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Geothermal Direct Use in Iran: A Country Update

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ABSTRACT

This paper describes a summary of geothermal direct use activities in Iran with emphasis on its developments for 2015-2019. Iran has a broad mixture of low to medium enthalpy geothermal resources that are associated mainly with volcanic and sedimentary activities. In this paper, we present advancements for direct use application of geothermal hot springs, which have a wide range of temperatures and are located all-around the country, and geothermal heat pump installations capacity and operation in the country. Furthermore, the updated geothermal direct heat use capacity of the county is reported. The most promising activities are recreation and balneology, and heat pumps for heating and cooling. The total direct heat use capacity is 139.8 MW (1769 TJ/year) and the heat pump installed capacity is .3 MW (0.008 TJ/year).

1. INTRODUCTION

Earth, with the temperature at its core of more than 5000 °C, is a massive source of thermal energy. The heat of the planet is transferred to the surface in many ways. Near the surface, the heat transfer phenomena is largely a result of heat conduction. Here, the temperature of the earth increases fairly linearly concerning its depth [1]. The thermal energy stored in the top 11 km of the Earth's crust is equivalent to 50 thousand times the total energy obtained from well-known oil and gas sources [2]. Extraction of these potential sources can be cost-effective in areas with excellent heat flow and near-surface fluid coincident with fractures [3], [4]. Geothermal energy, unlike other renewable energies, is not limited in season and can be extracted continuously. The cost of electricity at geothermal power plants is also comparable to that of other conventional power plants (fossil fuels) and is far less expensive than different types of renewable energy [5], [6].

Attention for exploration and development of geothermal resources in Iran started since 1975. Extensive geoscientific studies have been conducted to identify the potential of geothermal energy sources in the country. This investigation firstly was launched by the Iranian Ministry of Energy in the northern and northwestern provinces of Iran in an area of 260,000 square kilometers in 1976 [7]–[9]. The results of these studies were finalized in 1984, and revealed geothermal prospects in volcanic zones of Sabalan, Damavand, Khoy-Mako, and Sahand with a surface area of more than 31,000 square kilometers. These were defined as suitable for further studies, and for possible geothermal energy utilization [1], [10]–[12]. In this regard, a new exploration program, including geological, geochemical, and geophysical surveys, was planned [6]. As a result of these preliminary exploratory studies in each of the mentioned areas, the susceptible localities were more carefully identified. Several regions were selected for activities in the exploration phase. In the Sabalan area: Meshkinshahr, Sarein and Busheli regions. In the Damavand area: Neunal. In the Maku-Khoy regions: Black and Dasht. And in the Sahand area five smaller regions were selected [13]–[15].

After a relatively long interruption and to reactivate the plan, existing reports were revisited by UNDP experts in 1369, and the Meshkinshahr geothermal region was introduced as the priority for further exploratory studies. Following the studies mentioned above, the exploration, injection, and drilling project for describing the potential in the Meshkinshahr region was defined in the year 2002, when the first geothermal well was excavated in the same year. The earliest phase of this plan was finished in 2004 [11], [14], [15]. A total of three exploratory wells and two injection wells were drilled at this stage, and a two-rings test of three exploratory wells was successfully carried out. The most important achievement of this phase was the project to acquire technical know-how for digging geothermal wells. The secondary phase of the plan was established in 2005. Field development and drilling of more exploration wells continued in this field, and more 11 wells are drilled and tested. The construction of the powerhouse and piping is finished and hopefully the first 5 MW geothermal power plant will be launched in 2020 [16]–[18].

The latest hydrothermal geothermal resources map of Iran was developed by Yousefi et al., [18]. By this research, 18 promising geothermal areas were defined, but are not ranked. The results indicate that about 144,815 km^2 (8.8%) of Iran are described as a potential geothermal area. In addition to the already known thermal areas, this geothermal potential survey revealed several other high potential geothermal prospects. Further detailed geothermal exploration studies are recommended for each of the prospected sites to estimate their possible energy production. Figure 1. shows the geothermal resources map of Iran [1], [2], [4], [19].

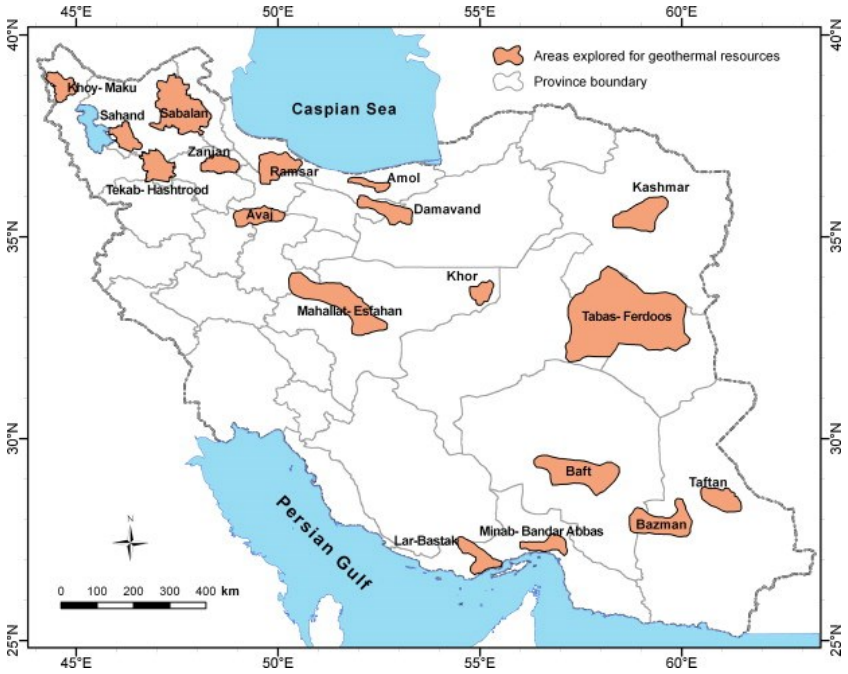

Figure 1. The geothermal resources map of Iran [18].

Energy consumption in Iran traditionally relies on fossil fuels, which are extracted from its national oil and gas fields. But attention to developing renewable energy resources has been raised in the last three decades. Present and planned production of electricity in Iran is given in Table 1. It is economically reasonable for a country like Iran, which vastly uses fossil fuel to produce electricity due to its massive oil and gas resources. Nevertheless, regarding environmental issues, as well as increasing energy security and sustainability, moving toward renewable energy has begun from the early 1980s [11], [20]. A lot of research has been done to pave the way for developing renewable energies from different points of view, such as technical, economical, and policymaking [13]–[16][21], [21], [22].

Table 1 Present and planned production of electricity in Iran from different resources

	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 (June 2019)	0	0	67218	280018	11938	15722	739	484	80915	303674
Under construction (June 2019)	55	375	10000	74000	210	270	402	628	10667	
Funds committed, but not yet under construction	55	375	5000	37000	-	-	1000	650	1055	
Total projected use by 2022	100	674.5	45568	209612	11296	30072	637.75	1696.415	58602	

2. GEOTHERMAL DIRECT HEAT USE

Direct-use of geothermal energy is one of the oldest, most useful and also the freest form of geothermal energy utilization. In Iran, even the direct use of geothermal hot water has a long history. As can be seen in Figure 1, the geothermal resources in Iran are distributed all over the country, and it makes it possible to use this type of energy in many places. Geothermal heat capacity for use in direct application is is 138.14 MWth, and mostly in balneotherapy and recreation in Iran. The total heat production is 520.34 GWh/year, which is about 10 % of the full capacity and 20 % of the total heat production in direct geothermal use in Iran. Recreation is one of the most promising fields of geothermal energy application in Iran [1], [2], [19].

A broad mixture of thermal manifestations with surface temperatures of about 25 to 85 °C are distributed throughout Iran. There are more than 200 hot springs with a temperature of above 30 °C. As an old tradition, these hot and warm spring waters are used for recreation in most of the country where the residential areas are located nearby. The hot springs are located throughout the

country, but the most significant number of geothermal bathing and recreation centers in Iran is located in the Northwest part of the country in the Ardebil Provinces [6], [13].

The Sabalan Mt. and Ardebil province in the Northwestern part of the country are the most prospective areas for geothermal energy use in Iran. Moreover, they are located in a beautiful touristic area, which generates demand for geothermal bathing and recreation. The hottest springs are found in the northwestern part of Iran, where it is freezing in wintertime. The typical winter temperature in this region is near to -15 °C. In this situation, a high volume of energy is needed for heating. In this regard, the direct use of geothermal resources can play an important role to supply the heating need [23].

The investigation of waters used for balneotherapeutic purposes is more detailed than water for recreational purposes. It is determined by the fact that geothermal pools in Iran were applied in medicine much earlier than in organized recreational centers. The history of the application of geothermal water in balneotherapy in Sablan and Sahand areas goes back to ancient times [24].

According to Table 2, there is almost 138.14 MWt capacity of direct use application around the country. Geothermal hot water is proposed to use for space heating, greenhouse heating, aquaculture pond heating, tourism utilization, and research centers for direct use utilization. But at the moment, the bathing and recreation application is the dominant use.

This kind of application can be considered as a basic form of geothermal energy direct use [5], [25]. The annual energy consumption of 1769.138 TJ/yr is calculated for 139.764 MWt with the condition that capacity factor is an equal one [25]. Since the capacity factor of 1 is not realistic, the annual energy calculated again due to a capacity factor of each location (with mean of nearly 0.43) and its value reduced to 1769.138 TJ/yr.

Table 2 Application of geothermal energy in Iran for direct use in 2020 (other than heat pumps).

locality			Maximum utilization			Capacity	Annual Utilization		
NO	Hot Spring Name	Type	Flow Rate	Temperature (°C)			Ave. Flow	Outlet	Capacity Factor
			(kg/s)	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	
1	Ramsar(4)	B	2	42	20	0.184	2	2.031	0.35
2	Khalil abad	B	3	33	20	0.163	3	1.955	0.38
3	Ramsar(1)	B	3	41	20	0.264	3	2.908	0.35
4	Ramsar(2)	B	6	48	20	0.703	6	7.756	0.35
5	Luyeh	B	5.2	32	20	0.261	5.2	2.634	0.32
6	Bashkandy	B	5.5	32	20	0.276	5.5	3.395	0.39
7	Shah abad	B	1	37	20	0.071	1	1.031	0.46
8	Zavieh	B	1	37	20	0.071	1	1.031	0.46
9	Siahcheshmeh	B	5.4	58	25	0.746	5.4	7.521	0.32
10	Shely	B	4	31	21	0.167	4	2.110	0.4
11	Ghareaghaj(1)	B	2	50	25	0.209	2	2.374	0.36
12	Khan	B	1.2	41	25	0.080	1.2	0.988	0.39
13	Derik	B	5.5	35.5	20	0.357	5.5	3.936	0.35
14	Istisu	B	5	38.5	20	0.387	5	4.392	0.36
15	Haft abad	B	5	34	20	0.293	5	3.324	0.36
16	Hamam	B	4	38	22	0.268	4	3.123	0.37
17	Ghare aghaj(2)	B	9	51	25	0.979	9	12.037	0.39
18	Manishgeh	B	54	44	25	4.293	0	48.719	0.36
19	Ahmad abad	B	6	35	20	0.377	6	5.342	0.45
20	Gheinarjeh	B	14	35	20	0.879	14	10.249	0.37

21	Darband	B	3	37	25	0.151	3	1.994	0.42
22	Hamam	B	5	55	25	0.628	5	7.320	0.37
23	Abish ahmad	B	40	60	25	5.858	40	66.478	0.36
24	Ghalehkandy	B	5.8	45	25	0.485	5.8	6.273	0.41
25	Shalghon	B	6.2	32	22	0.259	6.2	3.026	0.37
26	Lighvan	B	5	31	20	0.230	5	2.539	0.35
27	Bostan abad	B	15	41	25	1.004	15	11.080	0.35
28	Alah hagh	B	5.2	39	20	0.413	5.2	4.431	0.34
29	Asbforoshan	B	5	42	25	0.356	5	4.036	0.36
30	Ardahal	B	2	35	25	0.084	2	0.923	0.35
31	Jaldehbekhan	B	0.6	36	25	0.028	0.6	0.296	0.34
32	Shekar dareh	B	1.6	36	20	0.107	1.6	1.081	0.32
33	Boshlu	B	2	54	25	0.243	2	2.754	0.36
34	Nir	B	4	67	30	0.620	4	8.003	0.41
35	Gheinarjeh	B	16	85	25	4.017	16	46.851	0.37
36	Moeil	B	2.8	46	25	0.246	2.8	2.792	0.36
37	Ilandoo	B	7.5	39	20	0.596	7.5	6.203	0.33
38	Shahbil	B	2.2	51	25	0.239	2.2	2.490	0.33
39	Ghotorsui	B	37	39.5	20	3.019	37	36.163	0.38
40	Haft cheshmeh	B	2	35	20	0.126	2	1.899	0.48
41	Sardabeh	B	8	37	25	0.402	8	4.938	0.39
42	Ilsuyeh	B	2.6	47	20	0.294	2.6	3.611	0.39
43	Panj khaharan	B	3.2	45	25	0.268	3.2	2.955	0.35
44	Jeneral	B	2.4	45	25	0.201	2.4	2.153	0.34
45	Sari suyeh	B	9	47	25	0.828	9	8.618	0.33
46	Ghare suyeh	B	3.2	45	25	0.268	3.2	3.123	0.37
47	Gharmish goli	B	80	49	25	8.033	80	86.104	0.34
48	Abgarm-e-paein	B	1.8	41	20	0.158	1.8	1.895	0.38
49	Ilanjagh	B	18	56	25	2.335	18	28.704	0.39
50	Sakcelu	B	2.4	43	25	0.181	2.4	2.222	0.39
51	Ghare shalan	B	1.6	46	25	0.141	1.6	1.728	0.39
52	Khalkhal	B	8	66	25	1.372	8	16.873	0.39
53	Tashvir	B	0.5	30	20	0.021	0.5	0.224	0.34
54	Logahi	B	6	36	25	0.276	6	3.221	0.37
55	Abas abad	B	1.5	33	20	0.082	1.5	0.952	0.37
56	Hadighi	B	3	54	25	0.364	3	3.902	0.34

57	Sadat mahale	B	2	40	20	0.167	2	1.847	0.35
58	Yaleh gonbad	B	7	45	25	0.586	7	6.463	0.35
59	Larich(1)	B	45	47	25	4.142	45	54.844	0.42
60	Estrabako(2)	B	2	32	20	0.100	2	1.456	0.46
61	Estrabako(3)	B	0.5	31	21	0.021	0.5	0.303	0.46
62	Estrabako(4)	B	0.5	31.5	20	0.024	0.5	0.349	0.46
63	Larijan	B	40	65	25	6.694	40	97.078	0.46
64	Hormoz	B	6	32	20	0.301	6	4.084	0.43
65	Lavich(2)	B	2	45	25	0.167	2	2.480	0.47
66	Joshan	B	2	49	25	0.201	2	2.976	0.47
67	Dalir	B	3	35	20	0.188	3	2.315	0.39
68	Sadat mahaleh	B	7	40	20	0.586	7	6.832	0.37
69	Abgarm kesh	B	5	34	20	0.293	5	3.601	0.39
70	Ramsar(3)	B	5	37	20	0.356	5	5.269	0.47
71	Nimor	B	8	41	20	0.703	8	7.756	0.35
72	Mahalat(1)	B	10	47	25	0.920	10	13.058	0.45
73	Mahalat(2)	B	30	45	26	2.385	30	33.832	0.45
74	Mahalat(3)	B	6	32	22	0.251	6	3.561	0.45
75	Mahalat(4)	B	48	38	20	3.615	0	53.562	0.47
76	Keshvar	B	8	32	20	0.402	8	4.938	0.39
77	Dehluran	B	15	42	25	1.067	15	15.808	0.47
78	Ghir	B	7	32	20	0.351	7	5.097	0.46
79	Varton	B	4	41	25	0.268	4	3.968	0.47
80	Morad	B	3	36	20	0.201	3	2.976	0.47
81	Khor(1)	B	2	43	25	0.151	2	2.232	0.47
82	Khor(2)	B	2	43	25	0.151	2	2.232	0.47
83	Khor(4)	B	2	40	20	0.167	2	2.216	0.42
84	Khor(5)	B	2	38	20	0.151	2	1.994	0.42
85	Abgarm-e-semnan	B	2	35	20	0.126	2	1.820	0.46
86	Garu	B	6	38	20	0.452	6	5.556	0.39
87	Abmorad	B	10	39	20	0.795	10	11.779	0.47
88	Gholenj	B	8	35	25	0.335	8	4.959	0.47
89	Haji abad	B	40	37	20	2.845	40	41.258	0.46
90	Fotuhie	B	25	39	20	1.987	25	20.675	0.33
91	Todulieh	B	65	55	25	8.159	65	90.022	0.35
92	Gharb-e-todulieh	B	15	54	25	1.820	15	19.508	0.34

93	Charak	B	7	42	26	0.469	7	6.795	0.46
94	Ask	B	7	31	20	0.322	7	3.656	0.36
95	Molaeiji	B	2	38	20	0.151	2	1.757	0.37
96	Sayehkhosh	B	0.5	33	20	0.027	0.5	0.334	0.39
97	Badon	B	3	30	20	0.126	3	1.543	0.39
98	Chah ahmad	B	2	35	20	0.126	2	1.504	0.38
99	Khorgo(3)	B	25	44	25	1.987	25	29.447	0.47
100	Bari	B	7	39	20	0.556	7	8.245	0.47
101	Sorkhan	B	40	49	25	4.017	40	46.851	0.37
102	Nian	B	40	39	20	3.180	40	35.085	0.35
103	Khorgo(1)	B	7	32	20	0.351	7	4.543	0.41
104	Khorgo(2)	B	14	36	20	0.937	14	12.114	0.41
105	Bibihakimeh(1)	B	2	33	20	0.109	2	1.578	0.46
106	Bibihakimeh(2)	B	2	35	20	0.126	2	1.820	0.46
107	Norabad	B	40	31	20	1.841	40	26.697	0.46
108	Jegriz	B	35	50	25	3.661	35	41.549	0.36
109	Ab boti	B	82	33	20	4.460	82	52.024	0.37
110	Kherg	B	10	40	20	0.837	10	10.816	0.41
111	Ghalat	B	3	33	20	0.163	3	2.263	0.44
112	Ashke rostam	B	5	60	25	0.732	5	10.849	0.47
113	Ziaratgah	B	20	38	20	1.506	20	21.843	0.46
114	Dige rostam	B	36	75	25	7.531	36	111.587	0.47
115	Robat bozorg	B	30	31	20	1.381	30	18.717	0.43
116	Dalik	B	18	36	20	1.205	18	17.474	0.46
117	Borazjan	B	12	33	20	0.653	12	9.671	0.47
118	Aharb	B	12	44	25	0.954	12	11.428	0.38
119	Mir ahmad	B	12	35	20	0.753	12	9.259	0.39
120	Ghocharak	B	5	32	20	0.251	5	2.849	0.36
121	Niko	B	10	32	20	0.502	10	7.439	0.47
122	Dah sheikh	B	9	39	20	0.715	9	10.601	0.47
123	Dah reeis	B	0.5	35	20	0.031	0.5	0.425	0.43
124	Soltan hasan shah	B	14	41	20	1.230	14	17.450	0.45
125	Lale zar	B	5.3	40.5	20	0.455	5.3	6.019	0.42
126	Gishky	B	0.5	39	20	0.040	0.5	0.476	0.38
127	Abraq(1)	B	5.2	58	25	0.718	5.2	9.506	0.42
128	Abraq(2)	B	35	35	20	2.197	35	29.084	0.42

129	Maskon	B	0.7	40	20	0.059	0.7	0.683	0.37
130	Abgarm seied	B	4	34	20	0.234	4	2.807	0.38
131	Sarze	B	35	33	20	1.904	35	23.406	0.39
132	Ravar	B	0.5	34	20	0.029	0.5	0.425	0.46
133	Pozebagh	B	8	33	20	0.435	8	5.076	0.37
134	Tong	B	1	37	20	0.071	1	0.942	0.42
135	Makran	B	14	34	20	0.820	14	12.151	0.47
136	Tasht	B	6	33	20	0.326	6	4.527	0.44
137	Jamshid	B	8	44	20	0.803	8	9.370	0.37
138	Espidezh	B	7	33	25	0.234	7	3.472	0.47
139	Bazman(1)	B	8	35.5	20	0.519	8	6.869	0.42
140	Bazman(2)	B	14	35.5	20	0.908	14	12.021	0.42
141	Shargh-e-taftan	B	12	35	20	0.753	12	9.259	0.39
142	Cheshme ayoub	B	7	38	28	0.293	7	3.970	0.43
143	Alamkoh	B	5.2	33	20	0.283	5.2	3.477	0.39
144	Ghale no	B	12	34	20	0.703	12	8.642	0.39
145	Meshkinshahr Fish farming	Industry	10	39	15	1.004	10	25.325	0.8
Summation						139.764		1769.138	

A geologic investigation of the North Sabalan region verified that there are two main kinds of the basic framework: a collection of linear features and some ring-faults (Figure 2) [26].

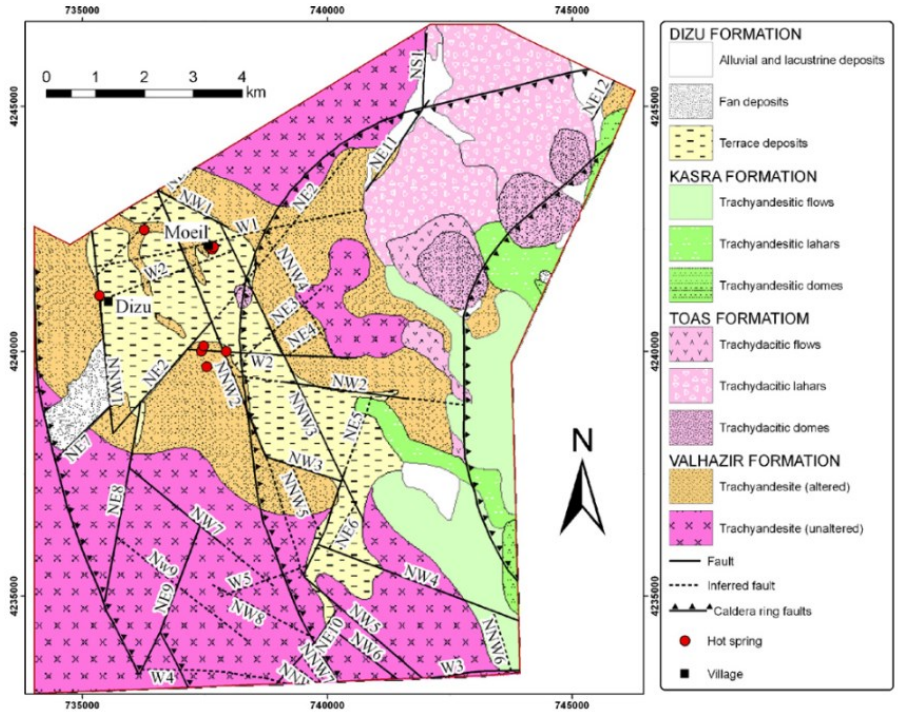

Figure. 2. Northwest Sabalan geothermal field.

3. GEOTHERMAL HEAT PUMPS

Geothermal Heat Pumps (GHPs) are known as a sustainable, green, cost-effective, excellent, and proper way for heating and cooling of residential and commercial buildings. They give support due to a notable decrease in energy demand. Also, they have quite a low maintenance requirement and have a small impact on the environment.

A geothermal heat pump has been applied to heat and cool the air in the south and north of Iran. In the south of Iran, is used for cooling where the temperature is about 40-50°C in 6 months of the year, with humidity of 80-90% [7][18]. The geothermal heat pump has some more advantages in comparison to the other renewable energy sources. For instance, less parasitic energy consumption through operation, the earth temperature as a heat source is more stable, and it requires less investment for designing and maintenance [19].

In Iran, the first step towards implementing the heat pump took place in 2013. In the first step, five heat pumps with a capacity of 750 kW each were placed in five different regions of the country to investigate the techno-economical parameters and determine the applicability of the system in different climates zones in Iran. The first system was installed in northwestern Iran, which is located in a cold region [4]. This heat pump system used a horizontal coil and supported an air circulation system. The extracted energy supplies cooling and heating for a 28 m^2 room, and decreased the energy demand of the building by 30%.

The second system was installed in Taleqghan city which is located in a region with hot summers and cold winters. A coil with nine wells was designed and unearthed 15 meters underground. The system became functional in 2007, and results show that the energy consumption decreased near 60% for a place with an area of 30 m^2 [4], [12].

Another system was installed in Rasht city, with high humidity near the Caspian Sea. The system was designed for a 45 m^2 area and reduced energy needs by 50%. The other systems are both located in regions with a high temperature in Ahwaz and Band-Abbas. Air to air heat pumps is pervasive for cooling due to the high temperatures and humidity. The heat pump was installed in Ahwaz to ascertain critical parameters like the efficiency of the heat pump and also determine the reduction of the amount of energy needed for heating and cooling for a place with an area of 40 m^2. The results showed that by applying geothermal heat pumps, the energy use decreased by 50-70%. [4]

In Bandar Abbas, the geothermal heat pump used to cover places with the 45 m^2 and outcomes showed that energy requirement for cooling reduced more than 70%. Table 3 shows some specifications of the installed heat pumps in Iran [24], [27].

The heat pump system installed in Vardavard power grid substation is the most significant heat pump system in Iran. It consists of 9 units of 60,000 Btu/hr geothermal heat pumps, and there are 16 boreholes, every one 160 meters deep. The result of running this system presents considerable energy savings, with an average of 45 % electricity consumption reduction compared to the previous heating and cooling systems [27].

The Mehregan Park geothermal heat pump system is supplying heating and cooling for a security police office in Mehregan Park, northeast of Tehran City. The system includes four boreholes with 75 m depth each. The building is used as an office for security police of the park. A 1-floor building with an area of about 120 m^2 needed a water to air heat pump with a single unit of 14 kW capacity, which was installed in 2016. It replaced an air source heat pump (cooling) and a natural gas furnace (heating).

The Qom geothermal heat pump project is developed in three different buildings. The device with the capacity of over 120,000 British Thermal Units (BTU/h) has been designed and produced locally for heating and cooling and hot water supply in Qom city in central Iran. Table 3 shows the specifications of each project [2].

4. CONCLUSIONS AND RECOMMENDATIONS

Iran has different weather conditions across the country. Some places have high temperature and humidity and some places experience extreme cold. In this situation, geothermal energy can play an essential role to save energy and supply space cooling and heating. According to this study, installed geothermal systems have the potential to decrease the energy use between 50 to 70%. In this article, the updated geothermal direct heat use capacity of the county is reported. The summary of the direct use of geothermal energy in Iran is presented in Table 4.

Table 3: A summary of the characteristics of geothermal heat pumps in 12 locations in Iran.

Location	Capacity (kW)	Coil type	Heating	Cooling	Energy supplied area (m^2)
Mehreghan park (Tehran)	14.5	Vertical	✓	✓	120
District 22 _Shahrak Rahahan (Tehran)	17.5	Vertical	✓	✓	150
VardAvad Substation (Tehran)	157	Vertical	✓	✓	1200
Mashhad (Abfa)	21		✓	✓	
Qanavat (Qom)	35	Vertical	✓	✓	220
Jemezghan (Qom)	10	Vertical	✓	✓	100
Salarieh (Qom)	5	Vertical	✓	✓	35
Meshkinshahr	5	Horizental	✓	✓	24
Taleghan	20	Vertical	✓	✓	30
Rasht	5	Horizontal-Vertical	✓	✓	45
Ahvaz	5	Horizontal		✓	35
Bandar-Abbas	5	Vertical		✓	45
Total capacity (kW)	300				2004

Table 4: Summary of direct geothermal use in Iran.

NO	Type of Direct Use	Capacity (MW)	Energy used (GWh)	Capacity factor
1	Balneology and Swimming pools	139.764	523.586	0.43
2	Aquacultural use	1.004	7.04	0.8
3	Heating and cooling by a heat pump	0.3	2.151	0.82
4	Total capacity	139.764	532.777	

REFERENCES

[1] Y. Noorollahi, M. R. Jamaledini, and F. Ghazban, "Geothermal potential areas in Iran," *Renew. Energy Orga nization Iran (SUNA), Tehran*, 1998.

[2] Y. Noorollahi, M. S. Shabbir, A. F. Siddiqi, L. K. Ilyashenko, and E. Ahmadi, "Review of two decade geothermal energy development in Iran, benefits, challenges, and future policy," *Geothermics*, vol. 77, pp. 257–266, 2019.

[3] N. Arianpoo, "The geothermal potential of Clarke Lake and Milo gas fields in northeast British Columbia." University of British Columbia, 2009.

[4] M. K. Moghaddam, F. Samadzadegan, Y. Noorollahi, M. A. Sharifi, and R. Itoi, "Spatial analysis and multi-criteria decision making for regional-scale geothermal favorability map," *Geothermics*, vol. 50, pp. 189–201, 2014.

[5] S. Porkhial, M. M. Ghomshei, and P. Yousefi, "Geothermal energy in Iran," *Weather*, vol. 2002, 2001.

[6] M. Seyedrahimi-Niaraq, F. D. Ardejani, Y. Noorollahi, S. Porkhial, R. Itoi, and S. J. Nasrabadi, "A three-dimensional numerical model to simulate Iranian NW Sabalan geothermal system," *Geothermics*, vol. 77, pp. 42–61, 2019.

[7] Y. Noorollahi, H. Yousefi, R. Itoi, and S. Ehara, "Geothermal energy resources and development in Iran," *Renew. Sustain. Energy Rev.*, vol. 13, no. 5, pp. 1127–1132, 2009.

[8] D. Jennejohn, "Research and development in geothermal exploration and drilling," *Geotherm. Energy Assoc.*, pp. 1–25, 2009.

[9] D. J. Entingh, "Enhanced Geothermal Systems (EGS) R&D Program," Princeton Energy Resources, International,

Rockville, MD, 1999.
[10] H. Yousefi, M. Hamlehdar, S. Tabasi, and Y. Noorollahi, “Economic and Thermodynamic Evaluations of Using Geothermal Heat Pumps in Different Climate Zone (Case Study: Iran),” *Proc. Geotherm. Reserv. Eng*, 2017.
[11] Y. Noorollahi and H. Yousefi, “Monitoring of surface and ground water quality in geothermal exploration drilling of Meshkinshahr geothermal field, NW-Iran,” in *Proceeding of World Geothermal Congress (WGC 2005), Turkey, Antalya*, 2005, pp. 1–11.
[12] M. Fotouhi and Y. Noorollahi, “Updated geothermal activities in Iran,” in *Proceedings of the World Geothermal Congress 2000, Kyushu-Tohoku, Japan*, 2000, pp. 183–185.
[13] A. Saffarzadeh and Y. Noorollahi, “Geothermal Development in Iran: A Country Update,” 2005.
[14] H. Yousefi, Y. Noorollahi, and T. Sohrab, “Environmental Impact Assessment of Meshkinshahr geothermal power plant,” in *Proceedings of the 4th National Energy Congress, 2003, Tehran, Iran*, 2003, pp. 210–219.
[15] Y. Noorollahi, “Preliminary environmental impact assessment of a geothermal project in Meshkinshahr, NW-Iran,” *001161368*, 2003.
[16] M. K. Moghaddam, Y. Noorollahi, F. Samadzadegan, M. A. Sharifi, and R. Itoi, “Spatial data analysis for exploration of regional scale geothermal resources,” *J. Volcanol. Geotherm. Res.*, vol. 266, pp. 69–83, 2013.
[17] Y. Noorollahi, S. Taghipoor, and B. Sajadi, “Geothermal sea water desalination system (GSWDS) using abandoned oil/gas wells,” *Geothermics*, vol. 67, pp. 66–75, 2017.
[18] H. Yousefi *et al.*, “Developing the geothermal resources map of Iran,” *Geothermics*, vol. 39, no. 2, pp. 140–151, 2010.
[19] Y. Noorollahi and H. Yousefi, “Geothermal Energy Resources and Applications in Iran,” in *Proceedings*, 2010, pp. 25–30.
[20] R. Saeidi, Y. Noorollahi, and V. Esfahanian, “Numerical simulation of a novel spiral type ground heat exchanger for enhancing heat transfer performance of geothermal heat pump,” *Energy Convers. Manag.*, vol. 168, pp. 296–307, 2018.
[21] M. Zandi *et al.*, “Evaluation and comparison of economic policies to increase distributed generation capacity in the Iranian household consumption sector using photovoltaic systems and RETScreen software,” *Renew. energy*, vol. 107, pp. 215–222, 2017.
[22] A. Gholami, I. Khazaee, S. Eslami, M. Zandi, and E. Akrami, “Experimental investigation of dust deposition effects on photo-voltaic output performance,” *Sol. Energy*, vol. 159, pp. 346–352, 2018.
[23] M. Seyedrahimi-Niaraq, F. D. Ardejani, Y. Noorollahi, and S. Porkhial, “Development of an updated geothermal reservoir conceptual model for NW Sabalan geothermal field, Iran,” *Geotherm. Energy*, vol. 5, no. 1, p. 14, 2017.
[24] H. Yousefi, Y. Noorollahi, S. Abedi, K. Panahian, A. H. MirAbadi, and S. Abedi, “Economic and environmental feasibility study of greenhouse heating and cooling using geothermal heat pump in northwest Iran,” in *Proceedings World Geothermal Congress, Melbourne, Australia*, 2015.
[25] J. W. Lund and T. L. Boyd, “Direct utilization of geothermal energy 2015 worldwide review,” *Geothermics*, vol. 60, pp. 66–93, 2016.
[26] Y. Noorollahi, R. Itoi, H. Fujii, and T. Tanaka, “GIS integration model for geothermal exploration and well siting,” *Geothermics*, vol. 37, no. 2, pp. 107–131, 2008.
[27] H. Yousefi, Y. Noorollahi, and S. Peirow, “Status of environmental impact assessment,” *Envtl. Pol’y L.*, vol. 45, p. 320, 2015.