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# Geothermal Development in Iran: A Country Update

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## ABSTRACT

This paper provides a summary of geothermal activities in Iran with emphasis on developments for 2000-2004. Iran has a wide variety of low to medium enthalpy resources that are substantially associated with volcanic provinces. In this paper, we present advancements from: i) the Meshkinshahr project purposed at generating electricity from the Sabalan geothermal field (Ardebil Province- NW of Iran) ii) direct utilization of hot springs in the Sabalan area which represents the most outstanding thermal manifestations in Iran and iii) a sampling of direct utilization projects that were proposed based on findings from a recently completed investigation of Iran's geothermal potential. Furthermore, Damavand prospect known as a potential field has recently attracted the attention of scientists and its detailed investigation has been prioritized.

## 1. INTRODUCTION

The state-run electric company of Italy (ENEL) with the accompaniment of Tehran Berkeley of Iran initiated the systematic study of Iran's geothermal fields in 1975 under a contract signed with the Ministry of Energy (hereinafter referred to as MOE) of Iran. The studies terminated in the early 1980's and led to the introduction of four major prospects. Amid 1990's, following a long gap, the growing needs to explore the clean sustainable sources of energy resulted in the setting up of specialized state-run establishments such as Electric Power Research Center (EPRC) and Renewable Energy Organization of Iran (SUNA). During recent years, the latter as an affiliate of MOE has been effectively engaged in the management and execution of a variety of renewable projects including geothermal. This company plays a fundamental administrative role in most of the nationwide geothermal projects and turns over jobs to both government and private sectors as its executive arms.

The idea of power generation from Sabalan geothermal prospect (officially named Meshkinshahr geothermal field) was initially proposed in 1994; thereafter emphasis has been put onto this field as the eminent priority. Upon detailed geo-based survey conducted by the joint collaboration of SUNA of Iran and Sinclair Knight Merz Ltd (SKM) of New Zealand within the time frame of 1998-2000, Meshkinshahr geothermal field was recognized satisfactory as a potential reservoir for power generation purposes. Based on their proposal, the exploratory drilling of three exploration wells started in 2002.

For the past decade, in parallel, SUNA has also conducted a series of countrywide potential investigation studies in order to evaluate appropriate zones for future investment particularly aiming at direct-heat utilizations in the remote areas bearing weaker economies. In this paper, we have also attempted to provide a simple calculation of the installed capacity of the thermal springs of Sabalan Mount region (NW of Iran) based on recent field measurements (2000and 2002).

## 2. GEOTHERMAL RESOURCES

As a part of Alpine-Himalayan orogenic belt, Iran's plateau is principally divided into five major geological units based on remarkable tectonic history, magmatic events or sedimentary features (Nabavi, 1976). These units are i) Zagros, ii) Sanandaj-Sirjan, iii) Central Iran, iv) East and South-East zones and v) Alborz and each major unit is subdivided into a number of sub-units with specific characteristics.

Most geothermal provinces of Iran are located in areas with higher heat flow and geothermal gradients. According to the above classification, the most important geothermal manifestations and thermal springs are in association with Alborz structural unit (unit v) extending from NW to the NE of Iranian territory where the most active volcanism of Late Alpine phase has occurred. However geothermal prospects are not merely restricted to this unit and several debatable thermal manifestations are present in other regions that might be ranked as lower priorities. In general, the Iranian plateau is characterized by low to moderate-enthalpy resources that are fundamentally incorporated into the areas with the most recent (Late Tertiary-Quaternary) volcanic activities. The country geothermal gradient values range fom 2°C/100m in the Zagros belt to 13 °C/100m around Damavand volcano in the north.

The systematic evaluation on geothermal resources of Iran was carried out in the 1970's. The conducted studies resulted in the introduction of four major prospects (ENEL, 1975-1983) including Damavand, Sabalan, Khoy-Maku and Sahand geothermal fields located on the north and northwestern Iran (Figure 1). The nationwide geothermal potential survey project (SUNA, 1998) also suggested ten areas in different parts of the country. They are assumed to possess reasonable potential and have been recommended for direct utilization purposes in particular (Figure 2). Work on other thermal provinces is yet to start.


**Figure 1: Four major prospects introduced by ENEL and Tehran Berkeley**

## 3. GEOTHERMAL POWER GENERATION PROJECT

Iran's conventional strategy for power generation has been largely established on the usage of inexpensive local fossil fuels (27,576 MWe) and to a lesser extent on hydroelectric resources (3037 MWe) as appear in Table 1. However during the past decade, a number of scientists and policy-makers have come to the consensus that other renewable energies can reasonably provide substitutes for the unsustainable and unclean fossil fuels. Among the various options, geothermal energy has a relatively longer background in comparison with other renewables in Iran, although it too, is very young in practice.

After the preliminary introduction of Sabalan geothermal field in the 1980's, further exploration began in 1995 based on evidences that the region offered strong potential for power generation development. In order to better understand the reservoir characteristics, geothermal professionals from Iran initiated the geo-related investigations. In the years after, a number of scientists from New Zealand have contributed to the running investigations.

As a result of these studies, the locations for three exploratory wells were determined, each with a target depth of 3000 m. Drilling started in late 2002. To-date, all wells have been completed. A downhole temperature of approximately 240 °C has been recorded for two wells at the final depth of 3200 m. The third well that was completed by late June 2004 demonstrates a downhole temperature of about 230 °C (total depth 2260 m) with promising flow rate. The fourth exploratory well has also been projected for the year to come. The total number of wells to be drilled for the development stage of production will be finalized upon completion of this exploratory stage. A maximum number of 30 wells have been proposed based upon preliminary studies. The installed capacity of the future power plant will be calculated on the basis of the real field data following analysis of the exploratory well tests (Table 2).

## 4. DIRECT HEAT UTILIZATION - PRESENT STATUS

A wide variety of thermal manifestations with the surface temperature of about 25 to 85 °C are scattered in various regions. However the hottest springs are geographically located in the northwestern part of the country which also experience the coldest winters. The temperature of the urban and rural areas in this region varies between -15 to maximum 30°C annually that normally absorbs huge amount of energy sources of different categories.

Because of the subsided sources of energy (oil, gas and electricity), the concepts of direct use of thermal waters have not yet been fully perceived. With regard to the chemical and physical characteristics of the thermal waters, they have been traditionally used for recreational and balneological purposes in the form of swimming and bathing pools as a fundamental version of direct-heat utilization of geothermal energy in the region.

However in recent years (2001 onwards), efforts have been made to publicize the concept of direct use for agricultural, fish-farming and greenhouse purposes at the level of governmental authorities. In an attempt to evaluate the current status of hot water utilizations, Ardebil province was selected as the most popular site for recreational use of thermal waters in Iran.

Ardebil province is located in the northwest of Iran and hosts one of the most active geothermal prospects in the vicinity of Sabalan stratovolcano (Bogie *et al*., 2000). A large number of thermal springs that have been historically identified and used are associated with Mt. Sabalan. The springs have been geographically positioned on the two extreme sides of the mount with a temperature range of 35-85 °C in four major prospects including Sarein, Meshkinshahr and Nir cities as well as Sardabeh village (Table 3). The most recent field measurements (2002) in the region are indicative of the total flow rate of 307.5 kg/s that can be collectively accounted for about 30 MWt as the present installed capacity for direct heat utilization (Table 3 and 4).

Nevertheless this figure seems to be far from reality since the earth's heat is recovered in a very small scale in Iran and utilization is almost only limited to recreational purposes. Authors believe that the lack of public awareness plays the most important role in the retardation of this branch during recent years, in spite of the existence of reasonable potential in several regions.

## 5. MANPOWER ALLOCATION AND INVESTMENT

The geothermal energy sector of Iran is totally run by the government (MOE and SUNA) and therefore most of the personnel are governmental staff. Table 5 shows the number of manpower based upon local and overseas professionals for the period of 2000-2004. Other private and governmental establishments provide contribution to the handling of various civil and drilling works that they have been assigned. In addition, a number of academic persons are temporarily paid for their assistance to the running projects.

The overall investment allocated to geothermal research and development plans for the duration of 2000-2004 was around US $ 9.6 million that has been totally provided by the government (Table 6). This budget has been used particularly for the purpose of financing the underway drilling project in Meshkinshar (Ardebil province).

## 6. OUTLOOK FOR THE FUTURE

Recently, decision-makers have begun to visualize that geothermal waters represent a clean, sustainable source of energy that, in addition to recreational applications, can be effectively used for agricultural and aquaculture purposes specifically in central and northwestern parts of Iran. In the country fourth development program, various strategies with regard to geothermal energy have been prioritized that can be categorized as follows:

- Completion of Meshkinshahr geothermal power plant project (in progress) including reservoir evaluation, field development, environmental study, drilling further exploratory wells (up to 30) and finally design, installation and commissioning the power plant provided that the well test results are approved
- Direct heat utilization development in the northwestern part of Iran based on more detailed geoscientific surveys, drilling exploratory wells and improving the present bathing and swimming facilities in Sarein and Meshkinshahr prospects as the first priority. Two more sites (Ramsar and Mahallat in north and west part of Iran, respectively) have been considered for experimental greenhouse, aquaculture and space heating purposes. The projects have been scheduled for the year 2005 to begin.
- Detailed exploratory surveys in Damavand geothermal field (Damavand Volcano- North of Iran). For this purpose, an agreement was made

between SUNA and Niroo Research Center (MATN, an affiliate of MOE) in 2003 in order to reconsider the previous exploration data of the Damavand prospect in the vicinity of Tehran for the efficient recovery of the surrounding thermal springs

- During the years 1995-2000, a working team at SUNA initiated and executed a project entitled “The Geothermal Potential Survey in Iran” in order to explore the geothermal resources in the country (Fotouhi, 2000) other than those described by ENEL (1983). This project led to the introduction of ten prospects across the Iranian territory among which geological and geochemical studies were carried out over two prospects. However, the project was temporarily suspended due to budgetary problems in the following years. Currently SUNA has adopted the policy to restart the preliminary geological and geochemical study of the introduced areas.

## 7. CONCLUSION

Preliminary explorations of geothermal provinces of Iran, although at an immature level, have demonstrated that such resources may offer a marked contribution to the local economy. Although during recent years (2000-present) great attention has been directed at generating power from geothermal energy, the authors firmly believe that direct utilization of thermal waters will provide a tangible flow of income to the remote areas as well.

Geothermal energy has been proved to be of great importance for environmental protection. On this basis, developed facilities in the branch of the tourist industry will significantly raise the number of tourists (local and overseas) to the areas with combined scenic landscapes and thermal manifestations (*e.g.* Sabalan, Damavand, Ramsar) in the short run. Greenhouse development in specific areas such as Mahallat (central Iran) may convert the needs of the people to the clean source of geothermal energy to heat the local greenhouses. Basic investment in the field of fish farming can create excess income in the rural communities in several regions. As another suggestion, a pre-feasibility study on the utilization of GHPs should also be practiced particularly in the southern regions of Iran that experience very hot and partly humid summers.

Fortunately, in 2000-2004 further practical progress has been achieved in comparison with the former periods particularly in the branch of power generation project. However, the more extensive exploitation of geothermal energy (as well as other renewables) in Iran is in dire need of several prerequisites including: 1- enhanced public understanding, 2- well-educated professionals, 3- government investment and support through the subsidization of prices, 4- encouraging role of government for private sector contribution as well as foreign collaboration, 5- course credits at the university level, 6- dispatching experts for short-term visits to geothermal sites (various applications) in other countries and 7- inviting experienced foreign lecturers to introduce recent achievements in the field of geothermal energy.

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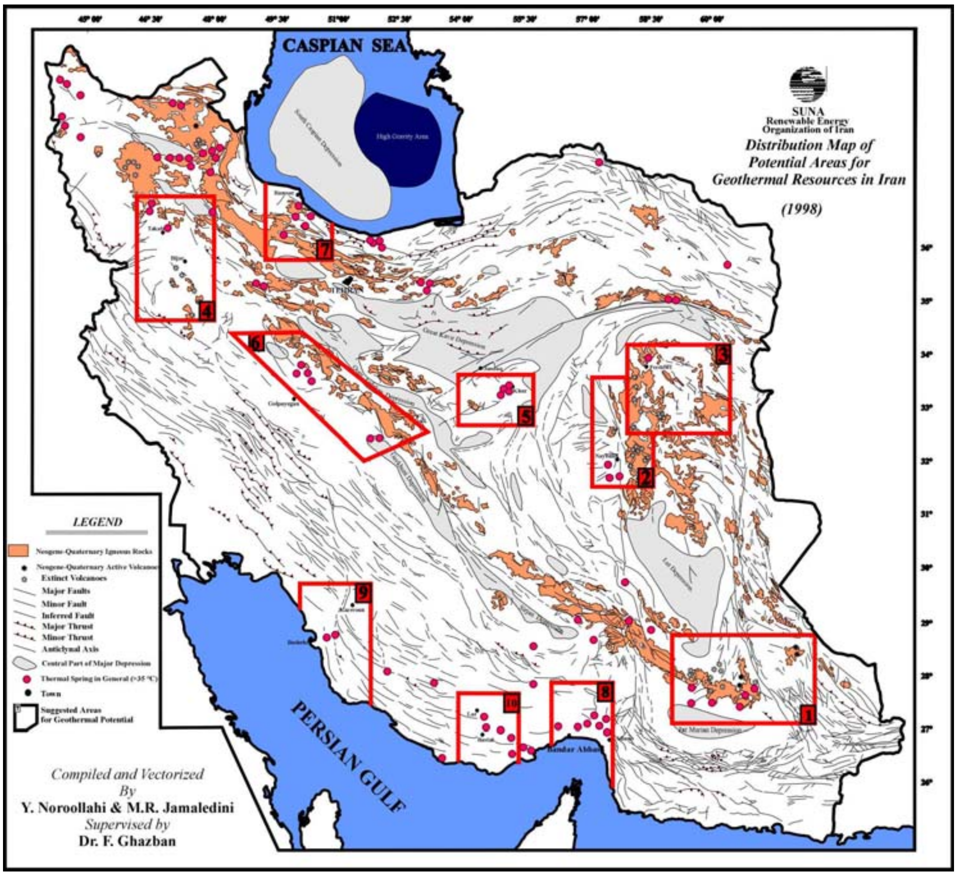


**Figure 2: Ten major prospects introduced as potential areas for geothermal resources in Iran**

**Table 1. Present and planned production of electricity (Installed capacity)**

| | Geothermal | | Fossil Fuels | | Hydro Small & Large | | Nuclear | | Other Renewables (Wind, Solar & Biomass) | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Capacity MWe | Gross Prod. GWh/yr | Capacity Mwe | Gross Prod. GWh/yr | Capacity MWe | Gross Prod. GWh/yr | Capacity MWe | Gross Prod. GWh/yr | Capacity MWe | Gross Prod. GWh/yr | Capacity MWe | Gross Prod. GWh/yr |
| In operation in December 2004 | 0 | 0 | 27576 | 127105 | 3037 | 8085 | 0 | 0 | 11.9 | 31.654 | 30625 | 135221.7 |
| Under construction in December 2004 | 16 | 108 | 27666 | 127520 | 4746 | 12635 | 1000 | Nill | 59.6 | 158.536 | 33488 | |
| Funds committed, but not yet under construction in December 2004 | 16 | 108 | 32187 | 148358 | 7816 | 20808 | 1000 | Nill | 148.4 | 394.744 | 41167 | |
| Total projected use by 2010 | 100 | 674.5 | 37924 | 174802 | 11296 | 30072 | 1000 | Nill | 637.75 | 1696.415 | 50958 | |

**Table 2. Wells drilled for electrical use of geothermal resources from January 1, 2000 to 2004**

| Purpose | Wellhead Temperature | Number of Wells Drilled | | | | Total Depth (km) |
|---|---|---|---|---|---|---|
| | | Electric Power | Direct Use | Combined | Other (specify) | |
| Exploration | Unknown | 3 | | | | 8.6 |
| Production | >150° C | | | | | |
| | 150-100° C | | | | | |
| | <100° C | | | | | |
| Injection | *For waste water disposal* | 2 | | | | 1.2 |
| Total | | 5 | | | | 9.8 |

**Table 3. Utilization of geothermal energy for direct use as of December 2004 (other than heat pumps)**

I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting
H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

| Locality | Type | Maximum Utilization | | | | | Capacity | Annual Utilization | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Flow Rate (kg/s) | Temperature (°C) | | Enthalpy (kJ/kg) | | (MWt) | Ave. Flow (kg/s) | Energy (TJ/yr) | Capacity Factor[5)] |
| | | | Inlet | Outlet | Inlet | Outlet | | | | |
| **Sarein City** | | | | | | | | | | |
| Sabalan swimming pool | B | 50 | 46 | 24 | | | 4.60 | 40 | 116.07 | 0.80 |
| Gavmish Goly | B | 140 | 47 | 25 | | | 12.89 | 120 | 348.22 | 0.86 |
| Other small baths | B | 26.5 | 42.8 | 22 | | | 2.31 | 17.8 | 48.83 | 0.67 |
| **Sardabeh Village** | | | | | | | | | | |
| Sardabeh hot spa | B | 30 | 36 | 20 | | | 2.01 | 25 | 52.76 | 0.83 |
| Yeddi blook | B | 5 | 38 | 17 | | | 0.44 | 3 | 8.31 | 0.60 |
| **Meshkinshahr City** | | | | | | | | | | |
| Gheynarjeh | B | 12 | 85 | 25 | | | 3.01 | 8 | 63.31 | 0.67 |
| Moeil | B | 2 | 46 | 25 | | | 0.18 | 1.5 | 4.15 | 0.75 |
| Elandoo | B | 5 | 35 | 24 | | | 0.23 | 4 | 5.80 | 0.80 |
| Ghotoursoo | B | 15 | 45 | 22 | | | 1.44 | 12 | 36.40 | 0.80 |
| Shabil | B | 3 | 52 | 24 | | | 0.35 | 2 | 7.39 | 0.67 |
| **Nir City** | | | | | | | | | | |
| Geinarjeh Boshli | B | 12 | 61 | 24 | | | 1.86 | 9 | 43.92 | 0.75 |
| Abgarm Boshli | B | 7 | 50 | 24 | | | 0.76 | 5 | 17.15 | 0.71 |
| **TOTAL** | | 307.5 | | | | | 30.08 | 247.3 | 752.32 | 0.74 |

**Table 4. Summary table of geothermal direct heat uses as of 31 December 2004**

| Use | Installed Capacity (MWt) | Annual Energy Use (TJ/yr = $10^{12}$ J/yr) | Capacity Factor |
|---|---|---|---|
| Individual Space Heating[4)] | | | |
| District Heating [4)] | | | |
| Air Conditioning (Cooling) | | | |
| Greenhouse Heating | | | |
| Fish Farming | | | |
| Animal Farming | | | |
| Agricultural Drying[5)] | | | |
| Industrial Process Heat[6)] | | | |
| Snow Melting | | | |
| Bathing and Swimming[7)] | 30.08 | 752.32 | 0.74 |
| Other Uses (specify) | | | |
| **Subtotal** | | | |
| Geothermal Heat Pumps | | | |
| **TOTAL** | 30.08 | 752.32 | 0.74 |

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

**Table 5. Allocation of professional personnel to geothermal activities**

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

| Year | Professional Person-Years of Effort | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| 2000 | 17 | | | 6 | | |
| 2001 | 17 | | | 3 | | |
| 2002 | 19 | | | 3 | | |
| 2003 | 32 | | | 3 | | |
| 2004 | 35 | | | 2 | | |
| Total | 120 | | | 17 | | |

**Table 6. Total investments in geothermal in (2004) US$**

| Period | Research & Development Incl. Surface Explor. & Exploration Drilling | Field Development Including Production Drilling & Surface Equipment | Utilization | | Funding Type | |
|---|---|---|---|---|---|---|
| | | | Direct | Electrical | Private | Public |
| | Million US$ | Million US$ | Million US$ | Million US$ | % | % |
| 1990-1994 | | | | | | |
| 1995-1999 | | | | | | |
| 2000-2004 | 9.6 | | | | | 100 |