, and production and management of geothermal reservoirs for optimum production modes, taking into account both shallow and deep-seated resources.

The perfection of elementary technologies for drilling, production and management of deep-seated high-temperature resources is expected to exert a stimulating effect on the development of other deep-seated high-temperature resources such as hot dry rock and magma. ◻

Geothermal Resource Surveys and the Development of Exploration Technology

Keiji Kimbara,
Director General,
Geothermal Energy Development Department,
New Energy and Industrial Technology Development Organization (NEDO)

Keiji Kimbara **was born on July 4, 1944. He graduated from the Geological and Mineralogical Institute, Faculty of Science, Niigata University, in March 1967 and obtained his Ph. D from the Physics Dept., Tokyo University of Education, in March 1973. He joined the Geological Survey of Japan, the Agency of Industrial Science and Technology, in April 1974 and was engaged in survey and research of geothermal resources. He was appointed Director General, Geothermal Energy Development Department, NEDO, in June 1992, and is in charge of the survey and development of exploration technology of geothermal resources.**

1. Foreword

NEDO is carrying out the geothermal resources survey and technology development as a part of the state's new energy development project (Fig. 1). I would like to explain the outlines of the geothermal resources survey, exploration technology development, development of geothermal reservoir evaluation technology and the diffusion and promotion of expertise.

2. Geothermal Resources Survey

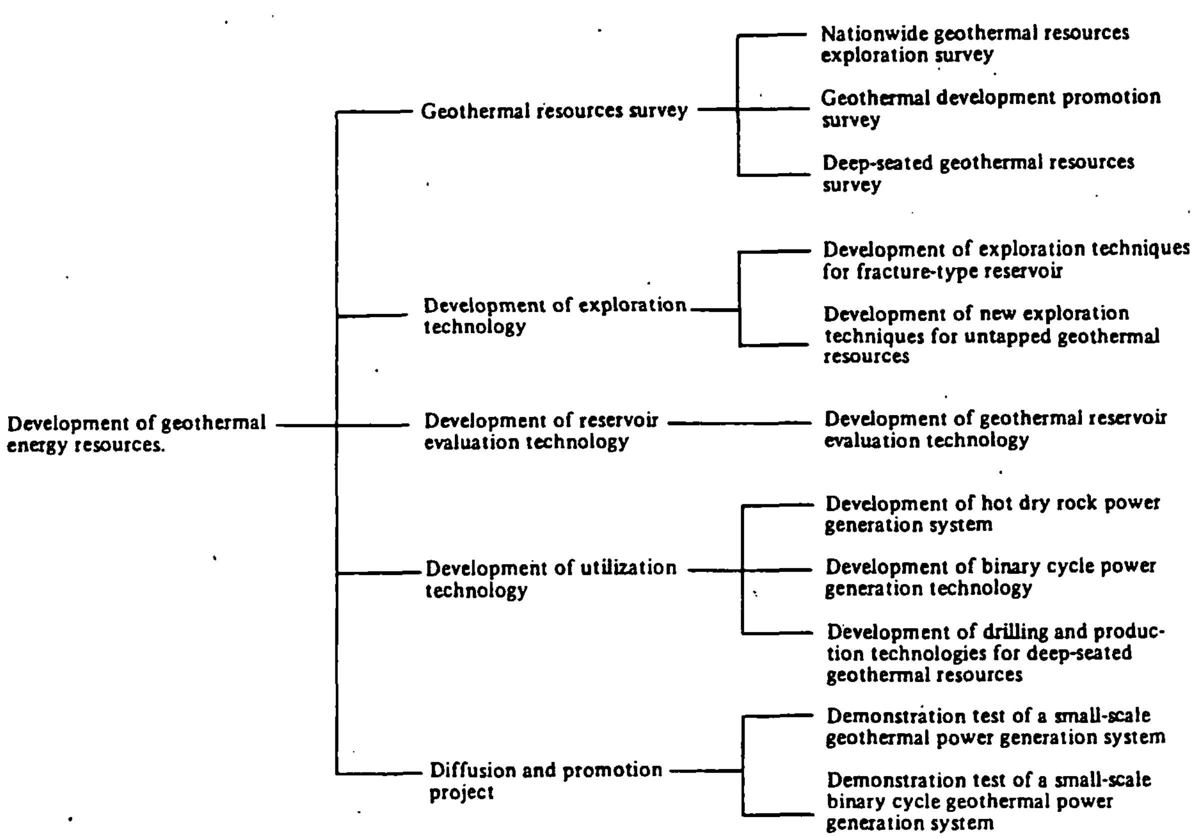
Since its establishment in 1979, NEDO has been conducting the geothermal resources survey of the country based on the flow chart in Fig. 2.

2.1 Nationwide Geothermal Resources Exploration Survey (FY1980 - 1992)

The first phase survey (FY1980-1983) comprised the advanced remote sensing surveys, including a radar (SAR) imagery survey, a curie point survey and a gravity survey covering Japan's entire territory (about 370,000km^2). The data, collected and analyzed on a nationwide basis, revealed several prospective geothermal types such as volcano-related hydrothermal convention systems, possible high temperature areas and hot water in deep sedimentary basin system areas. The Geological Survey of Japan evaluated from this data that shallow geothermal resources of over 150°C, enabling flash power generation, amounted to 20,540MWe/30 years.

The second and third phases (FY 1984 - 1992) were devoted to the surface survey of 10 prospective geo-

Fig. 1. Development of Geothermal Energy Resources in NEDO



thermal areas on wide-area scale (500 - 1,000km^2/area) and the analysis of their geothermal structure. The geothermal potential was evaluated and the heat source evaluation system was studied in the second phase, while various surface survey data was efficiently analyzed and a comprehensive analysis system was developed by applying advanced data processing technology in the third phase.

The third phase was also the period of research on survey methods of still untapped geothermal resources including hot dry rock, magma, deep-seated geothermal resources and medium-high temperature geothermal resources.

2.2 Geothermal Development Promotion Survey (FY1980-)

NEDO takes the initiative in this survey in prospective geothermal areas where the investigation is hampered by survey risks, thereby expediting the development of geothermal power generation by private-sector companies. The survey consists of the confirmation of the geothermal reservoir by drilling six to eight wells with depths of 1,000 - 1,800m per area (50 - 70km^2) for three years, in addition to various surface surveys. Surveys were finished in 32 areas since the start of project in 1980, and they are still continuing in six other areas (Fig. 3).

As a result, subterranean temperatures of over 200°C, enabling steam power generation, were confirmed in 21 areas. Development surveys are progressing based on preliminary results in Uenotai (Akita Prefecture, 27.5MW), Yanaizu-Nishiyama (Fukushima Pref., 65MW), Ogiri (Kagoshima Pref., 30MW) and Hachijo Island (Tokyo Metropolis).

However, it would be extremely difficult to achieve the development target of 1 million kW by 2000 and 3.5 million kW by by 2010 if development is to proceed at the present slow pace. Hence, a new geothermal development promotion survey was inaugurated in FY1992. The new project classifies the surveys in Survey A (district survey), survey B (same as previous surveys) and survey C (detailed survey) according to area characteristics and the state of existing data as shown in Fig. 2. This arrangement is aimed at a further reduction of survey risks and development lead time. If, in particular, the results of survey C, including geothermal reservoir evaluation using large-bore production wells (period of four years), are assessed as promising, the development project is to be handed over directly to private-sector companies.

2.3 Deep-seated Geothermal Resources Survey

The development of new areas or the premises expansion of existing power plants is not easy in Japan owing to limitations due to topography and the presence of hotsprings and national parks. Under these circumstances, it appears most efficient to develop deep-seated resources lying beneath the already available shallow resources at a depth of 1-2km as a step to expand the geothermal power generation capacity. NEDO inaugurated in FY1992 the project to ascertain the existence of deep-seated resources at a depth of 3-4km by drilling deep wells in areas where shallow resources have already been developed.

2.4 Other Geothermal Resources Surveys

NEDO conducted wide-area surveys including well drilling of the 3,000m class in Hohi (Oita and Kumamoto Pref.) in central Kyushu in FY1978 - 1985 and Sengan (Akita and Iwate Pref.) and Kurikoma (Miyagi Pref.) in northeastern Japan in FY1980 - 1988. The results of these surveys led to the development at Sumikawa (Akita Pref., 50MW) and Oguni (Kumamoto Pref., 25 - 30MW) by private-sector corporations.

3. Development of Exploration Technology (FY1988-)

In the initial stage of geothermal development the geothermal fluid was thought to be stored in a simple porous-type reservoir. However, further progress of the development led to the finding that the fluid is stored in complex subterranean fractures which are difficult to explore from the ground surface. NEDO, therefore, has been conducting since 1988 technical development of prospecting methods using seismic waves, electromagnetic waves and microearthquakes as methods to ex-

Fig. 2. Flow of exploration survey for geothermal resources

Survey	Nationwide survey 370,000km^2 →	Area survey (500 ~ 1000 km^2) →	District survey ↔ Detailed survey: Survey A 100~300km^2	Survey B 50~70km^2	Survey C 5~10km^2 →	Exploitation survey (3 ~ 4 km^2) →	Construction of power generation plant (1 ~ 2 km^2)
Purpose	Rough survey of the nationwide distribution of geothermal resources; selection and classification of prospective areas	Elucidation of wide-area geothermal structures and selection of prospective areas for district survey	Confirmation of high-temperature abnormal areas	Confirmation of geothermal reservoirs	Evaluation of geothermal reservoirs	Detailed evaluation of geothermal reservoirs and detailed design	Construction of geothermal power generation plants
Project	Nationwide geothermal resources exploration survey (Phase I)	Nationwide geothermal resources exploration survey (Phase II and III)	Previous geothermal development promotion survey; New geothermal development promotion survey			Private-sector companies	
Executing organization	NEDO	NEDO	NEDO			Geothermal development enterprises	Power utilities companies

plore fracture-type reservoirs.

NEDO has already completed basic experiments using seismic wave prospecting method such as VSP (vertical seismic profiling), seismic tomography, high-resolution seismic survey, etc. by means of three wells of 500 - 600m in the basic experimental field using the Tanna fault (Izu Peninsula, Shizuoka Pref.) as a fracture model. It has been conducting tests of prospecting methods in the application experimental field of Yutsubo near Otake Geothermal Power Plant (12.5MW) in Oita Prefecture since 1990.

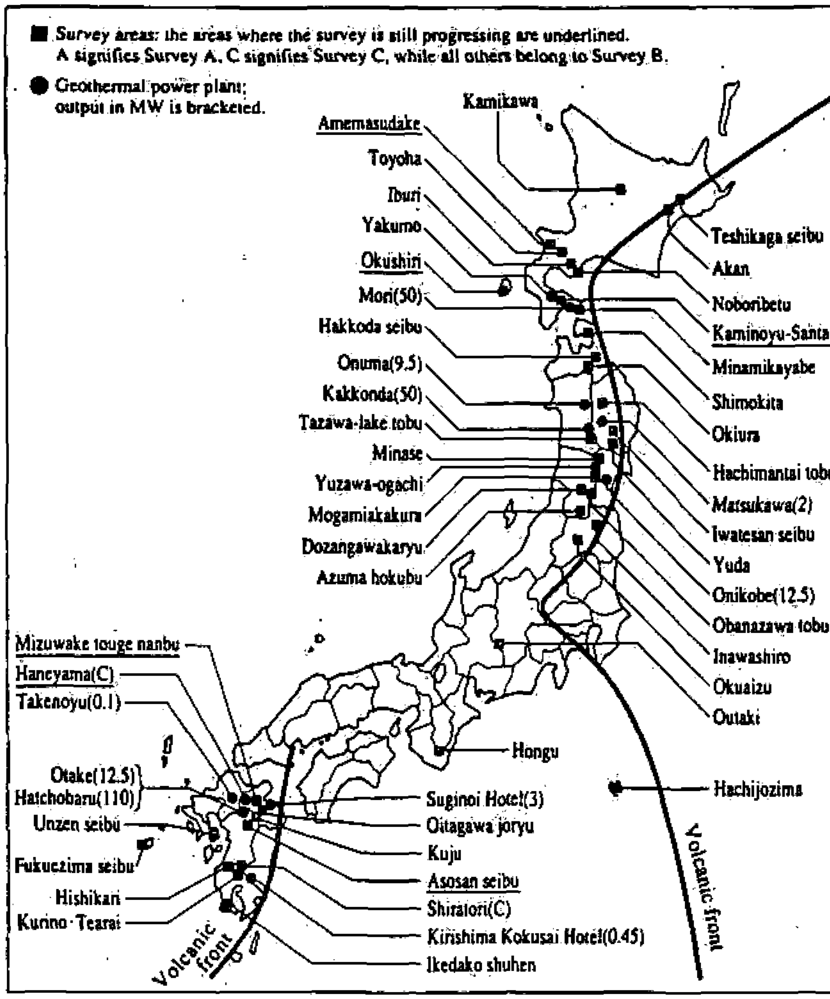
As regards the development of prospecting methods using electromagnetic waves, the array MT (magnetotelluric) method is being developed. This method, using linear arrangement of observation points, features data acquisition of higher accuracy than the previous MT method for prospecting the subterranean resistivity structure using discretely arranged observation points. The development of practical systems is underway for prospecting methods using microearthquakes by exploring geothermal reservoirs with microearthquakes generated by the movement of geothermal fluid.

4. Development of Geothermal Reservoir Evaluation Technology (FY1984 - 1992)

Accurate evaluation of the potential in a geothermal reservoir and the preliminary assessment of the generation capacity based on the potential is extremely important for reducing development risks. NEDO is conducting the development of a simulator for this purpose and application research on simulation methods in the model field.

It developed in Phase I (FY1984 - 1987) the reservoir simulator "SING I" assuming a reservoir made of porous media and the fluid consisting of pure water in gaseous and liquid phases, as well as the in-well dual phase flow simulator "WENG." This was followed by Phase II (FY1988-1992) in which SING II was being developed. This new simulator assumes a fracture-type reservoir and can handle multi-component fluid including CO_2 gas and chlorine. In parallel with the development of simulators, two or three observation wells of about 1,500m in depth have been drilled in four geothermal exploration model fields with different subterranean geological conditions for application research. The in-well test data and the continuous pressure observation data prepare the ground for natural condition simulation in these model fields, history matching simulation and the improvement of the reservoir model.

Fig. 3. Location of Geothermal Development Promotion Survey



5. Diffusion and Promotion Project

NEDO is conducting the following projects for the diffusion and promotion of geothermal energy resources development.

5.1 Demonstration Test of a Small-Scale Geothermal Power Generation System (FY1986 - 1992)

This project was aimed at the development of a small-scale geothermal power generation system that enables efficient operation even under adverse geothermal conditions, such as hotsprings wells with low steam pressure which are not utilized for power generation at present. Specifically, a condensing-type small-scale power generation system of 200kW (turbine entrance pressure of 0.6kg/cm^2) and a back pressure-type system of 300kW (3.0kg/cm^2) have been designed and constructed. A long-term demonstration test is being carried out at Kirishima International Hotel of Kagoshima Pref. using hotsprings wells.

5.2 Demonstration Test of a Small-Scale Binary Cycle Geothermal Power Generation System (FY 1991-)

This project concerns the development of a small-scale binary cycle geothermal power generation system applying medium-high temperature hot water resources of below 200°C which cannot be utilized for direct steam power generation. Specifically, a medium with a low boiling point is heated as a heat source and the obtained steam is then used for power generation. The project calls for the development and demonstration test of a small-scale power generation system (100kW) provided with a screw expander and a medium-class system (500kW) provided with a radial turbine for promoting their applications. ◘

Advancing the Utilization of Geothermal Energy & the Effective Use of Geothermal Water

Masahiko Hayakawa,
Executive Managing Director
New Energy Foundation

Masahiko Hayakawa **was born in 1930. He graduated from the Mechanical Engineering Department, Nagoya Institute of Technology, in 1957, and joined MITI in the same year. He later studied in the graduate school of Nuclear Engineering at Iowa State University of Agriculture & Engineering. He has been primarily engaged in the promotion and development of thermal and nuclear power. He became Managing Director of the New Energy Foundation in 1986 and currently serves as its Executive Managing Director.**

1. Geothermal Resources and Their Utilization in Japan

1) Estimated Geothermal Resources

JAPAN with its numerous volcanos has abundant geothermal resources with magma continuously discharging a tremendous amount of heat. Since the dawn of history, hot springs have existed at about 2,300 places throughout the country. Some 2,700 geothermal wells were in actual operation as of the end of March 1991, producing about 2,200 kl/min or 132,000 kl/h of hot water.

Assuming the temperature of hot water to be 50°C and that heat exchanges down to 15°C are possible, it can produce 4,600 x 10^3 Mcal/h or 5,350 MWt of thermal energy. The estimation of geothermal resources at 204 locations throughout the country in 1989 showed that the potential of high temperature geothermal fluid of over 150°C existing in depths less than 3km totaled 69,000 MWe (volumetric method, 30 years). Estimated amount of geothermal resources based on prospecting well surveys totaled 25,000 MWe.

Assuming that the steam/water ratio of the geothermal fluid is 1 : 2 in the development of the power generation of 25,000 MWe, directly utilizable thermal energy would amount to 170,000 MWt, or 30 times greater than the total heat energy of existing hot springs.

2) Actual Situation of Utilization

a. Utilization for power generation
The capacity of geothermal power generation, as of the end of March 1992, totaled 270 MWe. Resources in the process of development or development surveys come to roughly the same amount. Hence, total geothermal power generation capacity is estimated to increase to 540 MWe by 1996.

b. Direct utilization

* Assuming that the water in the temperature range between 50°C and 35°C can be utilized for bathing in hot springs, 2,289 MWt is actually being utilized at present.
* If waste water from existing hot springs in the range between 35°C and 15°C can be utilized in the future, 3,051 MWt will become available, markedly expanding the volume of waste heat utilization.
* Some 180~200 MWt produced by hot springs equipment and systems is utilized for various purposes, not including private bathing.

c. Geothermal co-generation

* 500 kl/h of hot water produced during geothermal power generation, average temperature being 75°C, is utilized. Most of the hot-temperature geothermal fluid is re-injected underground without being utilized.

* 35 MWt would become available if the geothermal fluid in the temperature range of 60deg. can be utilized.

2. Present Situation of Diffusion Promotion Policy

1) Promotion of District Energy Development and Utilization

The Ministry of International Trade and Industry (MITI) has formulated the following steps aimed at diversification of utilization forms and stages of natural energy, including geothermal energy, energy derived from waste heat, and products and improvement of the conventional energy supply system within the framework of the policy for promotion of district energy development and utilization.

a. Promotion of commercialization
* Surveys on feasibility and plans for commercialization
* Execution of model project
* Subsidy to general project

b. Promotion of enlightenment and diffusion.
c. Perfection of promoting organization.

The subsidies to geothermal utilization enterprises include the interest subsidy of 3~3.5% for the installation cost of systems for hot water receiving, water intake, heat exchange and transport (not including the cost for drilling geothermal wells), for the enterprise of direct utilization of geothermal energy less than ¥500 million. A geothermal power generation enterprise of less than ¥300 million will be entitled to the same interest subsidy.

The subsidy for geothermal energy utilization totaling ¥6,400 million was granted to 74 projects in the period from 1982 to 1992 and is used for the facilities of district hot water supply, space heating and hot water dispensing, eel culture, horticulture and snow melting. ¥150 million per power generation project of 200KW was granted.

2) Demonstration Studies on Hot Water Supply Projects at Geothermal Power Plants

MITI has been conducting the demonstration survey on hot water supply project at Shizukuishi-cho, Iwate Prefecture, and Kazuno City, Akita Prefecture, since 1980. Geothermal wells for power generation are over 1,000m deep. As the geothermal water contains harmful substances such as arsenic and silicon in high concentration, heat exchange must take place with clean water. Two types of hot water production systems are adopted: the type to evaporate the geothermal fluid (unit capacity: 400 t/h) and the tank and tube type (unit capacity: 11 t/h x 14 units).

3. Promotion of Effective Utilization of Hot Water and Related Tasks

1) Suitable Geothermal Resources and Multi-Stage Utilization

As geothermal resources are a natural occurrence, one should build the utilizing system conforming to the heat quantity, temperature and components of the heat transfer medium.

Geothermal resources are clean, domestically available and renewable energy sources. In order to achieve effective utilization to the maximum extent, heat extraction must be stepped up from surplus water and waste water of hot springs to deep-seated geothermal fluid and underground water. Multiple utilization forms should be considered corresponding to the temperature level of the heat medium, including multi-stage or cascade systems, the application of heat pumps to low temperature fluid and combined utilization of different heat sources according to varying load.

2) Location

Matching the locations of geothermal resources development and heat consumption areas is indispensable. The securing of clean water for heat exchange and adequate reinjecting capacity of original geothermal fluid are also essential tasks.

3) Economical Factor

The heat supply enterprises require heavy investment cost just like other public utility enterprises. The condition for the successful enterprise is rather stringent since supplied hot water must compete with kerosene and other fuels in cost.

The following factors must be considered as essential requirements of the enterprise:

a. High heat demand density;
b. Little fluctuation of heat load;
c. Performance and reliability of systems including the heat exchanger should be maintained; simplified systems are needed ("Keep it simple."),
d. The development of the heat demand market should be possible;
e. Possibility and condition for subsidies.

4) Harmonization with Nature and Society

A larger part of prospective geothermal areas in Japan overlaps with national parks. Harmonization with natural scenery is an essential condition. Present strict administrative control measures for the construction of geothermal power plants are an important factor limiting geothermal power generation and heat supply.

Co-existence with hot spring enterprises, together with the prevention of effect on hot springs, is important from the social standpoint.

5) Development and Demonstration of Technology

We cannot as yet regard as fully established the system engineering for simplifying and ensuring the reliability of design, construction and maintenance of systems and equipment for direct utilization. The pH control method for preventing the deposition of silica scale in the system is being tested. A system for the direct elimination of harmful ingredients from geothermal fluid, besides hot water production using a heat exchanger, should be demonstrated at an early date, from the standpoint of utilizing hot spring resources.

6) Heat Supply Enterprise Setup

Enterprises related to direct utilization are demanded to fulfill several tasks, including the stabilized supply of geothermal fluid, maintenance of equipment reliability not depending on the property of the fluid and the management of survey and development costs. For this purpose, securing of able and dedicated personnel as well as stabilized management organization are indispensable. Local public organizations are awaited to play their role positively in a project to improve the living conditions of regional communities.

7) Preparation of Circumstances for Participation of New Geothermal Enterprises

Enterprise risk should be reduced in order to facilitate the participation of new enterprises in the geothermal project. We need to establish information services, suitable circumstances for the investment related to society and living, and the preparation subsidies and other aids.

Heat supply enterprise needs large funds at the initial stage. Large capital cost should be supported by construction subsidy and other aids.

The information service should take following points into account:

a. Expansion of an organization with functions to collect and analyze the information on direct utilization;
b. The information furnishing service and introduction manuals should be improved;
c. Service and guidance related to feasibility studies should be improved. ◻

Japan Metals and Chemicals Co., Ltd. Working to Develop Geothermal Resources

Hitoshi Kojima,
Director,
Geothermal Division,
Japan Metals & Chemicals Co., Ltd.

Hitoshi Kojima was born in 1932. He graduated from No. 1 Faculty of Science & Engineering, Waseda University, in 1955, and joined Japan Metals and Chemicals Co., Ltd. in 1956. Since 1981 he has been engaged in the development of geothermal resources. He is now Director and General Manager, Geothermal Division, JMC.

The Company's Outlook

JAPAN Metals & Chemicals Co., Ltd. (JMC) was established in 1917 as a manufacturer of ferro alloys which are indispensable as auxiliary materials for steel making. JMC's advance into geothermal power generation was motivated by the need to secure the electric power needed for operating submerged are furnaces, the equipment for making ferro alloys. The company's business scope has been gradually expanded since its establishment, ranging over chemical fertilizers, electronic materials and computer software. JMC's activities are making substantial contributions to many sectors of society.

Matsukawa Area (Iwate Pref.)

Geothermal development by JMC was touched off in 1952 when a prospecting well drilled in quest of a hot spring here caused an abnormal eruption of a large quantity of steam. The first geothermal power station in Japan was built on this site in 1966 to supply electricity to a ferro alloy plant. As the eruption of steam alone is a rate phenomenon, Matsukawa is often compared to Geysers in the U.S. The capacity of this power plant was gradually expanded and at present it is providing a stabilized output of 22MW.

The natural ventilation type cooling tower, with a height of about 40 meters rearing up in the valley, harmonizes well with the surrounding scenery and has become a notable sightseeing spot.

Kakkonda Area (Iwate Pref.)

The success in Matsukawa became a great stimulus for the development of geothermal resources in other regions. JMC conducted joint development with an electric power company in the Kakkonda Area which is located across a mountain from Matsukawa. As this locality is a so-called water dominated area, several problems had to be solved such as the separation of steam and hot water, the reinjection of hot water into underground layers and the interference of reinjected water with production wells. A geothermal power station was built here in 1978 with a rated output of 50MW. This project was characterized by the division of labor with JMC undertaking the production of steam and an electricity utility company undertaking power generation. JMC thus became the first sales company of geothermal steam in Japan. Kakkonda plant started its operation in the midst of the oil crisis and geothermal energy came into the focus of general attention as a "domestically produced, clean and recoverable energy" in Japan. The success of this plant exerted a favorable effect on the state's energy policy.

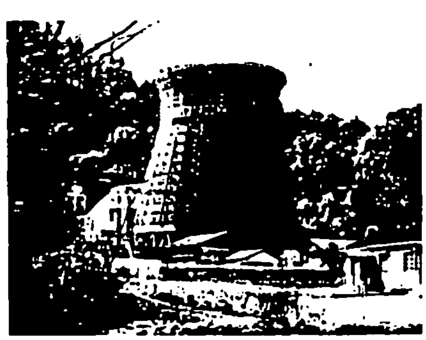
The "Geothermal Hot Water Reinjection System" developed in this area by JMC was commended by the state and the electric power company as an outstanding technology.

The government is at present conducting demonstration tests for utilizing hot water produced through heat exchange between the river water and the geothermal water after the separation of steam for power generation. The results are being looked forward to with much expectation by the local community.

The Kakkonda II Project is progressing in parallel and is scheduled to start operation in 1996 with a capacity of 30MW.

Mori Area (Hokkaido)

Mori Geothermal Power Station, built in a joint project of JMC and an electric power company, started operation in 1982 with an output of 50MW. The geothermal reservoir in this area is characterized by a caldera structure. As the wells tend to be clogged by scales of calcium carbonate, we have established a technology for injecting a scale inhibitor into wells through tubing pipe in order to prevent the growth of scales and thereby to ensure stable steam production.



Cooling Tower of Matsukawa

GRC Pioneer Award

As mentioned above, JMC has been promoting geothermal development projects in three areas with entirely different geological features. Our company received the GRC Pioneer Award from Geothermal Resources Council in 1990 for its success in Matsukawa and persistent activities in the development of geothermal resources.

Japan ranks 6th in the world in total power generation capacity of geothermal equipment. The JMC Group boasts a share of 45% in the total domestic geothermal power generation capacity of 270MW, and we believe that our efforts in the past have won high appreciation from the electric power industry.

R&D and International Cooperation

JMC with its numerous able engineers is in a position to offer wide expertise related to prospecting, drilling and plant design. Besides the maintenance work of already existing facilities, these engineers are pursuing their own research and development, including participation in the state R&D projects promoted mainly by NEDO (New Energy and Industrial Technology Development Organization) as well as overseas cooperation with JICA (Japan International Cooperation Agency).

JMC Geothermal Research & Development Co., Ltd. (JMCD), a company of the JMC Group, has been offering diversified exploration and drilling technology incorporating its rich experience and technical knowhow accumulated over the past 20 years as a torch-bearer of geothermal development. ◻

The Energy Development Programs of Geothermal Energy Research and Development Co., Ltd.

Masao Tsuge,
President
Geothermal Energy Research and Development Co., Ltd. (GERD)

Masao Tsuge was born on May 23, 1936. After graduating from the Department of Mineral Industry at Waseda University, he entered the Ministry of International Trade and Industry (MITI) in 1961 and became director of the Mexico Center of the Japan External Trade Organization (JETRO) in 1985. In 1988, he transferred from MITI to GERD and was promoted to president in 1990.

Foreword

DUE to the Middle East War in 1974, we were faced with a so-called energy crisis, such as shortage of oil for industry, a steep rise in energy prices, etc. This triggered the Agency of Industrial Science and Technology (AIST), MITI to begin a new R&D project – the Sunshine Project for the development of alternative energy sources, namely solar power, geothermal, coal, and hydrogen.

GERD was established to carry out part of the Sunshine Project in November 1975 with investment from 25 private companies (now 32, refer to Table 1). Our company aims are to develop technologies related to geothermal exploration, production of geothermal resources, environmental maintenance and so on, then to promote geothermal energy development in Japan.

So far under the Sunshine Project, we have conducted some 30 projects and four R&D projects are active now. On the tenth anniversary of the project, in September 1984, GERD was commended by AIST, MITI.

GERD also has a consulting business for geothermal energy development. We have applied technologies developed by our R&D and have introduced many excellent foreign technologies, in cooperation with about 40 foreign organizations.

Research & Development

Over the last 10 years the Sunshine Project has been concerned with seven major subjects, with cooperation from other companies.

We are currently involved with the following four subjects:

(a) Development of hot dry rock power generation technology;
(b) Development of technology for increasing geothermal energy recovery;
(c) Development of measurement while drilling system;
(d) Development of exploration technology for fracture-type geothermal reservoir exploration (Array CSMT method).

In this paper, I will outline the development of hot dry rock power generation technology, which, since 1985, has been field-tested in Hijiori, Yamagata Prefecture.

Hot dry rock (HDR) power generation harnesses the heat kept in high-temperature rocks deep in the earth. Since the thermal power available is tremendous, it should be harnessed worldwide, and will probably be a major energy resource for the next generation.

As shown in Fig. 1, a fracture zone is situated between two wells. Water injected through one well is heated in the fracture zone, and heated water in extracted through the other well and used for power generation.

In Japan, basic research has been conducted since fiscal year 1974 as part of the Sunshine Project. Experiments have been carried out with an artificial reservoir constructed in a granite layer 1,800m deep (at approximately 260°C) in Hijiori, Yamagata Prefecture. A plan is underway to construct an artificial reservoir on a larger scale at a depth of 2,300m, and to conduct experiments to evaluate it as a power generation system.

Consulting Business

Our consulting business consists of the following three streams:

(a) Geophysics; magnetotelluric method, the only method for deep resistivity sounding, and EM methods;
(b) Reservoir engineering; PTS (pressure, temperature, spinner) logging, pressure monitoring, and its analysis;
(c) Drilling service; steering tool service, downhole motor service and so on for mainly directional drilling service.

In addition, we try to introduce very common and valuable technologies used overseas to Japanese geothermal developers. When we introduce new technologies, we not only make a technical tie-up with the organization, but also develop software for analyses by employing the technology ourselves. Because we are

Table 1 GERD stockholders

Akita Geothermal Energy Co., Ltd.	Niigata Engineering Co., Ltd.
Chuo Kaihatsu Corporation	Nippon Mining & Metals Co., Ltd.
Furukawa Co., Ltd.	Nippon Steel Corporation
Hokuriku Electric Power Company	Nittetsu Mining Co., Ltd.
Idemitsu Geothermal Co., Ltd.	NKK Corporation
Ishikawajima Harima Heavy Industries Co., Ltd.	Sanki Engineering Co., Ltd.
Japan Metals & Chemicals Co., Ltd.	Sekisaku Co., Ltd.
Japan Petroleum Exploration Co., Ltd.	Sumitomo Metal Mining Co., Ltd.
Kawasaki Heavy Industries, Ltd.	Teikoku Oil Co., Ltd.
Kyushu Electric Power Co., Ltd.	The Dai-Ichi Kangyo Bank, Ltd.
Mitsubishi Heavy Industries, Ltd.	The Industrial Bank of Japan, Limited
Mitsubishi Materials Corporation	The Long-Term Bank of Japan, Ltd.
Mitsui Mining & Smelting Co., Ltd.	TIX Corporation
NEC Corporation	Tohoku Electric Power Co., Ltd.
Nichiboh Co., Ltd.	Toho Zinc Co., Ltd.
Nihon Cement Co., Ltd.	Toshiba Corporation

(32 companies in all, listed in alphabetical order)

well aware of the importance to the client of interpreting the data acquired by new technologies, we of course regard measurement of new technologies as vital.

Development of Technologies Adapted to Japanese Geothermal Fields

We introduced the MT (magnetotelluric) method from the US in 1981, and also started to develop modeling techniques.

Then, we were entrusted with the "Development of high-accuracy MT method", which adapted exploration to Japanese geothermal fields, which was one of the New Energy and Industrial Technology Development Organization (NEDO) R&D projects for 1984 through 1988. Through this R&D, we became the world's top level supplier of equipment, data processing, and analysis. There were three critical features employed in designing the MT method:

(a) complex geologic structures;
(b) abrupt topographic relief; and
(c) high cultural noise.

These are all commonplace problems faced by exploration in Japan, and have played an important role in the successful interpretation of MT data. As a result of this project, we have shown the MT method is useful for geothermal exploration. The following is a list of highlights of the high-accuracy MT system (refer to Fig. 2):

(a) Triple-reference and real time processing;
(b) Simultaneous 4-point measurement capability;
(c) Wide frequency band measurements (0.001Hz-20kHz);
(d) Parallel and serial measurement capability;
(e) Digital data communication via an optical fiber link.

In Future

We are determined to continue R&D into new technology developments and for our consulting business to introduce new foreign technologies and hope our activities will contribute to future development of Japan's geothermal resources.

We would also like to contribute to the New Sunshine Project, a new policy for MITI. This may enable us to apply technologies we have developed and improved through R&D and our consulting business to foreign geothermal development.

We are sure our activities can be of help both inside and outside Japan, from both geothermal development and global environmental standpoints. ◘

Fig. 2. The high-accuracy MT system, which has the capability of simultaneous measurements at 4 MT sounding stations with real time triple-reference data processing.

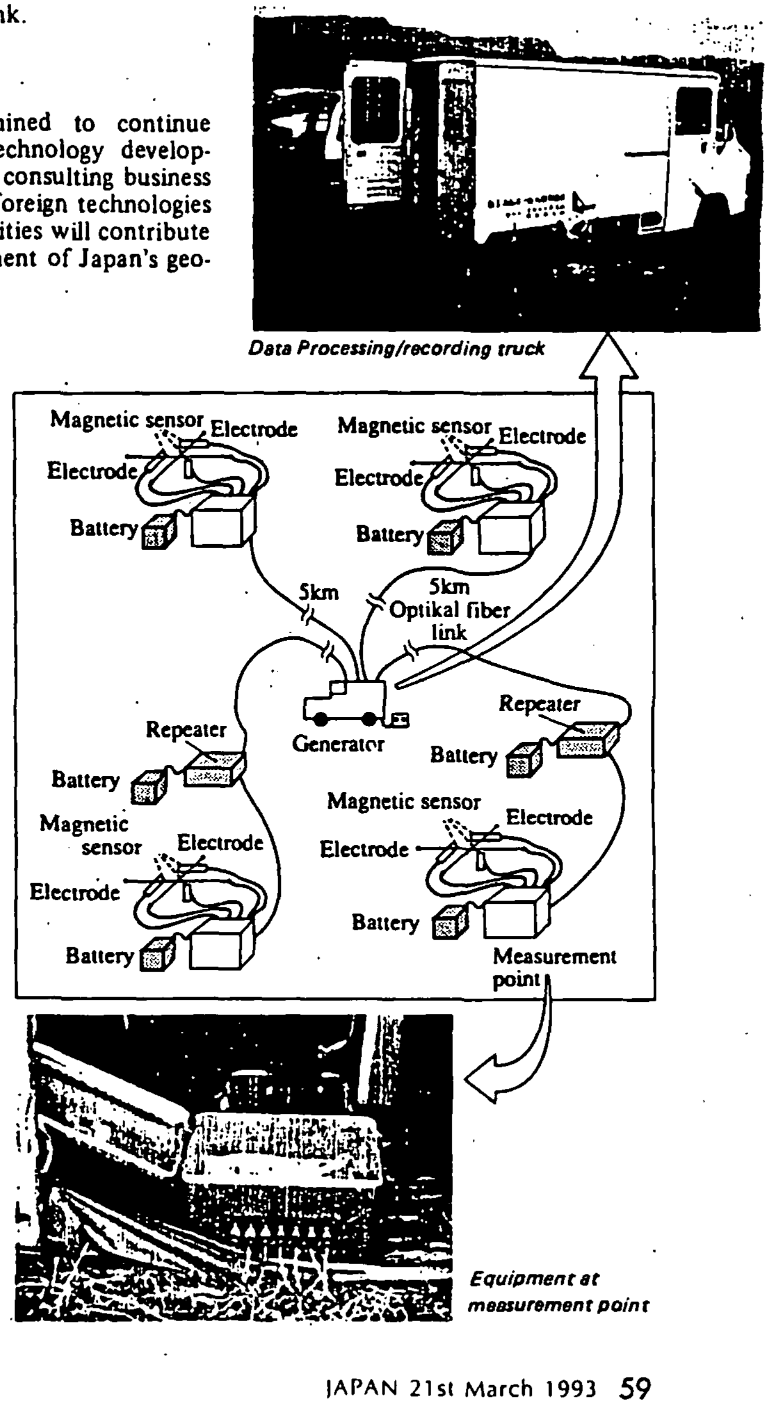
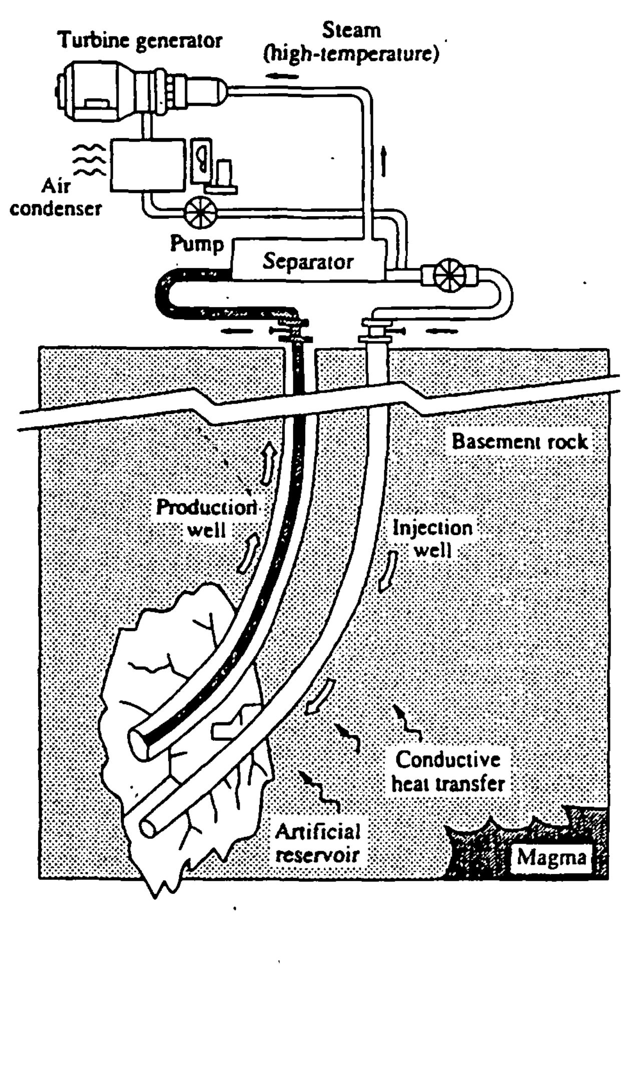


Fig. 1 Concept for hot dry rock power generation



Kyushu Electric Power Company Promotes the Development of Geothermal Energy

Kuniyoshi Ishii **graduated from the Electric Engineering Department, Faculty of Engineering, Kyushu University, in March 1957 and joined Kyushu Electric Power Co., Inc. in April of the same year. He was appointed General Manager of the Thermal Power Department in June 1987 and Director of the company in June 1991.**

Kuniyoshi Ishii,
Director,
Thermal Power Department,
Kyushu Electric Power Co., Inc.

1. Foreword

JAPAN as one of the leading volcanic countries of the world has been known to have geothermal resources since ancient days. Geothermal energy was familiar to all people in Japan mainly for bathing in hot springs. But it was only about 20 years ago that geothermal energy was conceived of as a source of electric power. Since then 12 geothermal power plants have started operation with a total output of 270,000kW.

The development of geothermal resources faces numerous difficulties. However, geothermal energy, as one of the few types of clean and domestically available energy, should be promoted by all means from the standpoint of the national energy situation and the global environment.

I would like to explain briefly the history of geothermal development by Kyushu Electric Power Co., (hereafter abbreviated KEPCO), its present situation and problems, and the future outlook.

2. The History of Geothermal Energy Development by KEPCO

KEPCO started the survey on geothermal resources as early as 1945-50 and constructed Japan's first geo-

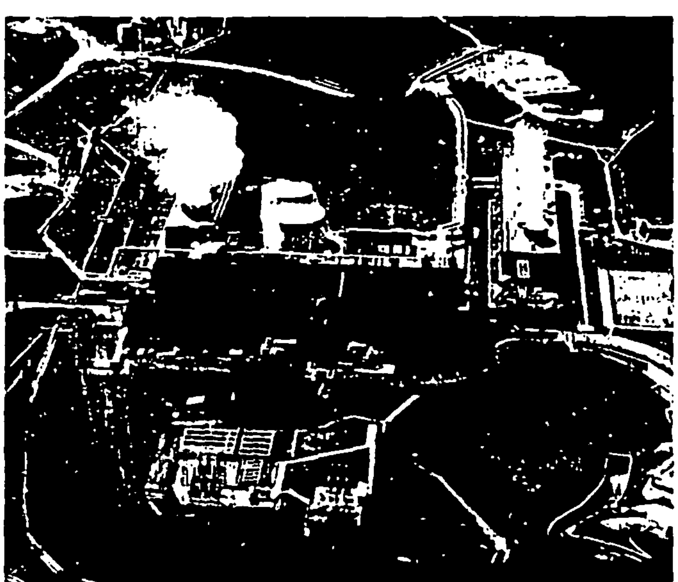
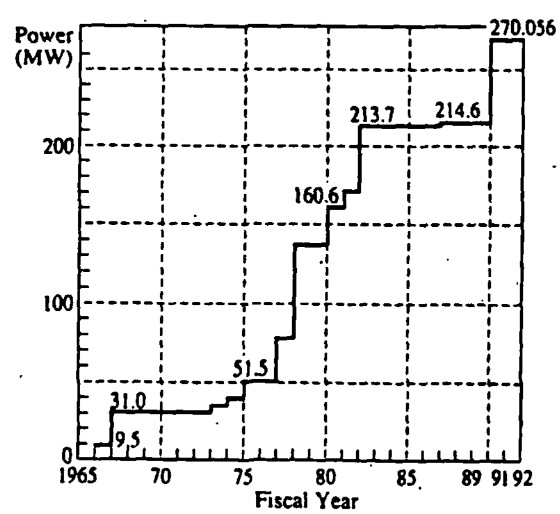


Fig. 1 Power Generating Capacity of Japan's Geothermal Power Plants



thermal power station for commercial use in 1967 with a capacity of 12,500kW in Otake, Oita Prefecture. Based on this success, the company built in 1977 the No. 1 Hatchobara Geothermal Power Station, a full-scale commercial geothermal power station, in Hatchobara, Oita Pref. adjacent to the Otake plant, and attained a rated output of 55,000kW in 1980. It was followed by the putting into commission of the No. 2 plant in June 1990 with an output of 55,000kW. KEPCO is probably the only company in the world that carries out an integrated development of geothermal resources covering survey, development, construction of the power plant and its management. We are positively promoting geothermal development, being aware that it contributes to effective utilization of domestic energy resources and to the preservation of the global environment.

3. Problems Related to Geothermal Power Development

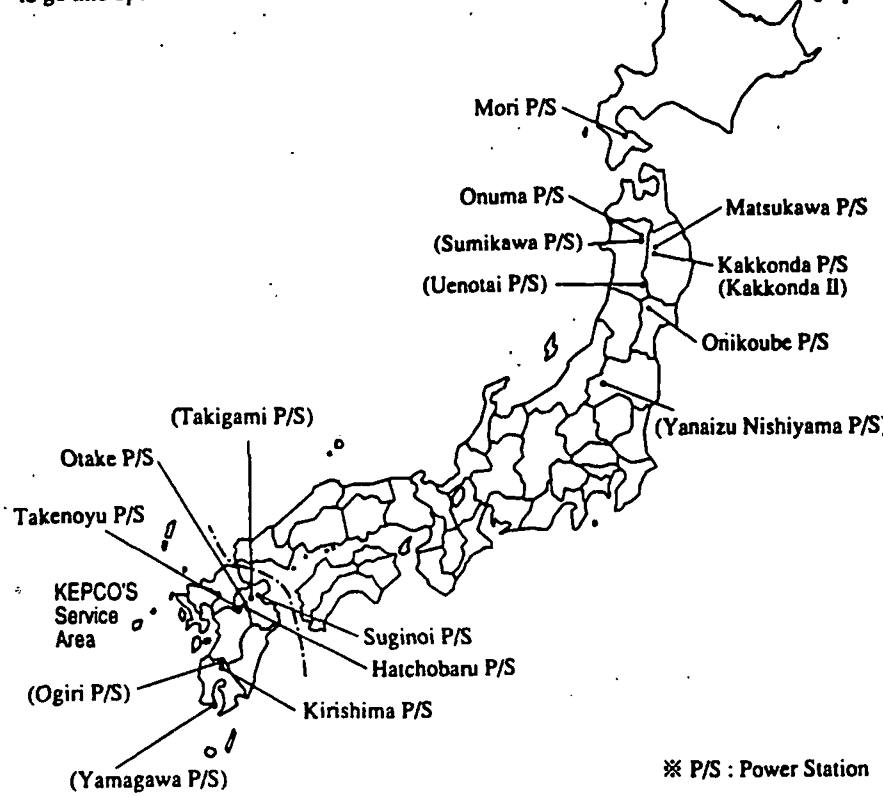
The development of geothermal resources is currently being carried out at seven localities in Japan in the form of joint projects by electric power utility companies and developers. But the total power generating capacity of all these plants far falls short of the target of 1 million kW by the year 2000, as set by the Electricity Utility Industry Council.

(1) Economic feasibility

Electricity is the only product resulting from geothermal development, with no by-products such as mineral resources that may bring profit to the industry. Geothermal power development is demanded to possess an economic feasibility comparable to that of other energy types such as petroleum, coal, atomic energy and LPG. However, the technology related to prospecting and drilling still has numerous gaps and a geothermal development project is always attended with more risks than conventional energy. In particular, a long period of time is needed from the survey to development and power generation and is very unfavorable to economic feasibility.

(2) Problems related to legal controls

Prospective geothermal areas are often located in or near sightseeing spots and hot springs. Development should not interfere with the existing landscape. Furthermore, many geothermal resources are located in national parks where development is forbidden.



Stations in parentheses are plants to go into operation after 1994

Since a law directly controlling geothermal power development is absent at present, the developer must follow complicated legal procedures under several jurisdictions including laws regarding forestry, hot springs and parks.

(3) Social environment

As stated in the previous section, prospective geothermal areas frequently overlap with old hot springs. Development is impossible without prior understanding and adjustment with local communities, which is very time-consuming. Adequate steps should be taken to protect the environment and to ensure co-existence with local communities.

4. Future Prospect

The solution of the above-mentioned problems is a prerequisite for successful geothermal power development. Establishment and improvement of prospecting technology are indispensable for enhancing economic performance. Development risks may be reduced and the evaluation of resources may be expedited by conducting sufficient surveys and adequate analysis utilizing advanced technology.

The economic performance is expected to be improved further through the currently enforced subsidy system and low interest loan system of the state to support development projects and the New Geothermal Power Development Promotion Surveys introduced in 1922. We hope for further expansion and improvement of these institutions.

The problems related to national park law and local communities may be solved by strict observance of harmony with the environment, contributions to the local community through effective utilization of hot water and the construction of power stations that tend to enhance the local image. The creation of a law pertaining to geothermal development is also desirable from this standpoint.

The development of geothermal resources thus seems to be indicated from the standpoint of effectively utilizing domestic energy sources and protecting the global environment. KEPCO is resolved to work for the solution of these problems and to promote the development of technology for exploiting precious domestic geothermal resources. ◘

Geothermal Energy Resource Development by the Electric Power Development Co., Ltd.

Terumi Ushijima,
Director,
Geothermal Engineering,
R&D Department,
Electric Power Development
Co., Ltd.

Terumi Ushijima was born in November, 1935. He graduated from the Civil Engineering Department of Kumamoto University in 1959, joining Electric Power Development Co. Ltd. (EPDC) the same year and was engaged in hydro and coal thermal power development projects. Since July 1991, he has been the Director of Geothermal Engineering Division of Research & Development Department.

1. Foreword

ELECTRIC Power Development Co., Ltd. (EPDC) was established as a state policy corporation for carrying out large-scale development of electric power resources in the country's reconstruction after World War II. It developed gigantic hydroelectric power resources, including the Sakuma Dam, and built thermal power plants burning domestically produced coal, large pumping-up power plants and thermal power plants using imported coal. The power generation facilities developed by EPDC are comprised of 55 hydroelectric power plants with a total capacity of 7,630,000kW and seven thermal power plants with a total capacity of 4,650,000kW, totaling 12,280,000kW. The power transmission lines for them have a cumulative length of about 2,271km. EPDC is also engaged in wide-area projects linking electricity utility companies in each district. It has extended overseas assistance to 39 countries of the world.

EPDC started the collection and analysis of data in 1960 as a preparatory step for the development of geothermal resources. It selected six prospective areas in Japan in 1961, which were regarded as promising in view of geological structure and freedom from hot springs and other impediments. They were Kussharo, Noboribetsu (Hokkaido), Onikobe (Miyagi Pref.,), Oshirakawa (Gifu Pref.), Tsukahara (Oita Pref.) and Shijuku (Kagoshima Pref.). After working out the basic survey plan, EPDC commenced on-the-spot surveys in these areas in 1962. The surveys led to the conclusion in 1964 that Oshirakawa Area and Onikobe Area were the most promising sites. Prospecting wells were drilled accordingly. However, Oshirakawa Area was later dropped because it was located within the special conservation area of a national park at the foot of Mt. Hakusan (Gifu Pref.). Onikobe Area was judged as more suitable in 1965 and after that the surveys were concentrated in that district.

2. Development of Onikobe Geothermal Power Station

Onikobe Area is located at about 50 minutes by car from Naruko Hot Springs of Miyagi Prefecture. It finds itself in a ring-shaped area called "Onikobe Caldera" where three geothermal manifestation called Arayu Jigoku (Hell), In Jigoku and Katayama Jigoku still constitute an active geothermal phenomenon.

Onikobe Geothermal Power Station is located in Katayama District. Prospective wells from GO-1 TO GO-12 were drilled and several surveys were conducted using electric prospecting (Schramberger method of C.G.G. Co.), refractive method and reflective method. We confirmed that high-quality and high-temperature steam is available at a relatively shallow stratum of 300m deep. On the other hand, two deep wells (1,350m and 1,300m. respectively) produced a steam jet of 30-40 t/h. However, this geothermal fluid was found unsuitable for power generation as it contains hydrochloric acid with pH of 2.6-3.2 and corrodes the strainer in a short period of time. The drilling of deep wells was discontinued afterwards.

Onikobe Geothermal Power Station began to operate with an output of 9,000kW on March 19, 1975, and the power was stepped up to 12,500kW after April 1976. The plant has already been operating for 17 years.

3. Commissioned Execution of Survey of Large-Scale Deep Geothermal Development with regard to Environmental Conservation

The oil crisis in 1973 was the direct motive for the planning and development of new energy resources after 1975. "Geothermal energy" came to the fore as the most fruitful energy source alternative to petroleum.

EPDC has carried out the "Environmental Protection Demonstration Survey for Large-Scale Deep-Seated Geothermal Power Generation" since FY1978 as a commissioned task of the Agency of Natural Resources and Energy within the framework of the Sunshine Project.

The purpose of this survey is to expand geothermal power generation by utilizing hitherto untapped deep-seated geothermal fluid of high temperature and pressure as a part of the state policy to expand the utilization of domestically available energy resources and to diversify energy supply. Surveys were mainly conducted in the Hohi District of Northern Kyushu in order to grasp deep-seated geothermal reservoir in wide area, to ascertain the feasibility of large-scale power generation and to assess the effect of collection and re-injection of geothermal fluid on the environment. EPDC accepted the survey project from New Energy and Industrial Technology Development Organization (NEDO) which was established in October 1980, and completed the survey in 1985 after establishing the R&D Department and Geothermal Development Office within the latter.

The surveyed site, called Hohi District, is located at about 40km to the southwest of Beppu City and covers an area of about 200km^2 (15km from west to east and 14km from north to south) stretching over Oita and Kumamoto prefectures.

This survey took place in close cooperation with the government, universities and the private sector. The latest high-precision methods were employed for surveying and analysis of data. The geothermal reservoir of Hohi District was investigated by means of five prospecting wells of the 3,000m class, 10 holes of the 1,500m class for surveying the geological structure, seven 500m geothermal wells and 82 80m test wells.

Modern equipment and methods were mobilized in the ground survey including gravity methods, analysis of terrestrial magnetism and electricity and aerial magnetism. These methods are going to exert a tremendous influence on future geothermal surveys. In particular, new methods of prospecting and analysis were taken over by the subsequent geothermal development promotion surveys.

4. Commissioned Execution of Survey and Development Tasks Related to Binary Cycle Power Generation

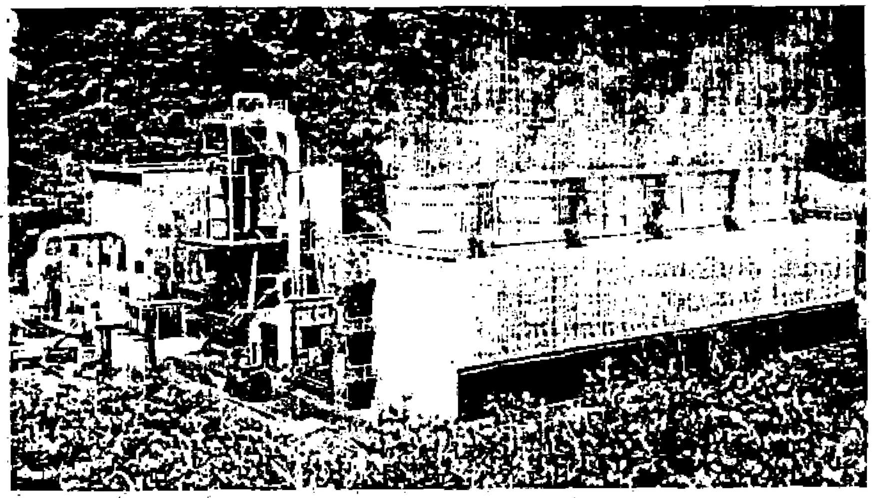
The research and development of binary cycle geothermal power generation in Japan was started simultaneously with the Sunshine Project in 1974. Operating tests were conducted until 1978 for evaluating technical feasibility at a pilot plant of 1,000kW. EPDC accepted the commissioned task of comprehensive equipment control and evaluation of the 1,000kW plant from the Agency of Industrial Science and Technology from FY1977 to 1979. Test operation and analysis were carried out in FY1978 and 1979 to evaluate technical feasibility.

It was followed by research on a demonstration plant of the 10,000kW class after FY1979. EPDC took charge of the overall coordination and the setting of field and economic conditions as a part of the plant concept design. The development of the downhole pump and the evaluation of the underground geothermal fluid resources were further research themes. We surveyed Sugawara District of Oita Pref. and obtained hot water corresponding to 20,000kW using three production wells. The presence of geothermal fluid resources sufficient for power generation of 10,000kW has been thereby confirmed.

Although the development of the downhole pump was hampered by several troubles, we successfully concluded in November 1992 the operating test for 1,000 hours under the condition of 200°C. On-location tests were started at Sugawara in February of this year, and the consecutive construction of a 10,000kW demonstration plant is planned if all goes well.

5. Development Survey of Oguni Area

Whereas Survey of Large-Scale Deep Geothermal Development with regard to Environmental Conservation is progressing, Oguni Area was found to be suitable for conventional geothermal power generation and its development survey was entrusted to EPDC in autumn of 1983. This site is located in the northeastern part of Kumamoto Pref. adjacent to and partially overlapping Oita Pref., covering an area of about 20km². The reservoir simulation evaluation is being conducted at present incorporating the results of long-term steam production tests conducted since autumn of last year. The expertise will serve for mapping out the power generation program.



Onikobe Geothermal Power Station

6. Overseas Technical Assistance

Our company is carrying out international technical assistance, endowed as it is with outstanding technical expertise on geothermal development and the ability to conduct development surveys in wide ranges.

For instance, EPDC conducted geothermal development surveys in Argentina from 1988 to 1992 at the request of JICA (Japan International Cooperation Agency). The survey took place in the Andes close to the border to Chile. The slim hole of NQ size was drilled and reached a steam reservoir at a depth of 1,065m, with successful production of 10t/h of steam.

The present development program calls for the power generation of 30,000kW as the first phase, taking into account the estimated energy demand of the region and hitherto available information.

7. Conclusion

The actual task of geothermal power generation in EPDC is mainly carried out at its Geothermal Engineering Office, R&D Department. The accumulation of diversified techniques and expertise is indispensable for the promotion of geothermal development. Our company is pursuing the development in close liaison with related firms in each business sector. It should be remarked in this connection that the concentration of total technology power in one group is very advantageous for the progress of development.

Geothermal energy is the most realistic, clean and domestically available type of energy alternative to petroleum. The demand for its development is destined to grow in the future. On the other hand, geothermal development faces several difficulties because most of the prospective sites are located within national and quasi-national parks or else the resources are of low quality and are attended with high risks. Moreover, the present development projects entail huge costs for surveys and well drilling, so that geothermal power is more expensive than other energy resources.

Further effort for winning understanding and support for geothermal development is essential for steady development of underground energy in the optimal composition of electric power sources in coming days. Enterprises engaged in the development of geothermal resources should demonstrate the safety and usefulness of this new energy source with actual results in order to obtain general support. Under these circumstances, Electric Power Development Co. as a state policy corporation intends to pursue the development of geothermal resources with new determination. ◘

Tohoku Electric's Geothermal Resource Development Projects

Minoru Morikuni,
General Manager,
Thermal Power Department,
Tohoku Electric Power Co., Inc.

Minoru Morikuni was born in 1936. He graduated from the Electric Engineering Department, Faculty of Engineering, Hokkaido University, in 1959, and joined Tohoku Electric Power Co., Inc. in the same year. He was mainly engaged in the planning of thermal power stations. He became general manager of Thermal Power Department in 1990 and concurrently one of the senior officers of the company in 1991.

Abundant Geothermal Resources in Tohoku

GEOTHERMAL power is one of the relatively abundant energy resources available in Japan proper. The Tohoku District of northeastern Japan is believed to account for about 30% of geothermal power resources existing in our country. There are four geothermal power stations, including private plants, in this area with a total approved generating capacity of 94,000kW, or 35% of Japan's total geothermal power generating capacity.

The development of geothermal resources by Tohoku Electric Power Co., Inc. started in 1978 with the putting into commission of the Kakkonda Geothermal Power Station in Shizukuishi-cho, Iwate Prefecture, with an output capacity of 50,000kW.

Based on the experience accumulated in the course of this project, Tohoku Electric Power is carrying out the development of three additional geothermal power stations at Uenotai, (Yuzawa City, Akita Pref.), Sumikawa, (Kazuno City, Akita Pref.), Yanaizu Nishiyama, (Yanaizu-cho, Fukushima Pref.), and an expansion of the Kakkonda Geothermal Power Station in Shizukuishi (Fig. 1).

Development of the Kakkonda Geothermal Power Station

The development of this plant was originally planned by Japan Metals & Chemicals Co., Ltd. (JMC) in 1969, and Tohoku Electric Power joined the project in 1970. It is a joint project between these two companies with JMC undertaking the steam production and Tohoku Electric undertaking the power generation.

This power station has the following distinctive features:

(1) The closed system for re-injection of high-temperature geothermal fluid is adopted.

(2) As this power plant is located within a national park, care is taken to preserve and maintain harmony with the natural landscape. Specifically, the main equipment is housed in a building, and the area of the premises is reduced with the adoption of a geothermal well base.

(3) Anti-corrosive material is employed inside the turbine. The cable coating material is sulfur-resistant.

(4) The operation is controlled with a remote monitoring system located in Shizukuishi at a distance of 23 kilometers.

This power station has operated for 13 years without major accident. The availability comes to 90%.

Development and Expansion of Plants

The geothermal development method of Tohoku Electric Power is characterized by the joint project with the geothermal field developer taking charge of steam production. Development is accomplished in the three steps cited below, while evaluating geothermal reserves and economical feasibility.

1. Establishment of a joint survey and study committee;
2. Signing of a contract for promoting the project;
3. Signing of the final agreement.

The development plan for four sites is summarized in Table 1.

(1) Uenotai Site

Dowa Mining Co., Ltd., the parent company of Akita Geothermal Energy Co. which is conducting actual development, started the survey in 1971. The two firms have been carrying out survey and study for joint development since 1981. A steam production volume of 270t/h has been confirmed using simultaneous continuous steam production tests using prospecting wells.

The capacity has been set at 27,500kW on the basis of the evaluated geothermal reserves including the production forecast for the next 30 years. The final agreement was concluded in 1989 and the application for site approval was submitted to local authorities in 1990.

An environment survey was simultaneously conducted by developers for one year and the development plan was approved by the Electric Power Development Coordination Council of the state in the spring of 1991, after due procedures for environmental assessment.

Construction commenced in spring of 1992 after the procedures required by the Electricity Utility Industry Law and the regulation regarding the termination of protective forests were met. Construction work is progressing smoothly for the scheduled start of commercial operation in 1994.

(2) Sumikawa Site

Mitsubishi Material, Corp. (formerly Mitsubishi Metal Corp.) started the basic survey of Sumikawa together with Onuma Geothermal Power Station in 1965. The survey at Sumikawa was stepped up in 1974. Tohoku Electric Power joined the survey in 1985. Steam production of 420t/h was confirmed using the simultaneous continuous steam production test with prospecting wells. The evaluation of steam production volume and estimated geothermal reserves showed that power generation of about 50,000kW is possible. The basic contract was concluded and the application for the site of a geothermal power station was submitted to local authorities in 1990.

The development plan was approved by the Electric Power Development Coordination Council in spring of 1992 after the due procedures of environmental assessment. Construction is to start in spring of this year with the scheduled start of operation in 1995.

Fig. 1. Geothermal Power Stations and Geothermal Development Sites in Tohoku District

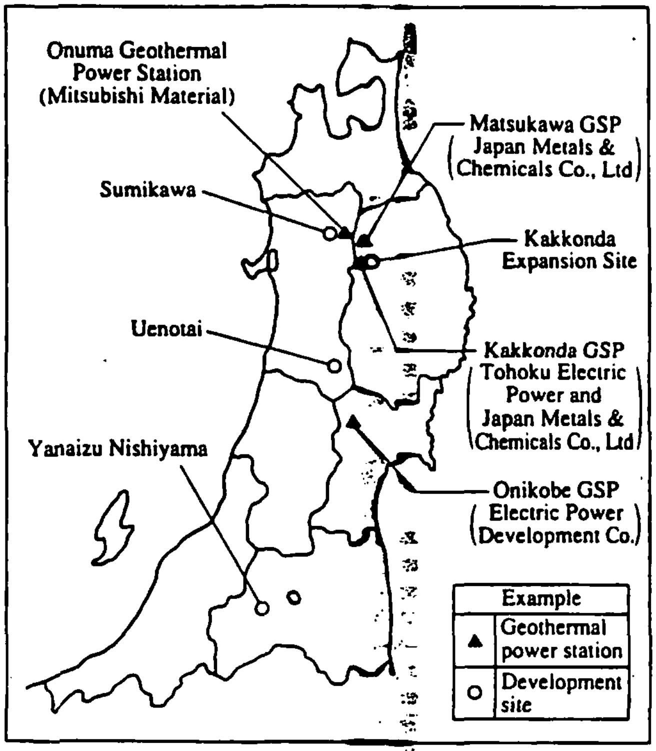
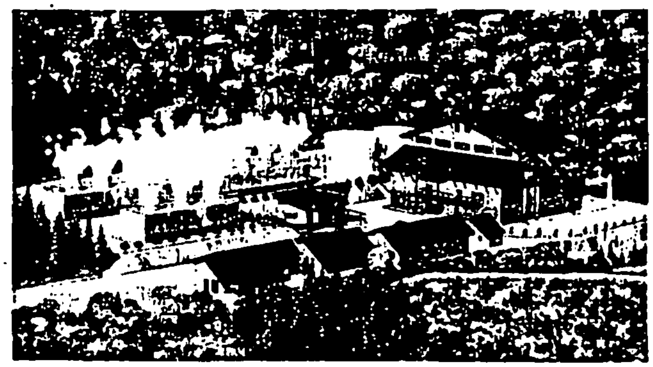


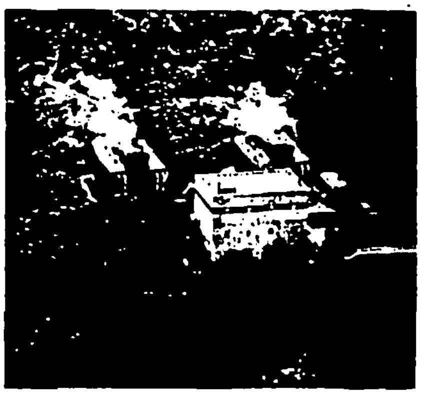
Table 1. Geothermal Development Schedule

Name (site)	Output capacity (kW)	Schedule (year, month)	Developers of steam production plant
Uenotai GSP (Yuzawa, Akita Pref.)	27,500	EPDCC 1991 - 3 Construction start 1992 - 4 Operation start 1994 - 3	Akita Geothermal Energy
Sumikawa GSP (Kazuno, Akita Pref.)	50,000	EPDCC 1992 - 3 Construction start 1993 - 4 Operation start 1995 - 3	Mitsubishi Material
Yanaizu Nishiyama GSP (Yanaizu, Fukushima Pref.)	65,000	EPDCC 1992 - 12 Construction start 1993 - 6 Operation start 1995 - 5	Oku Aizu Geothermal
Kakkonda No. 2 GSP (Shizukuishi, Iwate Pref.)	30,000	EPDCC 1993 - 3 Construction start 1994 - 4 Operation start 1996 - 3	Tohoku Geothermal Energy

Note: According to Facility Plan FY1992



Artist's Conception of Uenotai Geothermal Power Station (Operation scheduled to start in 1994; capacity 27,500kW)



Kakkonda Geothermal Power Station (Operation started in 1978; capacity 50,000kW)

(3) Yanaizu Nishiyama Site

Oku Aizu Geothermal Co. and its parent company, Mitsui Mining Co., Ltd. started a basic survey of this area in 1974. A basic survey by the state took place in FY1976 and 1977, and the geothermal energy development promotion survey in FY1982 and 1983. Oku Aizu Geothermal took over the survey and development in FY 1984 based on previous results.

Tohoku Electric Power and Oku Aizu Geothermal inaugurated a joint survey in 1986. Steam production volume of 470t/h was confirmed with tests using prospecting wells. Additional wells confirmed steam production capacity of 170t/h, so that total steam production capacity comes to 640t/h. This confirmed steam volume and the evaluation of geothermal reserve led to the decision to set the unit capacity at 65,000kW, the greatest in Japan.

The final agreement was signed in 1991 and was submitted to local authorities. The plan was approved by the Electric Power Development Coordination Council in autumn of 1992 and the power plant is slated to start operation in 1995.

(4) Expansion Project at Kakkonda

The site is adjacent to the existing power station. Survey and study for expansion are being conducted by Tohoku Geothermal Energy Co., which undertakes actual development work, and its parent company, JMC. Steam production of 170t/h was confirmed using prospecting wells. The evaluation of the deep-seated geothermal reserves at a depth of 3,000m was conducted for the entire area.

They next drilled deep prospecting wells for evaluation of deep-seated reservoirs. Steam production of 150t/h was confirmed using these deep wells, adding up to 320t/h.

This confirmed steam production capacity and the evaluation of geothermal reserves led to the decision to expand the power generation facilities by 30,000kW. The final agreement was signed in 1992 and submitted to local authorities for approval. Preparations are underway for deliberations at the Electric Power Development Coordination Council in spring of 1993. The construction of the power station is to start in 1994 and to be completed in 1996.

For Improvement of the Global Environment and the Revitalization of Local Economies

The development of renewable energy is coming into focus in connection with the global environment. Geothermal power generation is such energy. As stated above, our company is energetically promoting geothermal development at four sites with a total output capacity of 172,500kW. This project is expected to make a contribution, however slight, to improvement of the global environment. We also hope that the construction and operation of geothermal power stations will be a great stimulus to the revitalization of the local economies. ◘