Short Abstracts
of
Special Symposium on Geothermal Energy

“NEW PERSPECTIVE OF GEOTHERMAL ENERGY UTILIZATION IN JAPAN”

Unzen fumarole area, Nagasaki, Japan

10 October 2006, Makuhari, Chiba, Japan

IGAJ, Geothermal Research Society of Japan

日本地熱学会 **IGA** 専門部会

Preface

SPECIAL SYMPOSIUM ON GEOTHERMAL ENERGY "NEW PERSPECTIVE OF GEOTHERMAL ENERGY UTILIZATION IN JAPAN"

We are very happy to hold a special symposium on geothermal energy on 10 October 2006 at Makuhari, Chiba Prefecture, Japan at the occasion of the 41st IGA BoD Meeting.

In Japan the commercial geothermal power generation started in 1966 at Matsukawa Geothermal Power Station and in 1967 at Otake Geothermal Power Station. We have reached over 500 MWe at eighteen geothermal power stations in the middle of 2000. However, we have had no new geothermal power stations since then. Japanese Islands belong to part of the Pacific Ring of Fire. We have plenty of geothermal resource amounting over 20,000 MWe (Miyazaki et al, 1991). We also have much more hot spring sources more than 27,000 all over the Japanese Islands. Furthermore, researches on the ground-coupled heat pump system have started both in the northern and southern parts of Japan. Japan is a country rich in geothermal resources. We may be able to contribute much more to construct environmentally friendly sustainable society, if we are able to utilize much more geothermal energy.

We, all the geothermists in Japan, are struggling in order to promote the utilization of geothermal energy. At the occasion of IGA BoD Meeting where many overseas geothermal experts participate in, we have planned to have a symposium to promote the geothermal energy development in Japan. The objective of this symposium is to review the past developments of geothermal energy in Japan and also to investigate the new direction of geothermal energy developments in the future in Japan under the advice and suggestions from overseas geothermal experts.

In this symposium, ten papers are presented. Six of them are from Japanese scientists and engineers. In their papers, the history, the present situation and some of recent developments of geothermal energy in Japan are introduced. Several problems which retard the growth of the utilization of geothermal energy in Japan are also shown. In the latter half of the symposium, four papers are presented from overseas scientists and engineers. They are introducing recent developments of geothermal energy in each country and also giving some useful comments and suggestions to Japanese geothermal society. We will have a panel discussion on the future geothermal energy development in Japan with six panelists and all the audience at the end of the symposium.

We hope your earnest cooperation in carrying the Special Symposium. We would like to express our hearty thanks to all the participants, especially to overseas participants.

Sachio Ehara
Chairman of the Symposium
Professor at Kyushu University
Fukuoka, 819-0395, Japan

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SPECIAL SYMPOSIUM ON GEOTHERMAL ENERGY
"NEW PERSPECTIVE OF GEOTHERMAL ENERGY UTILIZATION IN JAPAN"

Tuesday, 10 October 2006
1:00 pm – 5:00 pm
Room 301, International Conference Hall, Makuhari Messe

Purpose: to investigate the new direction of geothermal energy developments in the future in Japan, by reviewing the past developments of geothermal energy in Japan and with advises from geothermal experts from overseas.

Part I: Utilization of Geothermal Energy in Japan (100 min.) 1:00 pm – 2:40 pm

Chair: Toshihiro Uchida

0. Introduction (5 min.) Sachio EHARA

1. History and present status of geothermal energy utilization in Japan (50 min.)
 1-1 Geothermal energy developments in Japan Mineyuki HANANO
 1-2 Development of geothermal power generation system Takuji FUJIKAWA
 1-3 Direct use of geothermal energy in Japan Kasumi YASUKAWA

2. Some Problems on Geothermal Energy Utilization in Japan (15 min.)
 2-1 Problems on geothermal power generation; economy, national parks, hot spring communities, and RPS
 Hirofumi MURAOKA

3. Recent Developments on Geothermal Energy Utilization in Japan (30 min)
 3-1 Energy In My Yard (EIMY) Hiroaki NIITSUMA
 3-2 Project on Kalina cycle power plant utilizing hot spring water Kazumi OSATO

Coffee Break (20 min.)

Part II: Utilization of Geothermal Energy in Japan – Future (120 min.) 3:00 pm – 5:00 pm

Chair: Kasumi YASUKAWA

0. Review: Achievements and Problems on Geothermal Energy Developments in Japan (10 min.)
 Sachio EHARA
1. Present Status of Geothermal Energy Utilization in Each Country and Some Comments and Suggestions to Japan (60 min.)
 1-1 Recent Geothermal Development in the USA John LUND and Gordon BLOOMQUIST
 1-2 Recent Geothermal Development in Europe Ladislaus RYBACH
 1-3 Environmental Developments of Geothermal Energy in New Zealand Jim LAWLESS
 1-4 Present status and future plan of geothermal development in Turkey Sakir SIMSEK

2. Panel Discussion on Geothermal Development in the Future (45 min.)
 Chairman Sachio EHARA
 Panelists John LUND, Ladislaus RYBACH and Jim LAWLESS
 Hiroaki NIITSUMA, Mineyuki HANANO and Hirofumi MURAOKA
 *Comments from the audience are always welcome.

3. Concluding Remarks: New Perspective of Geothermal Energy Utilization in Japan (5 min.)
 Sachio EHARA

5:00 pm – 5:50 pm: IGA 2006 Annual General Meeting
6:00 pm – 8:00 pm: Geothermal Reception

RE2006 地熱特別シンポジウム

2006 年 10 月 10 日（火）13:00－17:00
幕張メッセ国際会議場 301 会議室

テーマ：「**New perspective of geothermal energy utilization in Japan**」

目的： わが国のこれまでの地熱開発を総括し、外国の現状およびコメンテーターの意見も参考に、わが国の新しい地熱開発の方向を探る。

参加費： 無料

前半（100 分）：**Utilization of geothermal energy in Japan** (13:00 - 14:40)
司会:内田利弘(産総研)

0. 趣旨説明(5 分) 江原幸雄(九州大学)
1. 我が国の地熱利用の到達点(50 分)
   1) わが国の地熱開発の歴史(20 分) 花野峰行(日本重化学工業)
   2) 地熱発電システム開発の歴史と現状(15 分) 藤川卓爾(長崎総合科学大学)
   3) 直接利用の歴史と現状(15 分) 安川香澄(産総研)
2. 我が国における地熱開発上の問題点(15 分)
   1) 地熱発電の経済性・国立公園問題・温泉問題・RPS 村岡洋文(産総研)
3. 我が国における地熱開発における最近の新しい動き(30 分)
   1) EIMY の提案(15 分) 新妻弘明(東北大学)
   2) 温泉を利用したカリーナサイクル発電(15 分) 大里和己(地熱技術開発)

休憩（20 分） (14:40 - 15:00)

後半（120 分）：**Utilization of geothermal energy in Japan -future-** (15:00 - 17:00)
司会:安川香澄

0. 我が国における地熱開発の到達点と問題点の総括(10 分) 江原幸雄

1. 各国の地熱開発の現状と日本の地熱開発に関するコメント・提案(60 分)
   1) 米国における最近の地熱開発の現状 John Lund, Gordon Bloomquist(米国)
   2) 欧州における最近の地熱開発の現状 Ladislaus Rybach(スイス)
   3) ニュージーランドにおける地熱開発と環境問題 Jim Lawless(ニュージーランド)
   4) トルコにおける地熱開発の現状と将来 Sakir Simsek(トルコ)

2. パネルディスカッション(45 分)
   司会(江原幸雄)
   パネリスト: Lund、Rybach、Lawless、新妻、花野、村岡の各氏を予定

3. まとめ(5 分)
   わが国における今後の地熱開発の進め方の提案
   New perspective of geothermal energy utilization in Japan 江原幸雄

17:00 - 17:50 **IGA・2006 年総会**(どなたでも参加できます)
18:00 - 20:00 **懇親会**(会場:幕張メッセ国際会議場内のレストランNOA、Ocean B 室)

History of Geothermal Development in Japan

Mineyuki Hanano
Japan Metals and Chemicals Co., Ltd.

1918 ● Vice Admiral Masuji Yamauchi tapped the first geothermal steam well (about 24m depth) in Beppu, Oita, for the research on geothermal power generation.

1925 ● Dr. Heiji Tachikawa of Tokyo Electric Power Co. first succeeded experimental geothermal power generation (1.12kWe) in Beppu.

1926 ● Kyoto University established the Geophysical Laboratory in Beppu, then started systematic and academic research on geothermal systems and geothermal energy.

1947 ● Geological Survey of Japan (GSJ) started research and exploration for geothermal power development.

● Ministry of Trade and Industry established the committee on geothermal development technology.

1948 ● Tone Boring succeeded experimental geothermal power generation (3kWe) in Yunosawa, Shizuoka.

1949 ● Kyushu Electric Power Co. (KEP) started studies on geothermal power generation.

1951 ● Agency of Industrial Science and Technology succeeded experimental geothermal power generation (30kWe) in Beppu.

1952 ● Tone Boring succeeded experimental geothermal power generation (20 to 30kWe) in Hakone, Kanagawa.

● KEP started geothermal exploration in Otake, Oita.

1955 ● GSJ started geothermal studies in Matsukawa, Iwate.

1956 ● Mr. Matier of CGG (French company) visited some Japanese geothermal fields and denied possibility of geothermal power generation in Japan.

● Japan Metals and Chemicals Co. (JMC) started geothermal exploration in Matsukawa.

1960 ● Fujita-Kanko started geothermal power generation (30kWe) in Hakone for private use at their hotel (decommissioned in 1960).

1966 ● Matsukawa geothermal power station (GPS) started first commercial-level geothermal power generation at 9.5MWe for private-use, using dry steam (12.5MWe in 1967, 20MWe in 1968, 22MWe in 1973, 23.5MWe in 1993).

1967 ● Otake GPS started first commercial geothermal power generation using separated steam from two-phase fluid at 11MWe (12.5MWe in 1979)

1974 ● Onuma GPS started private-use power generation at 6MWe (9.5MWe in 1986).

1975 ● Onikobe GPS started commercial power generation at 9.5MWe (12.5MWe in 1976).

1977 ● Hatchobaru GPS started commercial power generation at 22MWe (55MWe in 1980).

1978 ● Kakkonda GPS started commercial power generation at 50MWe.

1980 ● NEDO started the Geothermal Development Promotion Survey.

1981 ● Suginoi Hotel started private-use geothermal power generation at 3MWe.

1982 ● Mori GPS started commercial power generation at 50MWe.

1990 ● Hatchobaru II started commercial power generation at 55MWe.

1994 ● Uenotai GPS started commercial power generation at 27.5MWe (28.8MWe in 1997).

1995 ● Yamakawa GPS started commercial power generation at 30MWe.

● Sumikawa GPS started commercial power generation at 50MWe.

● Yanaizu-Nishiyama GPS started commercial power generation at 65MWe.

1996 ● Kakkonda II started commercial power generation at 30MWe.

● Ogiri GPS started commercial power generation at 30MWe.

● Takigami GPS started commercial power generation at 25MWe.

● Total installed capacity of the Japanese GPS exceeded 500MWe.

1999 ● Hachijojima GPS started commercial power generation at 3MWe.

2000 ● Kuju-Kanko-Hotel started private-use geothermal power generation at 2MWe.

2003 ● Hatchobaru Binary GPS started commercial power generation at 2MWe.

History and Present Status of Geothermal Power Generation System

Takuji Fujikawa, Nagasaki Institute of Applied Science
Shojiro Saito, Mitsubishi Heavy Industries, Ltd.

1. History of Geothermal Power Generation

Geothermal power generation began in Italy in 1904. In Japan, a 1.12kW test was conducted in the early 20th century, but industrial scale geothermal power generation began only in 1966 (steam dominated-type) and 1967 (hot water dominated-type). At present, approximately 10,000MW total capacity is available around the world, and 21 units at 18 sites are producing electricity from geothermal energy in Japan.

2. Development of Geothermal Power Generation Technology

The development of technology to utilize hot water dominated-type geothermal resources increased the total capacity of global geothermal power generation, while the development of double flash cycle improved power generation efficiency. Moreover, the development of steam purification technology expanded the area of available geothermal resources.

3. Japan's Role in the Field of Geothermal Power Generation

1) Development of Geothermal Power Generation Technology

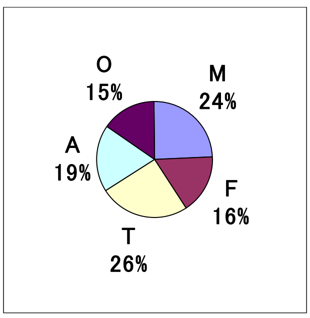
Mitsubishi Heavy Industries, Ltd. and Kyushu Electric Power Co., Inc. jointly developed the two phase flow transmission double flash system and other hot water dominated-type geothermal power generation techniques. Also, Japanese power plant manufacturers developed highly efficient and reliable geothermal power generation equipment.

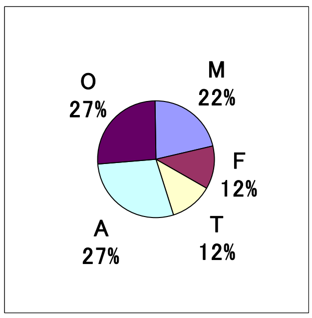
2) Supply of Geothermal Power Generation Equipment

(a) Japanese manufacturers supplied the main equipment (steam turbine, generator, condenser, cooling tower, etc.) for domestic geothermal power stations.

(b) They also supplied steam turbine-generators and, in some cases, auxiliary equipment for many geothermal power plants around the world. Globally, about 45% of turbine-generator units, and 67% of capacity, are presently derived from Japan. In the U.S.A., in particular, most of the latest turbine-generators have been supplied from Japan.

Kyushu Electric, Hatchobaru Power Station.
Two phase flow transmission, double flash
2×55MW, No.1 unit operation started in 1977.





Share of Japanese manufacturers in geothermal power generation main equipment around the world.
(M, F, T : Japanese Manufacturers)

Direct Use of Geothermal Energy in Japan

Kasumi YASUKAWA

Institute for Geo-Resources and Environment (GREEN),
National Institute of Advanced Industrial Science and Technology (AIST)

1. Direct use (excluding geothermal heat pumps)

Geothermal energy has been directly used in Japan since the time of myth and legend. The utilized heat by direct use of geothermal energy (except for geothermal heat pump application) in Japan is 10,300 TJ/a, 4^{th} in the world, following China, Turkey and Iceland (Lund et al., 2005). Nevertheless the way of utilization is not very sophisticated: half of utilization is for bathing (Bathing is not really heat utilization in case of Japan. Though part of heat is used, most part is just thrown away because hot water constantly recharged from spring source simultaneously flows away from the bath tab in most hot springs. Therefore the heat energy calculated from the flow rate overestimates the utilized energy.)

Percentage of all industrial utilizations in Japan, such as green house, fish farming, industrial processing, agricultural drying, are less than half of world average. Space heating is also limited in Japan. Only snow melting is larger percentage, besides bathing. Since bathing is quite a big business in Japan, the highest profit/cost of geothermal energy utilization may have been obtained by bathing use. Multi purpose and cascade use should be emphasized to encourage industrial utilization. Cooperation with municipals may also be important under the concept of EIMY (Niitsuma and Nakata, 2003).

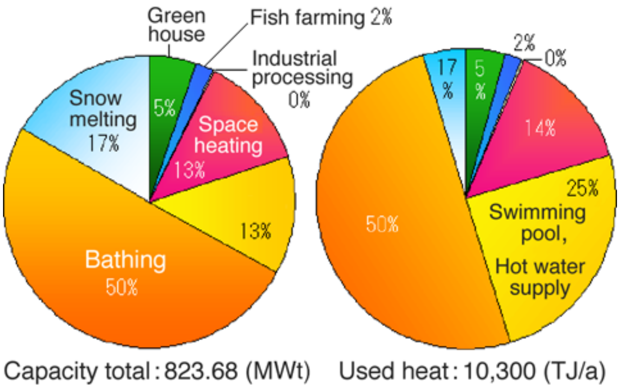


Fig.1 Direct use of geothermal energy in Japan (Kawazoe and Shirakura, 2005 and Lund et al., 2005)

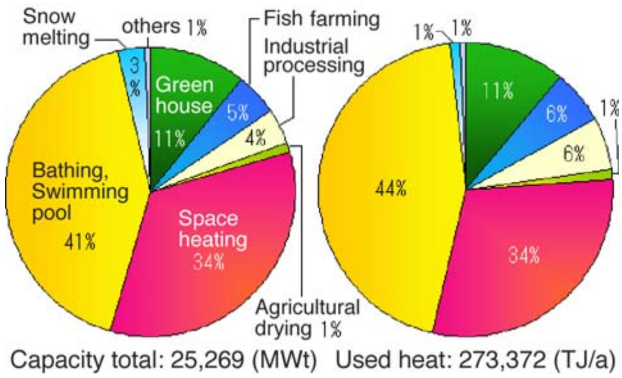


Fig.2 Direct use of geothermal energy in the world (Lund et al., 2005)

2. Geothermal heat pump application

Though some Japanese experts have started studies on downhole heat exchanger and geothermal heat pump systems in 1980s in Japan, most geothermists in Japan had not realized the importance of the system until WGC2000. The first application of Downhole Coaxial Heat Exchanger (DCHE) system for snow melting, which is the earliest geothermal snow melting system in Japan known as "Gaia system," has been in operation since 1995 (Morita and Tago, 2000). Intensive utilization of the system would contribute to 1) reduce the consumption of fossil fuels resulting in reduction CO_2 gas emission, 2) reduce the consumption of electricity with higher COP (Coefficient of performance), and 3) reduce urban heat island phenomenon by exhaust heat into underground.

The obstacles against dense installation of the system in Japan are: 1) high installation cost of geothermal heat pump system and popularization of low-price high-efficiency air-source air conditioner, 2) ignorance of the people about the system, and 3) structure of houses and buildings (low thermal insulation, no domestic pipelines for fluid circulation). To overcome these difficulties, several organizations such as Geothermal Research Association of Japan, Geo Heat Pump Association of Japan, and Heat pump & thermal storage Society of Japan are promoting the system since 2001. The number of installation is still limited, but it increased 100 % in recent two years: 43 installation with capacity of 1,273 kWt in 2003 (NEF, 2003), and 88 installations (or more) with total capacity of 47,745 kWt in 2005 (net searching by the author). For further promotion, technology to reduce the installation cost, to perform higher COP, compilation of subsurface data may be important besides enlightening of the people.

References

Kawazoe, S., Shirakura, N. (2005), Geothermal power generation and direct use in Japan, *Proc. WGC2005*.

Lund, J. W., Freeston、D. H., Boyd, T. L. (2005), Direct application of geothermal energy: 2005 Worldwide review, Geothermics, 34, 6, 691-727

Morita, K. and Tago, M. (2000) Operational characteristics of the GAIA snow-melting system in Ninohe, Iwate, Japan. *Proc. of the World Geothermal Congress 2000*, 3511-3516 (2000).

NEF(2003) : (cont.) The Current Status of Geothermal Direct Uses in Japan, Chinetsu Energy, **28**, 160-169 (in Japaese).

Niitsuma, H. and Nakata, T. (2003): EIMY (Energy In My Yard) – A Concept for Practical usage of Renewable Energy from Local Sources. Proc., EGC2003, I-2-02.

Obstacles of Geothermal Power Development in Japan

Hirofumi Muraoka
Geothermal Resources Research Group,
Institute for Geo-Resources and Environment (GREEN),
National Institute of Advanced Industrial Science and Technology (AIST)

Since the Hachijojima Geothermal Power Plant was installed in March 1999, none of geothermal power plants have been installed in Japan, except for a 2000 kW demonstration binary plant in Hatchobaru installed in 2004. How did this dark age come in Japan? The negative side overview is a main subject of this speech. To answer this, we must consider about “risks of investment” into a geothermal power development in Japan.

Japan is blessed with huge geothermal resource potentials. Probably Japan is the third largest geothermal resource potential country in the world, following Indonesia and USA. Natural factors are very optimistic. All the obstacles are derived from the social and political factors. The first obstacle is the National Parks; More than 60% of prospective areas lie within the parks. The second obstacle is the pre-existing hot spring spas; 27,644 hot spring sources ubiquitously conflict with geothermal developments everywhere in Japan. The third obstacle is legislation and regulation; They prolong the lead time to be 15 -25 years, resulting in the high construction cost. The fourth obstacle is the cost of geothermal power; Land property, public acceptance, drilling and lead time, all of the costs are much higher than the world standard. The fifth obstacle is the Governmental incentive policy; Geothermal energy was excluded from “new energy” in 1997 that initiated a tragedy in the geothermal market in Japan, though there is the current activity to revive geothermal energy into “new energy”.

Normally, we must invest 30 billion Yen (256 million US$) for the development of a 30 MWe class geothermal power plant in Japan. However, it will take at least 15 years to recover the capital by profits in Japan with large reservoir management risks. This is “high risks and low returns” compared to other investment fields under such a long deflation economy stage. This situation is a simple answer to the present dark age in a geothermal power market in Japan. If reasonable incentives are given by the Government such as a quota system or renewable portfolio standard (RPS), the situation will be dramatically improved. We have the RPS Law in Japan since December 2002, but the quota obligation is only 0.52 % in 2006 that is one or two magnitudes less than the world standard. This poor renewable energy policy is an essential obstacle to geothermal power development in Japan.

EIMY (Energy In My Yard): A Strategy to Increase Practical Usage of Renewable Energy from Local Sources

HIROAKI NIITSUMA
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Tohoku University, Sendai 980-8579, JAPAN

A strategy of geothermal development that is consistent with the expected earth environment of the 21st Century was studied by a group that included 10 people from universities, 2 from a national institute, 2 from NEDO and 4 from industry. The group conceived the concept of "*EIMY*; Energy In My Yard", which is the converse of NIMBY (Not In My Back Yard). *EIMY* proposes that local energy demands should be met from an optimum combination of local, renewable sources to the maximum degree that technical and economic considerations permit. Shortfalls and surpluses in local energy production would be accommodated through an interface with the national grid. This energy/social system is customized to the needs and resources of local communities, the design giving precedence to the welfare of the people in the area as well as the benefits to the local economy and energy security. This in turn would provide an incentive for local people to utilize local renewable energy.

The group also discussed the roles that the various kinds of renewable energy could play within the *EIMY* framework, according to their nature, ubiquity, and capacity. Sources such as wind, solar, geothermal, hydro and biomass were considered. Geothermal energy will play a key role in the *EIMY* system. One of the required features of geothermal for the *EIMY* is consistency with the environment and the other is ubiquity. Zero emission and sustainable production are essential features for the consistency. With regard to the latter, the technologies of reinjection and HDR/HWR are important. Technology to facilitate stepwise increases in production rate and their monitoring are also important for sustainable production, because an optimum production rate in a geothermal system is usually difficult to estimate in advance, and it is reasonable to start with a lower rate. The technologies of HDR/HWR, binary system and heat pump allow subsurface heat to be exploited from a diverse range of depths and conditions, and thereby greatly enhance the ubiquity of the geothermal resource. In this regard, it is necessary to compile a new database that shows the true picture of geothermal energy resources in a given area rather than just high density/quality resources.

Kalina Cycle Power Plant utilizing “ONSEN” (Hot springs)

Kazumi Osato
Geothermal Energy Research and Development Co., Ltd.

There are many high temperature hot springs (“ONSEN”) exceeding 80 degrees C in Japan. In some cases of them, necessary portion of them is using for taking bath and rest is discharging without utility – e.g. in Kusatsu Onsen (Gunma prefecture) and Tamagawa Onsen (Akita Prefecture). Since it is important not to mix hot spring water with fresh water and to maintain the effect with original hot spring water from a viewpoint of balneotherapy in Japan, the power generation using temperature difference attracts the attention as a method of cooling high temperature hot spring without dilution. Various governmental programs for CO_2 reduction of a local region using renewable energy are carried out by the Ministry of Economy, Trade and Industry, the Ministry of Environment and others as a subsidy with grant rate from 20% to 66%. Kalina Cycle© which uses ammonia-water heat medium attracts attention recently as thermal-energy-conversion technology using heat source less than 100 degree C. We introduce about the concept and possibility of the new geothermal energy enterprise which contributes to CO_2 reduction of a local region, performing power generation which used high temperature hot springs, and living together with hot spring communities by combination of geothermal energy and other renewable energy.

THE UNITED STATES OF AMERICAN COUNTRY UPDATE 2006

John W. Lund – Geo-Heat Center, Oregon Institute of Technology
R. Gordon Bloomquist – Washington State University Energy Program
Tonya L. Boyd – Geo-Heat Center, Oregon Institute of Technology
Joel Renner – Idaho National Engineering Laboratory

ABSTRACT

Geothermal energy is used extensively for electric power generation and direct utilization in the United States. The present installed capacity (gross) for electric power generation is 2,534 MWe with about 2,100 MWe net delivering power to the grid producing approximately 17,840 GWh per year for a 80.4% gross and 97% net capacity factors. Geothermal electric power plants are located in California, Nevada, Utah, Hawaii and Alaska. The two largest concentrations of plants are at The Geysers in northern California and the Imperial Valley in southern California. The latest development at The Geysers, starting in 1998, is injecting recycled wastewater from two communities into the reservoir, which presently has recovered about 100 MWe of power generation. The second pipeline from the Santa Rosa area came on line in 2004. The direct utilization of geothermal energy includes the heating of pools and spas, greenhouses and aquaculture facilities, space heating and district heating, snow melting, agricultural drying, industrial applications and ground-source heat pumps. The installed capacity is 9,017 MWt and the annual energy use is about 34,400 TJ or 9,560 GWh. The largest application is ground-source (geothermal) heat pumps (74% of the energy use), and the next largest direct-uses are in space heating and agricultural drying. Direct utilization (without heat pumps) is increasing at about 2.6% per year; whereas electric power plant development is almost static, with only about 70 MWe added since 2000. In 2006, a 200 kWe binary plant was placed in service at Chena Hot Springs, Alaska, using the lowest temperature geothermal resource in the world, 74^{o}C, for power generation. A new 185-MWe plant being proposed for the Imperial Valley and about 100 MWe for Glass Mountain in northern California could be online by 2007-2008. Several new plants are proposed for Nevada totaling about 100 MWe and projects have been proposed in Idaho, New Mexico, Oregon and Utah. The total planned in the next 10 years is 632 MWe. The energy savings from electric power generation, direct-uses and ground-source heat pumps amounts to almost nine million tonnes of equivalent fuel oil per years and reduces air pollution by almost eight million tonnes of carbon annually (compared to fuel oil).

Recent Geothermal Development in Europe and Comments to Japan

L. Rybach[1),2)]
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2) GEOWATT AG, CH-8050 Zurich, Switzerland
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Europe summary

The summary of geothermal power generation and direct use in Europe is based on data presented at the World Geothermal Congress 2005 and subsequent data adjustments. The operating power generation capacity in 8 European countries is 1.0 GWe and the production 7.2 TWhe/yr. The lead is clearly with the pioneer country Italy. Iceland comes next, followed by Turkey. France and Russia have significant production, but in non-European regions. Austria and Germany is newly generating geothermal electricity, albeit at low level.

The total numbers in direct use are 13.6 GWt and 154’000 TJ/yr; in absolute numbers, Sweden comes before Iceland, the traditional leader in geothermal direct use, and Turkey is number three. The largest contribution to direct use (7070 MWt or 52% in capacity and 56’000 TJ/yr or 36 % in production) is provided by geothermal heat pumps, in 26 countries. Europe has the largest share (nearly 50%) in world-wide direct use.

For the future prospects on the short term a speeding-up in geothermal power development can only be expected, when guaranteed feed-in tariffs in several European Union (EU) countries show an effect. On the other hand a further, accelerating advance of geothermal heat pumps can definitely be expected. On the long term the prospects depend on the success of the Enhanced Geothermal Systems (EGS). It will be crucial to demonstrate the feasibility of EGS technology at various sites with contrasting geologic characteristics.

Comments to Japan

Foremost and urgently: Japan needs the widespread use of geothermal heat pumps! Japan is especially well suited for this technology, which is booming in many other countries: land is rare and expensive, heat pump production is excellent, electricity is available everywhere. The main obstacle, the high drilling costs can be overcome. The example of Bikkuri Donkey – Geowatt AG Zurich cooperation demonstrates this: Geowatt ordered the special drilling rig, trained the Japanese drillers in Switzerland, and supervised drilling and system installation in Japan. By these means drilling costs have been reduced from >100 $/m (before) to < 50 $/m (the cost includes drilling, heat exchanger installation and connection).

Further recommendations: for high enthalpy resource development the dialog with onsen owners (who fear degradation of thermal spring flow) should continue. The Kazuno Symposium at WGC2000 was a start. Successful examples of remediation (e.g. from New Zealand, Chris Bromley’s work) should be publicized. For Enhanced Geothermal Systems (EGS) major cooperative projects started in the European Union, open to international participation (ENGINE, I-GET). Japan should join in.

Reference

Rybach, L. (2006): Status and prospects of geothermal energy in Europe – a summary. Geothermal Resources Council Transactions Vol. 30, p. 675-679.

Supplementary Injection to Mitigate Environmental Effects: Can it be Applied in Japan ?

Lawless, J.V. *Sinclair Knight Merz, PO Box 9806 Auckland, NZ Jlawless@skm.co.nz*

SUMMARY

Hot springs are revered because of their practical uses for bathing and cultural value in many countries. The potential for large scale geothermal energy development to affect hot spring can be a limitation to development. A recent initiative in New Zealand has been the use of supplementary injection at the Ngawha geothermal project. Ngawha is the only high temperature (>200 °C) geothermal resource located in New Zealand outside the Taupo Volcanic Zone. It has been used for 10 MWe of power generation since 1998, based on extraction of 10,000 tonnes per day (tpd) of fluid.

The resource is physically capable of much larger production, but there are concerns that larger extraction, even with full reinjection of all water, may adversely affect the surface thermal springs. A 3-month trial was carried out to test the concept that supplementary injection of up to 1,000 tpd of cold water would be sufficient to maintain reservoir pressures and hence maintain the thermal springs. That trial was successful in raising reservoir pressures without affecting production temperatures. Reservoir modelling has predicted that as little as 5% supplementary injection should be capable of maintaining reservoir pressures for the next 25 years, with production of 25,000 tpd, which is sufficient for 25 MWe. No adverse effects on production temperatures or the springs are predicted. Regulatory permission to expand the project has consequently been obtained.

Key words: Geothermal, Environmental, Reservoir Modelling, Injection, New Zealand, Japan.

INTRODUCTION

Hot springs are revered because of their practical uses for bathing and cultural value in many countries, but especially in New Zealand and Japan. The potential for large scale geothermal energy development to affect hot springs has been a limitation to development in both countries.

A recent initiative in New Zealand has been the use of supplementary cold water injection to maintain reservoir pressures at the Ngawha geothermal project. Successful application of the technique has been the key to unlocking the resource for large scale development and obtaining the necessary regulatory approvals. This paper describes the Ngawha example. More details can be found in Lawless *et al.* (2006).

It may well be the case that this technique can also be used to overcome similar difficulties in Japan.

THE NGAWHA PROJECT

The Ngawha geothermal system is located in Northland, New Zealand (Figure 1). The most comprehensive data compilation on Ngawha is that of Mongillo (1985).

Ngawha is the only high temperature (> 200°C) geothermal system in New Zealand that is located outside the Taupo Volcanic Zone (TVZ). Unlike the TVZ systems, which are associated with an extremely magmatically active rift, the Ngawha system is in a back-arc location. No magmatic heat source has yet been located at Ngawha, but the high temperatures (300 °C at a depth of 2255m, Mongillo, 1985), the close spatial and temporal association with recent basalts and rhyolites, and the chemistry of the geothermal fluids, strongly indicate that the heat source is a shallow silicic intrusive.

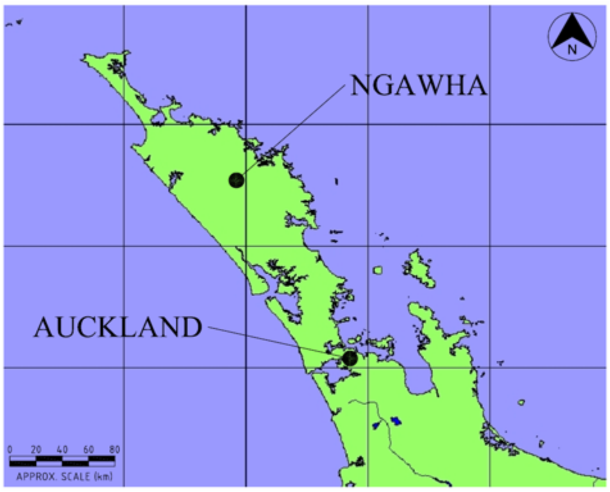

Figure 1. Location map

The geology can be broadly characterised as two layers. Below 500m depth occur ?Permian-Jurassic metasediments (greywackes and some argillites). They have low intrinsic porosity, but are locally extensively fractured and comprise the exploitable geothermal resource. The gas content (mainly CO_2) is comparatively high, at 1 to 2% by weight.

The upper 500m is made up of a variety of Tertiary sediments, predominantly marine and clay-rich, and in part allochthonous and overturned. These sediments form an effective caprock to the geothermal reservoir, except in a few places where they are cut through by fault zones, hosting hot and cold springs and gas seepages. Despite these leakages the deep reservoir is strongly artesian, with a pressure of 65 bars at 600 m depth (Grant, 1981). That is in marked contrast to the TVZ geothermal systems, which typically have higher vertical permeability, pressures below cold hydrostatic, and boiling-point-for-depth temperature gradients. Most of the fluid in the Ngawha reservoir is single phase liquid, though some limited two-phase (and hence gas rich) zones are thought to occur in the upper part of the reservoir.

Power has been generated at Ngawha since 1998. Two production wells supply 10,000 tpd of hot fluid to an Ormat ORC binary plant with a net output of 10 MWe. Apart from the non-condensible gases, all of the fluid extracted is reinjected at approximately the same depth as production, using two reinjection wells, two kilometres from the production wells. The plant is operating satisfactorily. As it is the only source of generation in the region there is a strong incentive to increase its capacity. Some additional potential production and reinjection wells already exist, from a previous Government-funded exploration programme in the 1980's.

There is no doubt that in terms of stored heat and fluid capacity the resource is capable of supporting greater generation. Applying industry-standard methods on a basis consistent with that which has been used elsewhere in New Zealand (Lawless, 2002) a median estimate of the capacity of the Ngawha system of 75 MWe over 30 years is calculated.

The principal constraint to further development of the Ngawha system is concern over possible effects on the surface thermal activity.

There is one main group of hot (but sub-boiling) "springs" close to Ngawha Village. Some are non-flowing pools, and others are artificial pits dug for bathing or from previous mercury mining rather than true springs. There are also a number of slightly warm springs and cold gas seepages over a several kilometre radius. It is the central springs near Ngawha village that are used for bathing and are valued by the bath owners and local inhabitants as having healing properties.

There was vigorous opposition from some concerned over effects on the springs of the original power plant and to a recent proposal to increase extraction and reinjection to 25,000 tpd.

CHANGES AND EFFECTS TO DATE

The production and reinjection of 10,000 tpd of geothermal fluid since 1998 has had very little effect on the geothermal reservoir. Pressures at depth have been monitored by a deep well, NG13, which was directionally drilled and passes close to the springs at depth (Figure 2). Monitoring of pressures in NG13 shows a deep pressure decline of about 1.25 bar since production began in 1998. That is much less than the pressure declines that have been caused by other geothermal projects in New Zealand and elsewhere (up to many tens of bars) even with full reinjection, and is a reflection of the small size of the current scheme compared to the thermal and volumetric capacity of the reservoir.

The gas content of the fluid from one of the production wells has declined from about 1.3 to 0.9 weight % over the same period, but mass balance considerations indicate that is likely to be a near-well effect rather than indicating a bulk de-gassing of the reservoir.

Determining whether there have been any changes in the springs which have been caused by the power scheme is not straightforward. The springs have feeble flows. To put that in perspective the total flux of deep geothermal fluid through the Ngawha springs is estimated to be about 2 kg/s, compared to hundreds of kg/s at some of the TVZ systems. Intense rainfall events are common in the area in any season of the year, which can flood or affect the springs. Hence the Ngawha springs are naturally quite variable in terms of flow rate, temperature and composition, as well as being affected by management for bathing purposes.

Because of the reputed healing properties, the composition of the springs is regarded as important as well as their flow rate and temperature. However, the small flow rate of the springs mean that not only does one spring differ in composition from another but individual springs vary in composition from time to time due to climatic effects.

There has been detailed monitoring of physical and chemical parameters at the springs since 1993, and intermittently since the mid 1940's (e.g. Ellis and Mahon, 1966). There have been both long and short term variations in that period, but the range of variations since the power plant started operation is no greater than beforehand and it cannot be demonstrated that the current power plant operation has had any systematic effect on the springs. Nor would any necessarily be expected, in view of the relatively small pressure change that has occurred to date.

PREDICTED EFFECTS

The effects of either continuing or expanding the power scheme have been predicted using two TOUGH2 reservoir models, one to look at the reservoir as a whole, and the other a detailed model to investigate reservoir–spring interactions. The models were developed by Auckland University (O'Sullivan) and Industrial Research Ltd respectively: neither have yet been formally published but details were made public at a regulatory hearing in 2006.

The whole-reservoir model predicts that with the current 10,000 tpd production and reinjection, the reservoir pressures and temperatures under the springs will not change significantly and so the spring flows and temperatures should remain unchanged over the next 25 years. However, expansion of the scheme to 25,000 tpd was predicted to cause an incremental pressure drop during this period of about 3.5 bars (though virtually no temperature drop). It was considered that this could possibly affect the springs, and a means of mitigation was sought.

MITIGATION PROPOSED AND TRIALLED

Given that there is in excess of 98% mass replacement in both the current and proposed scheme, the reason for the pressure declines observed and predicted was principally cooling in the reinjection area rather than mass depletion. It was suggested that this could be mitigated by injecting a small supplementary percentage of cold water from a surface stream.

Full pressure maintenance simply on a density basis if the reservoir is cooled from 230°C to 90°C would require about 14% additional fluid mass, but the reservoir rock has a considerable stored heat capacity so in practice less than that is needed. Reservoir modelling suggests that about 5% supplementary injection may be required to give full pressure support, and indeed restore the current ~ 1 bar drawdown. .

To test the concept, a three month trial of supplementary injection was carried out starting on 4 July 2005. During that period the regular 10,000 tpd of production and reinjection continued unchanged. An unused production well, NG4, was used for the supplementary injection (Figure 2).

It was originally intended to inject 1,000 tpd of cold water to NG4 for the full 3 month trial period. However, in practice problems with the temporary water supply and mechanical equipment led to lesser amounts being injected for some of the period. The average rate was 740 tpd. In fact the change in rate was useful, in that it allowed for some interpretation of the sensitivity of the reservoir pressure response to changing injection quantities.

During the trial, and for a period before and afterwards, the regular monitoring of the individual springs and production wells was intensified.

RESULTS

Reservoir Pressures

Pressures in the monitor well NG13, located some 500 m from the supplementary injection point, started to rise within 10 hours of increased injection commencing. The pressure rise continued at a rate significantly greater than the rate of previous pressure drawdown (Figure 3). Since injection stopped, pressures have started to decline again but at a much slower rate than they rose.

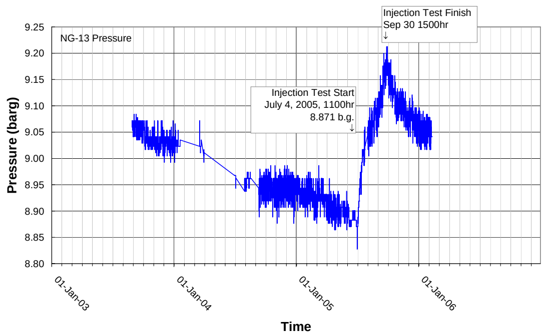

Figure 3. NG13 pressure response

Before injection the pressure was falling at 2.6×10^{-4} bar/day or 0.096 bar/yr. During the initial injection period the rise was 2.7×10^{-3} bar/day or 0.99 bar/yr.

Production Wells

There were no clear long term trends in temperature or flowing pressure for either production well, nor any effects apparent as a result of the mitigation trial (Figure 4).

The final enthalpy measurement in NG12 was lower than the recent average before the trial, but was within the range of variations previously observed. This variation is not considered significant. In both wells higher values in the Cl/Ca ratios were observed at the end of the mitigation period, but the trend has quite quickly reversed. This change is due to the calcium concentration decreasing, rather than the chloride increasing. As the supplementary river water injected contains effectively no calcium or chloride, this effect cannot be due to the mitigation trial affecting the well chemistry. It is probably due to the temporary change in gas content described below.

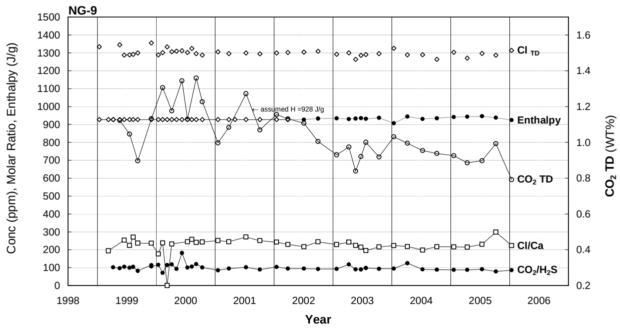

Figure 4. Physical and chemical trends in NG9

There has been a long term overall decline in gas content in NG9 (Figure 4) and to a lesser extent in NG12. There was a slightly higher than average gas content recorded in both wells at the end of the mitigation trial, but on a longer time scale, apart from that "blip" the same trends appear to have continued during the mitigation trial and the latest measurements are significantly lower again. It is possible that the reservoir pressure rise caused by the mitigation trial has induced a temporary increase in gas content in the well discharges. If the previous decline in reservoir pressure had caused the geothermal fluid to become partially degassed as it moved towards the well, then it is conceivable that the increase in pressure due to the mitigation trial may have reversed that trend. In any event this must have been a very localised effect close to the well bore.

No other changes in chemistry outside the previous range of variation were measured.

It can be concluded that the mitigation trial has had no detectable physical effect, and only very minor and reversible chemical effects on the production wells. The chemical effects are considered to be due to the effect of the pressure increase on the fluid near the production wells, rather than to any mixing of the injected fluid with the produced fluid. That is as expected, given the small total quantity of injectate compared to the size of the reservoir and the quantity of production.

Springs and Stream

Flow rates, temperatures and chemistry were intensively monitored both in individual springs and in the stream which captures the flow from all of the principal springs during the period of the trial and afterwards (Figure 5).

There were no systematic variations in stream or spring chemistry that could be correlated with the mitigation trial (Figure 6). As with the Mangamutu Stream chloride flux, this was not unexpected in view of the magnitude of the reservoir pressure rise induced, and the length of the trial. Any change would have been within the range of variations observed

The lack of correlation is not surprising. Reservoir modelling by IRL suggested that a period of about 9 months with significantly raised reservoir pressures trial would be required before any change in the springs became apparent.

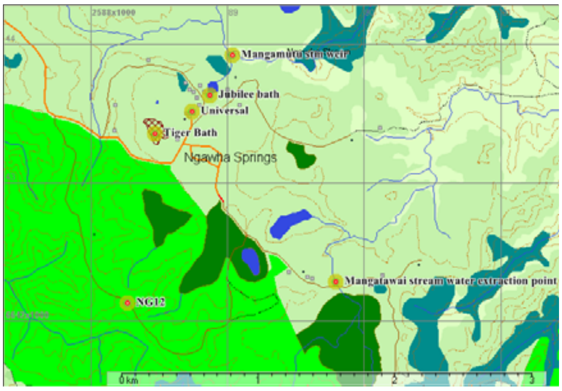

Figure 5. Spring sampling sites

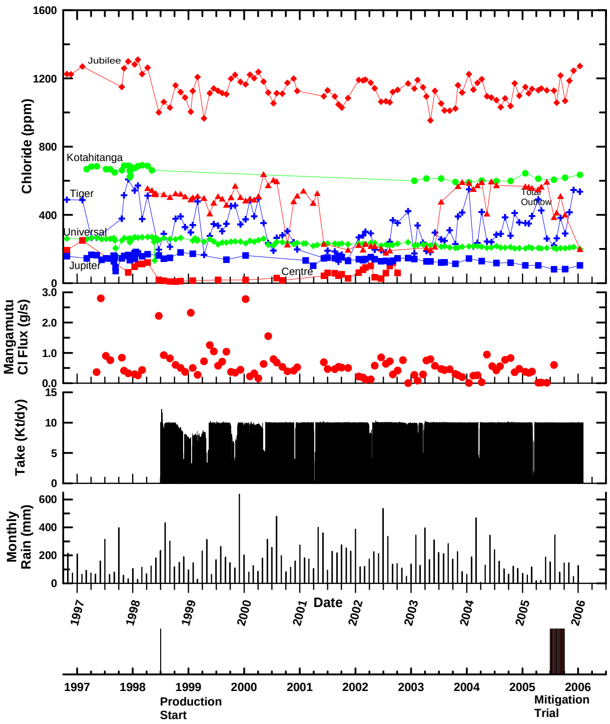

Figure 6. Chloride Concentration in Springs and Mangamutu Stream, Daily Rainfall, Cl Flux and Station Take versus Time

ACCEPTANCE BY REGULATOR

As a result of the mitigation trial the concept of supplementary injection has been accepted by the regulatory agency, and agreement has been reached on a set of conditions under which the expanded power scheme can operate. Extraction and reinjection of geothermal fluid will be averaged on a monthly basis rather than daily (as is more common in New Zealand) to give the necessary flexibility. Supplementary injection of up to 3.000 tonnes per day of surface water will be permitted.

A key requirement will be to maintain deep reservoir pressures no lower than 1 bar less than at the start of operation, and no more than 1.5 bar higher. Given that reservoir pressures appear to respond to changes in injection rate within hours to day, but the effects of deep pressure changes on the springs are predicted to take about a year to reach the surface, it is anticipated that adequate control should be achievable. Although at the time of writing there are still some legal processes to work through, it appears that the principal technical obstacle to expansion has been overcome.

CONCLUSIONS

The mitigation trial at the Ngawha Geothermal Project, involving supplementary injection of cold water to maintain reservoir pressures has been a success in demonstrating the practicality of the concept.

Reservoir pressures in NG13, the closest well to the springs, showed a rapid response to the injection to NG4. The rate of pressure increase was several times higher than the previous rate of pressure decline. It proved possible to maintain reservoir pressure in NG13 with as little as 5% supplementary injection.

No effects on production well chemistry, temperature or flowing pressure were detectable, apart from a possible short term increase in gas content. That was as predicted in view of the quantity injected and the duration of the trial.

No systematic effects on the springs, baths or Mangamutu Stream could be detected in terms of changes in chloride flux or temperature.

Through supplementary injection the flow rates, temperatures and composition of the springs and baths should be able to be maintained as they were before production started.

This concept has applicability to other geothermal projects, not only for conservation of surface thermal activity. Supplementary injection of municipal waste to maintain reservoir pressures has been successfully carried out at The Geysers dry steam resource in the USA for several years. Supplementary injection to prevent ground subsidence due to reservoir pressure drawdown (which is not an issue for Ngawha) has been proposed at the Wairakei-Tauhara field in New Zealand, but its implementation remains controversial.

REFERENCES

Ellis, A. J. and Mahon, W. A. J. 1966. Geochemistry of the Ngawha Hydrothermal Area. New Zealand Journal of Science, 9: 440-456.

Grant, M. A. 1981. Ngawha geothermal hydrology. NZ DSIR Geothermal Report 7: 60-86.

Lawless, J. V. 2002. New Zealand's Geothermal Resource Revisited: Proceedings of the New Zealand Geothermal Association Seminar, Taupo.

Lawless, J.V., Franks, K., Scott, P., Smith, A. C. T.: 2006: Supplementary Injection to Mitigate Environmental Effects at the Ngawha Geothermal Project, New Zealand. Proceedings of the 2006 Australian Earth Science Convention.

Mongillo, M. A. 1985. The Ngawha Geothermal Field: An Introduction and Summary in *The Ngawha Geothermal Field:*

New and Updated Scientific Investigations edited by M. A. Mongillo. NZ DSIR Geothermal Report Number 8.

PB Power, 2002, Ngawha Geothermal field. Reservoir numerical modelling: Phase I. Unpublished report for Top Energy P:\40231

PB Power, 2005, Ngawha Geothermal field. Reservoir numerical modelling. Phase II Extension. Unpublished report for Top Energy P:\40321

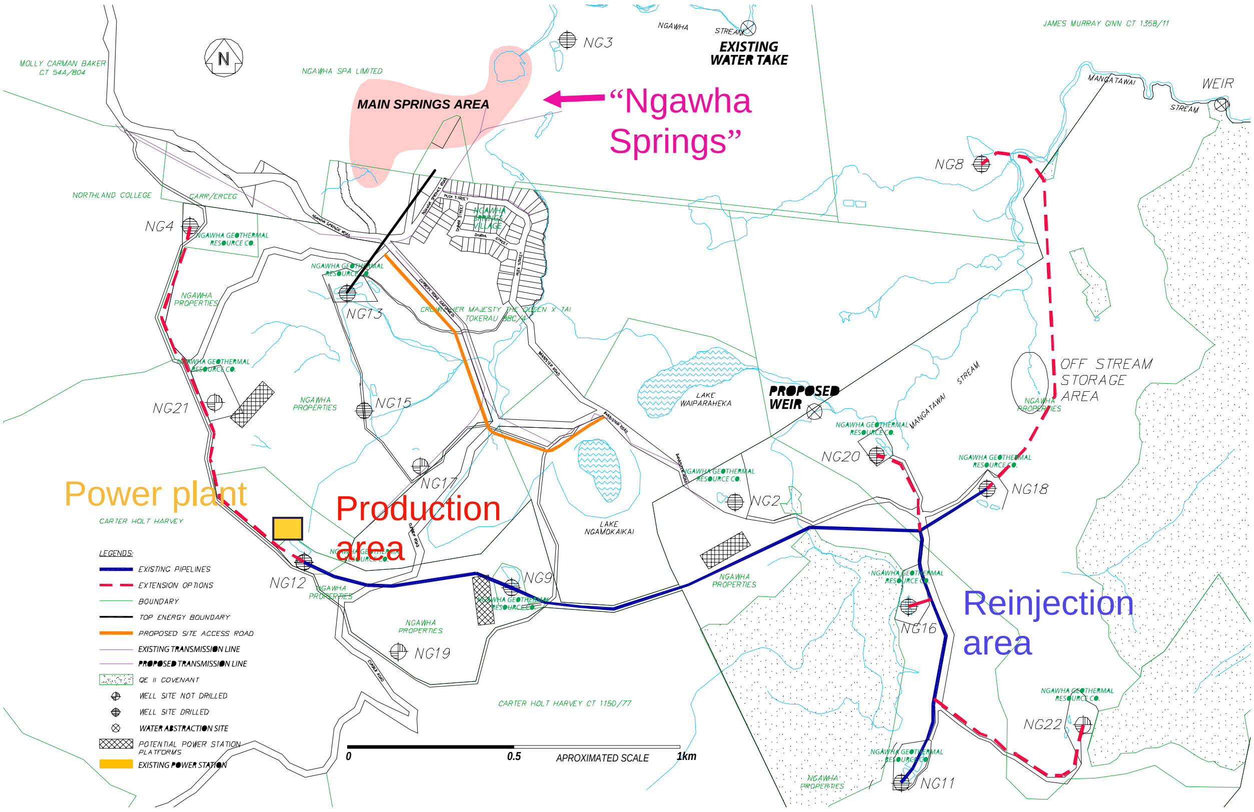

Figure 2. Site map

PRESENT STATUS AND FUTURE PLAN OF GEOTHERMAL DEVELOPMENT IN TURKEY

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Turkey is located on the Alpine-Himalayan orogenic belt, which have high geothermal potential. The first geothermal researches and investigations in Turkey started in 1960's. Upon this, 172 geothermal fields have been discovered by MTA (MTA, 2005). Main resources are located on, Aegean grabens, Northern Anatolian Fault Zone (NAFZ) and Volcanic and tectonic areas in Central and Eastern Anatolia (Simsek et al. 2005). Around 1500 hot and mineralized natural springs and geothermal wells exist in Turkey (Figure.1). With the existing geothermal wells discharge water (2924 MWt) and springs (600 MWt), the proven geothermal capacity calculated by MTA is totally 3524 MWt (exhaust temperature is assumed to be 35 °C). The expectations in the commission report prepared by State Planning Organization (SPO-DPT), which includes the geothermal activities in Turkey between 2007-2013, will also be clarified (Mertoglu et al. 2006).

As it will be considered, the number of geothermal production wells is too few if compared to the high geothermal potential of Turkey. Most of these wells have been drilled by MTA and financed by the Governorships, Municipalities and their companies, which constitutes 66.2 % and followed by MTA with 16.5 % and 11.7 % Private.

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Figure 1: Main neotectonic lines and hot spring distribution of Turkey

A total of 28 MWe for power production installed capacity (Denizli-Kizildere-20 MWe and Aydin-Salavatli 8.0MWe) in Turkey. Utilization of the discharge water of Kızıldere-Sarayköy Geothermal Power Plant - 6,85 MWe, Aydin-Germencik Power Plant- 45MWe and Çanakkale-Tuzla Geothermal Power Plant -7,5 MWe (total 59.35 MWe) Licence obtained. Kutahya-Simav Geothermal Power Plant – 10 MWe on project phase.

Geothermal Power Plants (GPP) in Turkey.

1) 20 MWe (Denizli – Kızıldere) in operation since 1984
2) Aydin-Salavatlı GPP 8 MWe in operation since 2006

Licenced (giving by Ministry of Energy and Naturel Resources and EPDK)
And Under construction

3) Aydin-Germencik GPP 45.0 MWe
4) Denizli- Kızıldere GPP 6,85 MWe
5) Çanakkale-Tuzla GPP 7.5 MWe

On project phase.

6) Kutahya-Simav GPP 10 MWe

Geothermal fields which their reservoir temperatures over than 140 ºC are given below.

1. Denizli-Kızıldere Field (200-242 °C)
2. Aydın-Germencik -Omerbeyli Field (232 °C)
3. Manisa –Salihli-Göbekli Field (182 ° C)
4. Çanakkale- Tuzla Field (174 ° C)
5. Aydın-Salavatlı Field (171 °C)
6. Kütahya-Simav Field (162 °C)
7. Manisa- Salihli-Caferbey Field (150 °C)
8. Izmir- Seferihisar Field (153 °C)
9. Aydın-Sultanhisar Field (145°C)
9. Izmir-Balçova Field (142°C)
10. Aydın-Yılmazköy Field (142 °C)
11. Izmir-Dikili Field (130°C).

Most of the development is achieved in geothermal direct use applications by 103 000 residences equivalence geothermal heating (827 MWt) including district heating, thermal facilities and 635,000 m^2 geothermal greenhouse heating (Table 1, 2). Main city centers heated by geothermal energy as Izmir-Balcova, Narlidere, Afyon, Kirsehir and Afyon-Sandikli, Kutahya-Simav, Ankara-Kizilcahamam, Balikesir-Gonen, Nevsehir-Kozakli, Manisa-Salihli, Agri-Diyadin, Denizli-Saraykoy, Balikesir-Edremit, Bigadic. 215 spas are used for balneological purposes (402 MWt). By summing up all this geothermal utilizations in Turkey, the installed capacity is 1229 MWt for direct use (Mertoglu et al. 2006). This amount of heat is equivalent as 900.000 tons/year fuel oil . A liquid carbon dioxide production factory 120000 tons/year is integrated to power plant in Kizildere (Figure.2).

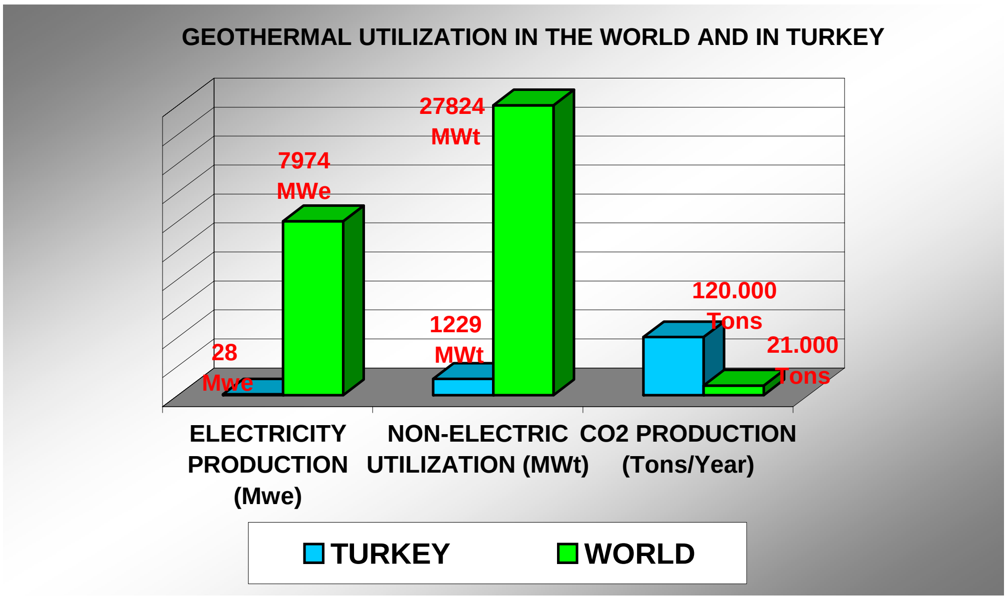

Figure 2. Installed capacities of geothermal applications in Turkey and the World.

Being one of the richest countries in geothermal potential, Turkey's geothermal activity has been developed mostly to district heating systems between 2000-2005 (Table.1).

Table1. Comparison of Geothermal Direct Use Applications for the years 2000 and 2005

Applications	2000	2005	Increament (%)
District Heating (Residences+Thermal Facilities)	392 MWt	635 MWt	62
Greenhouse Heating	101 MWt	192 MWt	90
Thermal Tourism Applications	327 MWt	402MWt	23
Total Direct Use	820 MWt	1229 MWt	50
Mineral Production	120000ton/yıl	120000ton/yıl	
Proven capacity of existing geothermal wells and natural discharges	3045 MWt	3524 MWt	16

Mertoglu et al. 2006

Table.2. Geothermal district heating systems in Turkey

Location	Geoth. Heated Residences	Start-up	Geoth. Water temp. (oC)	Investor
9 Eylul Unv. Campus	2500	1983	115-60	Governorship, University Rectorate
Gonen	3400	1987	80	Mainly Municipality Inc.
Simav	5000	1991	137	Municipality
Kırsehir	1800	1994	57	Governorship (mainly) + Municipality Inc.
Kızılcahamam	2500	1995	80	Mainly Municipality Inc.
Balçova	15000	1996	137	Mainly Governorship Ltd. Company
Afyon	4500	1996	95	Governorship (mainly) + Municipality Inc.
Kozaklı	1200	1996	90	Mainly Municipality Inc.
Narlıdere	1500	1998	125	Mainly Governorship Ltd. Company
Sandıklı	3200/5000	1998	70	Mainly Municipality Inc.
Diyadin	400	1999	70	Mainly Governorship Inc.
Salihli	4500/24000	2002	94	Municipality
Saraykoy	1500/5000	2002	140	Mainly Municipality Inc.
Edremit	1300/7500	2003	60	Municipality + Private Sector Inc.
Bigadic	500/3000	2005	96	Municipality
Sarıkaya	10/2000	2006	50,5	Governorship + Municipality+ Private Sector cooperation is planned
Thermal Facilities and 635.000 m2 greenhouse heating (Şanlıurfa, Dikili, Balçova, …)				Investment in the field= Governorship Greenhouse investment= Private Sector

Mertoglu et al. 2006

In addition to these, big portion of geothermal potential in Turkey is suitable for heating purposes, geothermal district heating investments could be realized and operated with the cooperation of local governments, municipalities, people and private sector.

The district heating system was established earlier in Turkey using lignite for heating in furnaces. Moreover the people were introduced to a higher living standard by means of geothermal district heating systems. People show a very high demand for geothermal district heating systems is Turkey. The people prefer to buy or rent geothermally heated residences and this causes an increment of the renting or selling prices of these houses 3-4 times in comparison to the other houses. With integration of the geothermal district heating systems (GDHS) to the above mentioned electricity production, greenhouse heating and balneological applications (cascade use), the technical and economical aspects of the investment also becomes more favorable and convenient. In addition to these, big portion of geothermal potential in Turkey is suitable for heating purposes, geothermal district heating investments could be realized and operated with the cooperation of local governments, municipalities, people and private sector (Mertoglu et al. 2006).

There is a high thermal tourism potential in Turkey. Moreover combining thermal tourism with the sea/sun/cultural tourism brings important economical development to the region and country. The demand for balneological utilization of geothermal waters has been increased in the recent years in Turkey. A possible producable potential amount of geothermal flowrate (~40°) has been estimated for the balneological use in Turkey, which is 50.000 l/s. This equals to the benefit of 8 million people/day from thermal waters in spa's in Turkey.

Main important items for research and development for the next period of geothermal energy in Turkey

- Existing fields should be managed and developed,
- New fields should be investigated,
- Deep reservoirs should be searched,
- Exploration of new fields, and for determination of characteristics and capacities of present field, providing the required support to MTA, Universities and Private Organizations for their research, development and application projects.
- Since the solution alternatives for waste water problem are incrased (as reenjection), with regard to the environment geothermal fields must be activated very rapidly.
- Scaling and corrosion problems which effect the management of geothermal energy, have been solved by the injection of the chemical inhibitor. Consequently, it is necessary to activate the fields and to accelerate the investments at this sector.
- More geothermal wells should be drilled and the well risk should supported by the state,
- Determination of utilization possibilities of geothermal fields and planning of these fields in the form of integrated utilization (electricity generation, district heating, thermal and balneological applications) and encouragement of the geothermal uses.
- Turkey is suitable for heating purposes, geothermal district heating investments could be realized and operated with the cooperation of local governments, municipalities, people and private sector.
- Thermal tourism and balneological utilization with the sea/sun/cultural tourism brings important economical development to the region and country.
- More financing aids should be received and international cooperation should be developed for the geothermal development projects.
- To supply the required support about know-how transfer, education, finance and equipment necessities via realization of projects in common with international organizations,
- Turkish geothermal law should be finalized as soon as possible,

The realization of the World Geothermal Congress 2005 in Antalya/Turkey, has been important benefit to the development and widening of geothermal explorations and applications in Turkey.

Geothermal energy in Turkey must be used as the main energy source at the regions where it is found, since it is very cheap, clean, and sustainable for the benefit of the mankind.

References

MERTOGLU, O. BAKIR,N., SIMSEK, S et al. (2006). Geothermal Energy Development Plan in Turkey. Turkish Prime Ministry State Planning Organisation (SPO-DPT) 9th Development Plan (2007-2013) Ankara

MTA, 2005, Geothermal Inventory of Turkey. MTA publication. Ankara

SIMSEK, S, MERTOGLU, O. BAKIR, N., AKKUS, and AYDOGDU, O. 2005. Geothermal energy utilization, development and projections-Country update report (2000-2004) of Turkey. Proceedings World Geothermal Congress 2005. R-0126, (Ed.R.Horne&E.Okandan) ISBN 975-98332-0-4, Antalya-Turkey.

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