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Geothermal Energy Developments in Iran

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ABSTRACT

In this paper, an overview of recent developments (2005-2009) on geothermal energy is described in the Iranian territories. Within this time frame, the number of geothermal-related projects noticeably increased. The Meshkinshahr project in NW of Iran with the goal to generate 55 MWe power nominally, whose exploration drilling phase is in progress, is a national project that is entirely managed by the Renewable Organization of Iran (SUNA). Besides, a small-scale power generation unit has been planned to be set up in the site using geothermal fluids of one of the existing exploration wells. As for direct utilization, a national survey project has been handed over to the private sector using government budget on the existing thermal manifestations. The purpose of the project is to present master plans for selected geographic areas with reasonable potential that are appropriate for tourism facilities. A project was also defined and conducted jointly by SUNA and private sector on the possible direct utilizations of wastewater from the future power plant near Meshkinshahr city. A recent study around Damavand Volcano (north of Iran) demonstrated reasonable geothermal resource with moderate temperature (estimated 130-175°C). As a new technological approach, SUNA launched a feasibility study project for the installation of 5 geothermal heat pumps in different climatic conditions in order to evaluate the efficiency of this technology in the country. In order to promote the standards of geothermal activities in Iran, cooperation with foreign scientists has been continued for transferring technologies within the past 4 years.

1. INTRODUCTION

Iran's strategy for power generation significantly persisted on the usage of inexpensive domestic fossil fuels (44,996 MWe) and to a lesser extent on hydroelectric resources (7,669 MWe) as recorded in Table 1. Nevertheless, during the past 15 years, the decision makers recognized that other sources of renewable energies can provide reasonable substitutes for the unsustainable and unclean fossil fuels. Among the various alternatives, geothermal energy was evaluated as one of the major options with relatively longer record of investigation in comparison with other renewable energies in Iran.

Focusing on major geothermal activities within the time frame of 2005- 2009, in this paper, an overview of recent developments on geothermal energy is presented. The Meshkinshahr project near Sabalan volcano in NW of Iran with the goal to generate 55 MWe power is a national project whose detailed exploration is still underway and is planned to be terminated by 2010. The project is entirely managed by the Renewable Organization of Iran (SUNA), an affiliate of Ministry of Energy (MOE). Besides, a small-scale power generation unit (2-3 MWe) has been planned to be set up on one of the existing exploration wells as a demonstration and test project.

As for direct utilization, a national survey project has been handed over to the private sector on the existing thermal manifestations in order to present master plans for selected geographic areas that might be appropriate for tourism facilities (ATEC, 2006). A project was also defined and conducted jointly by SUNA and private sector on the possible direct utilizations of wastewater from the future power plant near Meshkinshahr city. A recent study around Damavand Volcano (north of Iran) demonstrated reasonable geothermal resource with moderate temperature (130-175°C) (Nouraliee and Talebi, 2007). A feasibility study project was launched by SUNA for the installation of 5 geothermal heat pumps in different climatic conditions in order to evaluate the efficiency of this technology in the country (Porkhial et al, 2008).

Interests on the public utilization of thermal springs in the country has attracted the attention of private and public investors for the erection of sanitary recreation facilities in the vicinity of promising zones in the country. This has persuaded them to invest capitals on the designing projects in certain geographic locations. Finally, several experts joined international short courses or continued graduate study abroad in geothermal field. The cooperation with foreign scientists also continued for transferring technologies within the past 4 years.

2. GEOTHERMAL POTENTIAL

Most geothermal prospects of Iran with low to medium enthalpy are located in areas with high heat flow and geothermal gradients substantially associated with volcanic provinces. The most important geothermal manifestations and thermal springs are in association with Alborz structural unit (from NW to the NE) and the Urumieh-Dokhtar magmatic zone extending from NW to the SE of the Iranian territory (Figure 1) where the most active volcanism of Late Alpine phase has occurred. Extensive areas of Iran are made up of volcanic sequences forming thick pile of Tertiary volcanic rocks across the country in a 2255 km long belt (Urumieh-Dokhtar magmatic belt) from Turkey to Pakistan (Ghazban, 2004). A number of dormant or recently extinct volcanoes exist within the Tertiary volcanic belt (Figure1). Geothermal prospects however are not merely restricted to the aforesaid units. Several debatable thermal manifestations are present in other regions that might be ranked as lower priorities. The country geothermal gradient values range from 2°C/100m in the Zagros belt to 13°C/100m around Damavand volcano in the north.

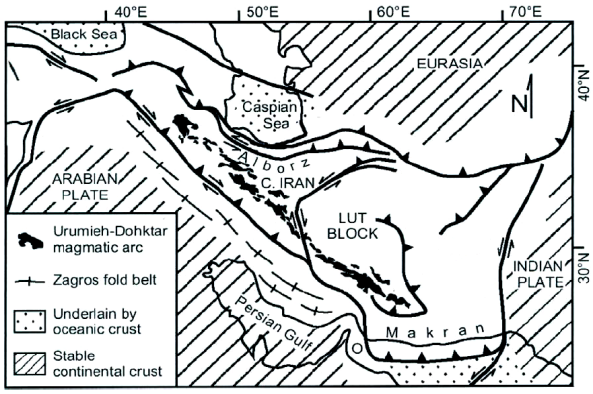

Figure 1: Regional tectonic map of Iran showing the Tertiary volcanic belt (after Alavi, 1994, revised in Ghazban, 2004).

The systematic evaluation on geothermal resources of Iran was carried out in early 70's. The conducted studies resulted in the presentation of four major prospects (ENEL, 1983) including Damavand, Sabalan, Khoy-Maku and Sahand geothermal fields located in the north and northwestern Iran (Figure 2, prospects 1 to 4). The nationwide geothermal potential survey project (SUNA, 1998) also suggested ten additional areas in different geographic locations. They are assumed to possess reasonable potential and have been recommended for direct utilization purposes in particular (Figure 2, prospects 5 to 14). The available data so far prove that Iran has valuable geothermal energy potential (Ghazban, 2004). Geothermal resources are present throughout the country in a variety of appearances and settings with hot springs that are mostly utilized for bathing and therapeutic purposes.

3. POWER GENERATION PROJECT

Following the preliminary presentation of Sabalan geothermal field (Figure 2) in the 1970's, advanced exploration began in 1995. In order to better understand the reservoir characteristics, Iranian professionals initiated the geo-related investigations. In the years after, a number of foreign consultants have contributed to the running investigations. Anchored in exploratory evidences, the Renewable Energy Organization of Iran (SUNA) identified that the region benefits from strong potential for power generation development. It is worth to know that the project is officially nominated as *Meshkinshahr geothermal power generation project* as it is located near Meshkinshahr city, Ardebil province.

As a result, the locations for three exploratory wells were determined, each with a target depth of 3000 m. Drilling phase of the wells started in late 2002 and completed in 2004 with the total depth of 8.6 km (Saffarzadeh & Noorollahi, 2005). A downhole temperature of approximately 240°C was recorded for the wells at the final depth of drilling with promising flow rates. In continuation of the 1st stage drilling, the 2nd stage of exploratory drilling was launched with delay in 2007; with the total depth of 7.56 km within 4 new wells (by October 2009). To date, 7 exploratory wells have been drilled in total for electrical use purpose in Sabalan geothermal area with the total depth of 16.3 km (Table 2); almost doubled comparing to the period of 2000-2004 (Saffarzadeh & Noorollahi, 2005). However the drilling of the 7th well (NWS-8) is still in progress (450 m deep by October 2009) and the drilling of the last exploratory well (NWS-9) will commence in 2010. Upon completion of the whole wells and conducting necessary field and laboratory tests as well as reservoir modeling, preparation will be made for the stage of production drilling. A maximum number of 30 wells have already been proposed based upon preliminary studies. The installed capacity of the future power plant however will be calculated on the basis of the genuine field data following analysis of the exploratory well tests.

Figure 2: Distribution of major geothermal prospects considered as potential areas for further investigations (after Ghobadian et al, 2009).

As an effort for the utilization of heat from the existing drilled wells, SUNA bid a tender in 2007 for the design and erection of a small-scale power generation unit (2-3 MWe) in the Meshkinshahr project site - using geothermal fluids of one of the existing exploration wells - with the purpose of demonstration and testing the reservoir characteristics before the whole wells come on stream. The assigned consultant is now reviewing the prospective for the design and construction of the small size unit.

4. DIRECT HEAT UTILIZATIONS

4.1 Direct Uses

In recent years (2005 onwards), efforts have been made to publicize the concept of direct use of geothermal energy for agricultural, fish-farming and greenhouse purposes at the level of governmental authorities. With regard to the chemical and physical characteristics of the thermal waters in Iran, 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 country.

A wide variety of mineral thermal springs with the surface temperature of about 25 to 85°C are scattered in various regions of the country. However the hottest springs are geographically distributed in the northwestern part of Iran which also experience the coldest winters that normally demands huge amount of energy in different categories (oil, gas and electricity). Because of the national subsided sources of energy, the concepts of direct use of earth heat have not yet been fully perceived.

Gradually but slowly, few attempts have been made to promote the utilization of thermal waters for certain purposes yet with emphasis on recreational activities. As a challenging topic, a feasibility study project was launched

and conducted jointly by SUNA and consulting engineers in 2006 on the various utilizations of wastewater from the future power plant near Meshkinshahr city using GIS database and field investigation. The 1st phase of the project was completed in 2007 with reasonable achievements but temporarily halted due to reformation of SUNA's strategies. As another effort in 2006, Iran's Cultural Heritage, Handicrafts and Tourism Organization (ICHHTO) handed over a national survey project to the private sector on the existing thermal springs. The purpose of the project is to conduct survey in 29 provinces of the country with geothermal potential and present master plans for selected geographic areas with reasonable potential that are appropriate for recreational facilities (ATEC, 2006). The project was completed in 2006 through which 375 locations (mineral cold and hot springs) were prioritized. Master plan for 40 promising localities is under preparation from the above prospects.

A joint venture of private-public sectors has invested capital on the design and construction of a huge modern facility (tourism village) in the vicinity of Sarein city (Ardebil province) - famous for thermal baths- for recreational, balneological and tourism purposes in 2006. Natural hot springs of Sarein city (5 km far) is expected to partly supply the thermal waters required for the facility. Basic architectural design has already been completed and additional evaluations (technical, environmental, social, economical) are in progress.

Several modern recreational facilities (spas) have been developed or renovated for using natural thermal springs in different geographic locations. Gheynarjeh swimming and recreational facility (Figure 3) is one of the newly established centers (2005) near Meshkinshahr city (Ardebil province) that makes use of Gheynarjeh thermal spring water (nearly 87°C) for the baths and swimming pools. Lavidj spa (Mazandaran province) is also a good example for the renovated facilities (Figure 4) surrounded by miraculous landscape. The temperature of thermal mineral waters in this prospect is over 45°C which is enriched in sulfur.

Figure 3: Gheynarjeh modern swimming and recreational facility near Meshkinshahr city.

Other organizations are also involved in the evaluation of the potential of additional geothermal prospects (for both direct and indirect uses) in the country. In 2006, a repeated assessment survey of Damavand geothermal resource (central Alborz, northern Iran- see Figure 2) was conducted by Niroo Research Institute in order to reexamine previous studies and to evaluate the capacity of the resource mainly for direct utilizations. An appreciable amount of thermal springs and geological features are present around Damavand volcano. However hot springs are only used for bathing purposes in primitive small centers. The recent study around Damavand volcano demonstrated reasonable geothermal resource with moderate temperature (~175°C) in the reservoir (Nouraliee and Talebi, 2007).

Unfortunately there is no reliable updated data available for the current status of the utilization of present thermal waters nationwide. In this paper, in addition to the data provided in the past (Saffarzadeh and Noorollahi, 2005), that only belongs to Ardebil province (NW of Iran), a rough estimation has also been provided in total for other geographic locations (Table 3). Budget support from the government will be required to perform national assessment on Iran's geothermal resources.

The data are indicative of the total flow rate of 427.5 kg/s that can be collectively accounted for about 42 MWt as the present installed capacity for direct heat utilization (Table 3). 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 bathing and recreational purposes. Authors believe that the lack of public awareness, supply of inexpensive conventional energies and insufficient budget play the most important roles in the retardation of geothermal investigations, in spite of the existence of reasonable potential in several geographic regions.

Figure 4: Lavidj spa in a resort area- Mazandaran Province.

4.2 Ground-Source Heat Pumps

A feasibility study was launched by SUNA from 2005 onward as a demonstration project for the evaluation of geothermal heat pump (GHP) in Iran. For this purpose, heat pumps were installed in five different regions (Meshkinshahr, Taleghan, Rasht, Ahvaz, and Bandar Abbas) with different climatic conditions in order to evaluate the efficiency of this technology in the country. The GHPs were effectively utilized for both cooling and heating purposes as well as warm water supply for domestic uses. The installed GHPs could manage to reduce the power consumption by 50% and 70% (in average) for cooling and heating modes, respectively (Porkhial et al, 2008). A technical summary of the installed GHPs has been presented in Table 4.

5. MANPOWER ALLOCATION

Table 6 shows the number of manpower based upon the number of professionals from different sectors for the period of 2005-2009. Experts from government and public

utilities characterize the majority of personnel who are active in the Iranian geothermal projects, as this industry in Iran is almost entirely supported and financed by the government (Figure 5). Other 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 hired for their assistance to the ongoing projects in SUNA. Figure 5 indicates that the number of personnel from government and public utilities has remained almost constant from 2005 - 2009, however an increasing trend is observed in the number of academicians and particularly foreign consultants who have contributed to the Meshkinshahr geothermal power generation project. At the same time, a number of persons belong to the private industry appeared in the scene. They have been mostly involved in the development of direct utilization of geothermal waters particularly recreational services. Year 2009 implies greater activities in the geothermal business in Iran. Data in Table 6 and Figure 5 has been provided based on our record in SUNA and other formal sectors. Certainly additional workers are engaged in this business especially in the research centers.

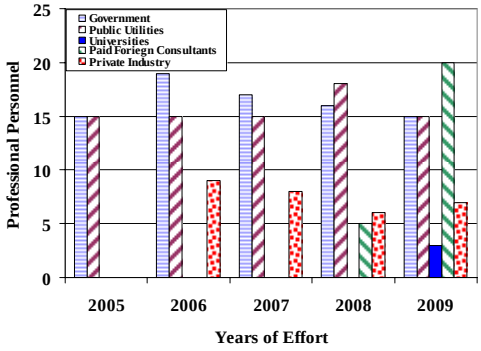

Figure 5: Presents the number of personnel involved in geothermal industry from 2005 to 2009.

6. INVESTMENT

The major source of budget allocated to geothermal research and development plans for the duration of 2005-2009 was around US$4.2 million that has been totally provided by the government (Table 7). This budget has been used particularly for the purpose of financing the Meshkinshar power generation project. In addition, in this period a certain budget (0.4 Million US$) was provided from different sources to support direct utilization plans (Table 7). However on a national scale the recent fund is negligible taking the extensive geothermal resources into account.

7. DISCUSSION AND CONCLUSION

Following the Second World War, due to rapid modernization and notably expansion of energy demand, the core energy policy of the Iranian government principally focused on the exploration and production of fossil fuels (coal, oil, natural gas). Therefore the utilization of these fuels played very critical roles on the economy of the country. Owing to several factors (e.g. increasing energy demand, scarcity of fossil fuels reserves and environmental issues), however, the Iranian government adopted the policy for the development of other resources including hydro- and nuclear powers during the 1960's with emphasis on power generation purposes. Accordingly, several huge hydropower plants were built and the design and construction of a nuclear plant initiated in 1974. In addition, systematic investigation on promising geothermal zones across the country was launched amidst 1970s.

However, as a result of immense political changes in late 70's, the utilization of modern and renewable sources of energy was retarded for almost two decades. Consequently, Iran's strategy for power generation significantly persisted on the usage of inexpensive domestic fossil fuels and to a lesser extent on hydroelectric resources. Nevertheless, during the past 15 years, the decision makers recognized that other sources of renewable energies can provide reasonable substitutes for the unsustainable fossil fuels. However, because of the limitation of the existing technologies for steady and reliable supply of energy and much higher unit cost of electricity generated by these resources, it is not expected that renewable play a major role in Iran's electricity generation in near future. Due to a very cheap price of primary energy and the increase in population, the final energy consumption has increased more than 7% annually and electricity production has risen 10% per year in the last two decades to meet rapid consumption growth (IAEA, 2009). Figure 6 shows the general trend on Iran's electricity generation and consumption from 1984 to 2006 (EIA, 2007).

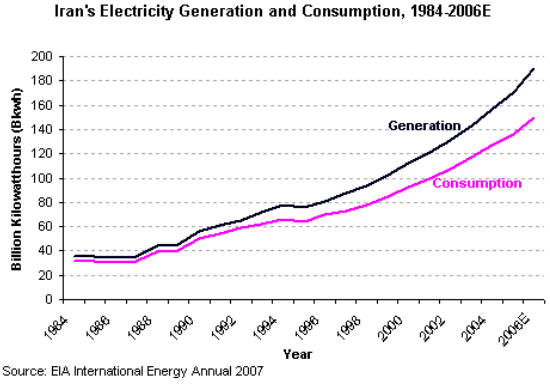

Figure 6: General trends on Iran's electricity generation and consumption, 1984-2006.

There are ample potentials of renewable energies in Iran (solar, geothermal, wind, nuclear). Among the various alternatives, geothermal energy was evaluated as one of the major options with relatively longer investigation record in comparison with other renewable in Iran. On this basis, decision-makers have begun to visualize that geothermal fluids represent a clean, sustainable source of energy that, in addition to recreational utilizations, 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:

- Development of Meshkinshahr geothermal project including reservoir evaluation, field development, environmental study, drilling further exploratory and production wells and finally design, installation and commissioning the power plant provided that the well test results are approved.

- Direct heat utilization development in the northwestern and central parts 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.

- To involve private sector (and their budget) into direct use business is one of the objectives in this regard. We have seen initiatives on the development and renovation of existing recreational facilities from 2005 onward as already discussed under the heading 4-1.

- 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 (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. The 1st phase geoscientific investigation has already been completed and advanced investigations are under evaluation.

Preliminary explorations of geothermal provinces of Iran, although at an immature level, have demonstrated that the development of such resources particularly for direct use purposes may offer a marked contribution to the local economy. Traditional utilization of several thermal springs for bathing purposes in certain geographic areas provides reasonable opportunities for the local communities to benefit from enduring source of income, higher social level and overcoming their population emigration. Sarein city is an ideal instance for the influence of vast thermal springs utilization on the rapid transformation of a rural community to a small but developed urban society within the past 30 years in the foothills of Sabalan volcano in Ardebil province (NW of Iran).

Although during recent years great attention has been given to 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. On this basis, developed facilities in the branch of the tourist industry will significantly raise the number of tourists (both local and overseas) to the areas with combined scenic landscapes and thermal manifestations (e.g. Sabalan, Damavand, Ramsar) even in 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.

From 2005 onward additional 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 renewable) in Iran is in dire need of several prerequisites including: 1- enhanced public understanding and awareness, 2- strongly persuading educated professionals by all means to encourage them to contribute to geothermal projects, 3- government investment and support through the subsidization of geothermal development costs, 4- encouraging role of government for private sector contribution as well as foreign collaboration, 5- providing course credits at the university level, 6- dispatching experts for short-term visits to geothermal sites (various applications) in other countries, 7- inviting experienced foreign scientists to introduce recent achievements in the field of geothermal energy utilizations and to provide key advice for the development of local geothermal projects, and 8- serious governmental budget support for conducting fundamental geothermal-oriented researches in academic centers.

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Table 1: Present and planned production of electricity in Iran.

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity Mwe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2009	0	Nil	44,996	208,810	7,669	4,750	0	Nil	63	196	52,728	213,756
Under construction in December 2009	55	Nil	2,621	12,163	460	285	1000	Nil	Data unavailable	Data unavailable	4,136	
Funds committed, but not yet under construction in December 2009	0	Nil	Data unavailable	Data unavailable	Data unavailable	Data unavailable	2000	Nil	20	62		
Total projected use by 2015	55	Nil	71,400	Data unavailable	11,530	Data unavailable	2000	Nil	600	Data unavailable	85,585	

Table 2: Wells drilled for electrical use of geothermal resources from January 1, 2005 to December 31, 2009.

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	7				16.3
Production	>150° C	-				
	150-100° C	-				
	<100° C	-				
Injection	For wastewater disposal	2				1.2
Total		9				17.5

Table 3: Utilization of geothermal energy for direct use as of 31 December 2009 (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[1)]	Maximum Utilization			Capacity[3)]	Annual Utilization		
		Flow Rate (kg/s)	Temperature (°C) Inlet	Outlet	(MWt)	Ave. Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
Sarein City								
Sabalan swimming pool	B	50	46	24	4.60	40	116.07	0.80
Gavmish Goli	B	140	47	25	12.89	120	348.22	0.86
Other baths (Total)	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 Blok	B	5	38	17	0.44	3	8.31	0.60
Meshkinshar 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
Ghotoursooi	B	15	45	22	1.44	12	36.40	0.80
Shabil	B	3	52	24	0.35	2	7.39	0.67
Other baths (Total)	B	10	45	23	0.92	8	23.21	0.80
Nir City								
Gheynarjeh-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
Other geographic locations (total)	B & F	110	45	22	10.58	95	288.20	0.86
TOTAL		427.5			41.58	350.3	1063.72	0.76

Table 4: Geothermal (Ground-Source) Heat Pumps as of 31 December 2009.

Locality	Ground or water temp. (°C)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type	COP	Heating Equivalent Full Load Hr/Year	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Meshkinshahr	10-12	5	4	H	4.5	5500	0.186	0.105
Taleghan	14-16	5	1	V	4.7	6450	0.164	0.120
Rasht	15-17	5	1	H - V	4.7	7500	0.142	0.143
Ahvaz	20-22	5	1	H	4.7	6500	0.098	0.149
Bandar Abbas	18-20	5	1	H	4.7	6350	0.085	0.143
TOTAL	10-22	25	8		23.3	32300	0.675	0.660

Table 5: Summary table of geothermal direct heat uses as of 31 December 2009.

Use	Installed Capacity (MWt)	Annual Energy Use ($TJ/yr = 10^{12}$ J/yr)	Capacity Factor
Bathing and Swimming[1)]	41.58	1063.72	0.76
Subtotal	41.58	1063.72	0.76
Geothermal Heat Pumps	0.025	0.68	0.86
TOTAL	41.605	1064.40	0.81

Table 6: 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)
2005	15	15				
2006	19	15				9
2007	17	15				8
2008	16	18		5		6
2009	15	15	3	20		7
Total	82	78	3	25		30

Table 7: Total investments in geothermal in (2009) US$.

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1995-1999	1					
2000-2004	6					
2005-2009	4.2		0.4			100