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GEOTHERMAL ENERGY DEVELOPMENT IN IRAN

[1]Younes Noorollahi, [2]Hossein Yousefi, [2]Sachio Ehara, [2]Ryuichi Itoi
[1]Renewable Energy Organization of Iran
Tehran
IRAN
[2]Dep. of Earth Resources Engineering
Kyushu University
Fukuoka
JAPAN
Yo_noorollahi@yahoo.com

ABSTRACT

Interest in geothermal energy originated in Iran when James R. McNitt, a United Nations geothermal expert visited the country in December 1974. In 1975, a contract among the Ministry of Energy, ENEL (Entes Nazionale per L'Energia Elettrica) of Italy and TB (Tehran Berkeley) of Iran was signed for geothermal exploration in the north-western part of Iran. In 1983 the result of investigations defined Sabalan, Damavand, Khoy-Maku and Sahand regions as four prospected geothermal sites in north western Iran.

From 1996 to 1999 a countrywide geothermal energy resource exploration project was carried out by Renewable Energy Organization of Iran (SUNA) and ten more potential areas were indicated additionally.

Geothermal potential site selection using Geographic Information System (GIS) was carried out in Kyushu University in 2007. The results indicated 8.8% of Iran as prospected geothermal areas in 18 fields.

Sabalan as a first priority of geothermal potential regions was selected for detailed explorations. Since 1995, surface exploration and feasibility studies have been carried out and five promising areas were defined. Among those prospective areas, NW Sabalan geothermal filed was defined for detailed exploration to justify exploration drilling and to estimate the reservoir characteristics and capacity.

From 2002 to 2004 three deep exploration wells were drilled for evaluation of subsurface geological conditions, geothermal reservoir assessment and response simulation. Two of the wells were successful and a maximum temperature of 240°C at a depth of 3197 m was recorded. As a result of the reservoir simulation, a 55 MW power plant is projected to be installed in the Sabalan field as a first in geothermal power generation. To supply the required steam for the geothermal power plant (GPP) 17 deep production and reinjection wells are planned to be drilled this year.

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 (MOE) of Iran. The studies terminated in the early 1980's and led to the introduction of four major prospects.

Amid the 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 (Northwest Sabalan geothermal field) was initially proposed in 1994; thereafter emphasis has been put onto this field as an 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 1998-2005, NW Sabalan geothermal field was recognized satisfactorily as a potential reservoir for power generation purposes. Based on their proposal, the exploratory drilling of three exploration wells carried out in 2002-2004. Numerical modelling of the reservoir was accomplished and the capacity of the field was approved to install a 55 MW geothermal power plant.

Over 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. Ten geothermal potential sites in Iran were defined (Noorollahi. et. al, 1998) in addition to four previously defined areas in north-western part.

A new updated and more accurate digital geothermal potential map of Iran using Geographic Information System (GIS) was developed in Kyushu University in year 2007(Yousefi. et. al, 2007). The results indicated 8.8% of Iran as prospected geothermal areas in 18 promising fields. At present, identified 18 prospected areas for geothermal energy development in Iran and first priority for power generation was given to Sabalan area.

However in recent years (from 2001 onward), 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 Iran. A project, to publicize geothermal heat pumps, was initiate from 2004 and 5 geothermal heat pumps were installed in different parts of country.

A brief description of geothermal activities is presented in this paper, which is divided into three main sections including; geothermal resources in Iran, Power generation project and direct utilizations.

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 the Alborz structural unit (unit v) extending from NW to the NE of the Iranian territory where the most active volcanism of the 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 from 2°C/100m in the Zagros belt to 13 °C/100m around the Damavand volcano in the north.

In the beginning, geothermal energy development in Iran was started by Mr. James R. Mc Nit, one of the United Nations experts who visited Iran in 1974, and reported that Iran had very promising prospects for geothermal energy development (Fotouhi, 1995). Upon his recommendation in 1975, a contract between the Ministry of Energy (MOE) and ENEL of Italy accompanied by Tehran Berkeley (TB) of Iran was signed for geothermal exploration in 260,000 km^2 in the northern part of Iran.
The systematic evaluation on the geothermal resources of Iran was carried out in the 1970's. The conducted studies resulted in the introduction of four major prospects (TB, 1979; ENEL, 1983) including the Damavand, Sabalan, Khoy-Maku and Sahand geothermal fields located on the north and north-western parts of Iran (Figure 1).

The nationwide geothermal potential survey project was carried out by the Renewable Energy Organization of Iran from 1995-1998. The results suggest ten more geothermal prospected areas in other parts of the country. They are assumed to possess a reasonable potential and have been recommended for power generation and direct utilization purposes (Fotouhi and Noorollahi, 2000).
A new updated and more accurate digital geothermal potential map of Iran using Geographic Information System was developed in Kyushu University in year 2007(Yousefi. et. al, 2007). The results indicated 8.8% of Iran as prospected geothermal potential areas in 18 promising fields. These eighteen prospected areas are suggested for detailed geological, geochemical and geophysical investigations. Figure 2 shows the eighteen potential geothermal areas in Iran.

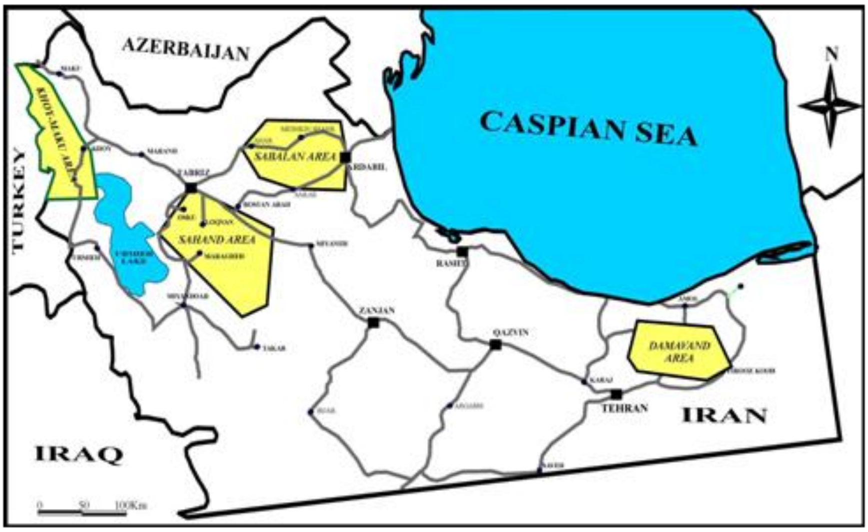

FIGURE 1: Four potential geothermal areas in northwestern Iran (ENEL, 1983)

FIGURE 2**:** Geothermal resources map of Iran (Yousefi, et. al., 2007)

3. POWER GENERATION PROJECT

Iran's conventional strategy for power generation has been largely established on the usage of inexpensive local fossil fuels and to a lesser extent on hydroelectric resources as shown in Table 1. However during the past decade, a number of scientists and policymakers have come to the consensus that 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 renewable energies in Iran, although it is very young in practice.

The idea of power generation from the NW Sabalan geothermal field was initially proposed in 1994; thereafter emphasis has been put onto this field as the first priority. A detailed geo-based survey was conducted by the joint collaboration of SUNA of Iran and SKM of New Zealand within the time frame of 1998 to 2000.

The NW Sabalan geothermal prospect lies in the Moeil valley on the western slopes of Mt. Sabalan, approximately 16 km southeast of the Meshkinshahr city (Yousefi, 2004). The NW Sabalan geothermal field was recognized satisfactory as a potential reservoir for power generation purpose.

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 contracted to the running investigations.

As a result of the geological, geochemical and geophysical surveys, the locations for three exploratory wells were determined; each with a target depth of 3000 m. Table 2 shows the characteristics of three exploration wells.

Drilling was started in late 2002 and three deep exploration wells were completed in 2004. Downhole temperature of approximately 240 °C has been recorded for two wells at the final depth of about 3200 m (SKM, 1998). Completion test and discharge evaluations of the wells were conducted successfully.

Numerical modelling of the reservoir was accomplished and the capacity of the field was approved to install a 55 MW geothermal power plant. Seventeen more production and injection wells are planning to drill to supply the required steam for the planned power plant.

TABLE 1: Present and planned production of electricity in Iran

	Geothermal		**Fossil fuels**		**Hydro small and large**		**Other renewable (wind, solar and biomass)**		**Total**	
	Capacity (MW)	Gross prod. (GWh/yr)	Capacity (MW)	Gross prod. (GWh/yr)	Capacity (MW)	Gross prod. (GWh/yr)	Capacity (MW)	Gross prod. (GWh/yr)	Capacity (MW)	Gross prod. (GWh/yr)
In operation	0	0	39568	182000	3037	8085	11.9	31.654	43714	190116
Under construction	55	375	10000	46000	4746	12635	59.6	158.536	15861	
Funds committed, but not yet under construction	55	375			7816	20808	148.4	394.744	28019	
Total projected use by 2010	100	674.5	45568	209612	11296	30072	637.75	1696.415	58602	

TABLE 2: Specifications of three exploration wells

Well		**NWS1**	**NWS3**	**NWS4**
Location (UTM)		739108E 4238580N	737028E 4240784N	738712E 4239833N
Elevation (m a.s.l) Well depth (m)		2632 3197	2277 3177	2487 2266
Casing depth (m RKB)	Conductor 30"	27	24	26
	Surface 20"	110	113	105
	Anchor 13-3/8"	380	357	541
	Production 9-5/8"	1587	1599	1195
	Liner 7"	3197	3170	2265
Well permeable zones (m a.s.l)		1800-1400	No permeable zone	1050 - 900
		200 - 0		880-890
		-200- -350		
Maximum T (°C)		240	148	229

4. DIRECT HEAT UTILIZATION

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 north-western part of the country where it is very cold in winter. The average ambient temperature in this area is about -15 °C in long winter seasons which requires a huge amount of energy for heating. Direct utilization of geothermal energy can be used but because of availability of cheaper subsidized fossil fuels (oil and natural gas) the concepts of direct use of geothermal energy 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 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 (from 2001 onward), 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 utilization, direct utilization of geothermal energy in the most popular site for recreational use of thermal waters, Ardebil province, was evaluated (Saffarzadeh and Noorollahi, 2005). This province is located in the northwest of Iran and hosts one of the most active geothermal prospects in the vicinity of Sabalan stratovolcano. 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 25- 85 °C in four major prospects including Sarein, Meshkinshahr and Sarab 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 (Saffarzadeh and Noorollahi,2005) (Tables 3 and 4).

The 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. GEOTHERMAL HEAT PUMPS

Geothermal Heat Pumps (GHPs) are considered as modern and suitable air conditioning and water heating systems. They provide comfort, leading to a significant reduction of electrical energy use and demand, have very low levels of maintenance requirements and have the lowest damage to environment.

Geothermal heat pumps are superior to other systems like air source heat pumps. The importance of these advantages are: a) lesser energy consumption during operation, b) use of earth temperature as a more stable energy source (compared to air), c) low cost of design and maintenance, d) no need to supplement heat during extremely low environment temperatures, e) less amount of refrigerant needed and f) the place where the temperature is to be controlled can be apart from where the system is installed.

A project to publicize the application of the geothermal direct utilization as heat pumps was invested and started in 2003. Since 2003, five units of heat pumps, each 750 kW, were installed in five different cities in countrywide. The first one was designed and installed in Tabriz city in the north-western part of Iran in 2004.

6. MANPOWER ALLOCATION AND INVESTMENT

The geothermal energy sector of Iran is totally run by the government. Therefore most of the personnel are government staff. Table 5 shows the amount of manpower based upon local and overseas professionals for the period of 2000 to 2007. Other private and governmental establishments provide a 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 of the projects.

Highly-educated scientists and engineers in geothermal projects in Iran have made it capable to work on geothermal projects effectively. A number of scientists and engineers were supported and trained by international organizations particularly by the United Nation University - Geothermal Training Program in Iceland for a six month training course as well as in master courses. Figure 3 shows the number of internationally trained scientists and engineers since 1995.

The overall investment allocated to geothermal research and development plans for the duration of 2000 to 2007 was around US $ 12.3 million that was totally provided by the government (Table 6). This budget was used particularly for the purpose of financing the underway power generation project, NW Sabalan.

TABLE 3: Direct utilization of geothermal energy in Iran (Saffarzadeh and Noorollahi, 2005)

Locality	Name	Maximum utilization			Capacity (MWt)	Annual utilization		
		Flow Rate (kg/s)	Temperature (^oC)			Ave. flow (kg/s)	Energy (TJ/yr)	Capacity factor
			Inlet	Outlet				
Sarein City	Sabalan pool	50	46	24	4.60	40.00	116.07	0.80
	Gavmish goly	140	47	25	12.89	120.00	348.22	0.86
	Other small baths	26.5	42.8	22	2.31	17.80	48.83	0.67
Sardabeh Village	Hot spa	30	36	20	2.01	25.00	52.76	0.83
	Yeddi blakh	5	38	17	0.44	3.00	8.31	0.60
Meshkinshahr City	Gheynarjeh	12	85	25	3.01	8.00	63.31	0.67
	Moeil	2	46	25	0.18	1.50	4.15	0.75
	Ilandoo	5	35	24	0.23	4.00	5.80	0.80
	Gotourso	15	45	22	1.44	12.00	36.40	0.80
	Shabil	3	52	24	0.35	2.00	7.39	0.67
Sarab City	Gheynarjeh	12	61	24	1.86	9.00	43.92	0.75
	Boushli	7	50	24	0.76	5.00	17.15	0.72
Total		**307.5**			30.07	247.30	752.32	0.74

TABLE 4: Summary of geothermal direct heat uses

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr = 10^{12} J/yr)	Capacity Factor
Bathing and Swimming	30.07	752.32	0.74
Heat pumps	5	122	
Total	35.07	874.32	

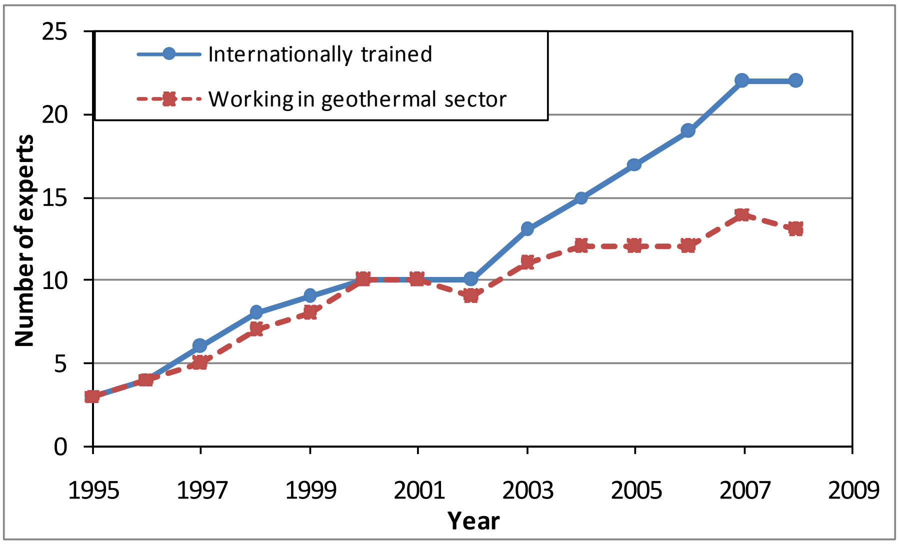

FIGURE 3: Number of internationally trained experts in Iran

TABLE 5: Allocation of professional personnel to geothermal activities in Iran

Year	**Professional person-year of efforts**				
	Government	Public utilities	Universities	Paid foreign consultants	Private industry
2000	17	0	0	6	0
2001	17	0	0	3	0
2002	19	0	0	3	0
2003	32	0	0	3	0
2004	35	0	0	2	0
2006	40	0	0	4	10
2007	51	20	20	10	10
Total	211	20	20	31	20

TABLE 6: Total investments of geothermal development in Iran

Period	**Research development including surface exploration and exploration drilling (Million US$)**	**Field development including production drilling and surface equipment (Million US$)**	**Utilization (Million US$)**		**Funding type (%)**	
			Direct	**Electrical**	**Private**	**Public**
1990-1994	0	0	1	0		0
1995-1999	3	0	0	0		100
2000-2007	12.3	0	0.3	0		100
2008-2010		68.75	1			100

7. OUTLOOK FOR THE FUTURE

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

Completion of the NW Sabalan 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 of the power plant, provided that the well test results are approved.

Direct heat utilization development in the north-western part of Iran based on more detailed geoscientific surveys, drilling exploratory wells and improving the present bathing and swimming facilities in the Sarein and Meshkinshahr prospects as the first priority. Two more sites (Ramsar and Damavand in the northern parts of Iran, respectively) have been considered for experimental greenhouse, aquaculture and space heating purposes.

For detailed exploratory surveys in the Damavand geothermal field (Damavand Volcano- North of Iran) 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 (Saffarzadeh and Noorollahi, 2005).

8. DISCUSSION AND RECOMMENDATIONS

Although, during recent years (2000-present) great attention has been directed at generating power from geothermal energy, the authors 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 and 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 2000-2007 further practical progress has been achieved in comparison with the former periods particularly in the branch of power generation projects. However, the more extensive use 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 and introduction of geothermal potential areas to private sectors, 4- an 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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