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Geothermal Resources and Development in Mongolia: Country Update

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ABSTRACT

There are numerous hot springs in Mongolia, and many are utilized for heating, bathing and medicinal purposes, but there is presently no geothermal electric power utilisation. Feasibility studies for small-scale energy development projects, however, have been conducted by domestic and foreign developers as Mongolia presently depends on non-renewable sources of energy for almost all of its electrical power requirements. National Sanatoriums, which directly utilise thermal waters by shallow (typically <100m) drilling, have been constructed at Tsenkher, Shargarljuut, Khujirt, Zaart, Shivert, Khalzan Uul, Eruu and Tsagaan Khundii; whilst the springs at Tsenkher, Shargarljuut and Khujirt, in particular, have become popular tourist sites.

Regional surveys have identified 5 areas (including 43 hot spring fields) with anomalous heat flow characteristics and geothermal resource potential, in the (i) Mongolian Altai (54±24 mW/m^2); (ii) Khangai region (52±6 mW/m^2); (iii) Khentii region (65±10 mW/m^2); (iv) Khuvsgul nuur region (60±12 mW/m^2); and (v) Dornod Mongolian region (44±6 mW/m^2), which are all associated with Late Cenozoic volcanism and faulting – of these, the Khangai region has attracted most interest for future geothermal development.

The Khangai region is subdivided into the Tarbagatai-Uliastai (low flow (0.1-1.5 l/min), <60 °C, low-Rn, SO_4-HCO_3 and SO_4-Cl springs) and more southerly Baidrag-Tamir/Orkhon-Taats (high flow (up to 50 l/min), 50-98 °C, high-Rn, HCO_3-Na, low salinity/low-Cl springs) area, with many hot spring systems coincident with the intersection of NE-SW and cross-cutting WNW Paleocene faults. There is no obvious heat source for thermal manifestations in the Khangai region (i.e. no active volcanoes), although solute geothermometry indicates reservoir temperatures up to 150 °C (e.g. at Shargaljuut, Baidrag-Tamir area). The high temperature, high flow springs at Shargaljuut and Tsenkher (Orkhon-Taats) are "high-fluoride" waters, which point to the source of geothermal energy in southern Khangai being conductive heat from magma associated with the Khangai Batholith, linked with the N-S trending Baikal rifting system, and transferred through metamorphosed Palaeozoic rocks to heat meteoric waters that are channeled to the surface via intersecting faults and fractures.

INTRODUCTION

Mongolia is a large (1,570,000 km^2), sparsely populated (1.9 inhabitants/km^2) central Asian country, with most of its people engaged in agriculture-related industries (accounting for 33% of GDP). Primary energy resources in Mongolia are indigenous coal (for electricity and heat) and imported petroleum products (for transportation and rural electricity generation). Thermal power generation capacity in Mongolia consists of 7 coal-fired combined heat and power generation plants (Asian Development Bank, 2002), as well as diesel generators for rural users. Mongolia has limited hydro-electric power resources, and these are not fully developed. At present, no power stations utilise geothermal energy for electricity generation, although the Mongolian government is considering a range of renewable energy options (including wind, solar *and* geothermal systems) to alleviate the country's energy problems.

In Mongolia, the Energy Law provides the regulatory structure for electricity producers, suppliers and consumers. Today, the Mongolian electricity industry has a total installed capacity of >1000 MW (and gross production of >2,355 GWh/y; Rentsen and Enebish, 2003), with 9 generation, 2 heat distribution, 4 electricity distribution and 3 electricity transmission companies. A single buyer model has been introduced in Mongolia (Asian Development Bank, 2002) to implement a wholesale electricity market (transmission companies allocate a proportion of their revenues to distribution companies, under the guidance of an Energy Regulatory Authority, who set requirements for the issue of generation, transmission, and distribution of heat and electricity licences).

The reliability of electricity supplies varies widely across Mongolia. The urban population receives poor quality electricity and the rural population, despite Government subsidies for the operation of utilities in the provinces, has little or none. In 2002, 33% of the population did not have access to electricity, and 43% lacked access to central heating (World Bank, 2002). Of 314 villages, 117 were connected to grid-based electricity supply (Asian Development Bank, 2002), with the remaining utilising small diesel generators (60-100kW capacity, that typically operate for 3-5 hours each day). The Mongolian Government has focused on improving rural living conditions, which has created a huge demand on schools, hospitals and other social infrastructure services.

In 2002, the Asian Development Bank concluded that the development of renewable resources (e.g. wind, solar and geothermal) would be uneconomical for large-scale power generation, but small projects could be implemented for isolated areas. The Asian Development Bank (2002) stated, considering Mongolia's vast land area and sparse population (in isolated small settlements), that an off-grid solution was the best option to provide electricity to rural areas and isolated towns. The diesel system has inherent problems, as diesel needs to be imported, transported and stockpiled at high volumes, supply interruptions and mechanical breakdowns can occur, and these cause severe power shortages, with flow-on effects to health, education and municipal services.

Mongolia has great potential to benefit from use of its geothermal resources and hot spring areas (shown in Fig 1). Geothermal resource utilisation, however, is not restricted to electricity generation. Other applications include house heating, hot water supply, and agricultural uses (i.e. greenhouses, wool washing and drying). Large scale use of geothermal (and other) renewable energy resources, however, will require policy support, and capital investment from the international geothermal community.

GEOLOGICAL BACKGROUND

The geology of Mongolia can be subdivided into several terranes associated with the Central Asian Orogenic Belt (CAOB), an accretionary orogen that occurred in Neoproterozoic to late Palaeozoic (including island arc and continental margin arc systems, ophiolite, accretionary wedges, passive continental margins, microcontinents and turbidite basins - with seven Precambrian microcontinents, consisting mostly of Archaean-Proterozoic metamorphic rocks (the oldest is tonalitic gneiss from the Baidrag block, in central Mongolia, with a zircon age of 2646 ± 45 Ma).

The EW-trending Main Mongolian Lineament separates northern terranes that had amalgamated by the mid-Ordovician, from terranes in southern Mongolia which did 130not amalgamate until the late Palaeozoic. Middle to late Palaeozoic arcs, ophiolites and blueschists also occur. By the early Permian two Andean-type continental margins had consolidate and accretion of the CAOB was terminated by formation of the Solonker suture in the late Permian. The most recent period of tectonism (there is presently no active volcanism in the region) started at the end of the Mesozoic and beginning of the Oligocene, which produced the mountainous region of central Mongolian. The multiple, recurrent volcanic events which occurred during this time are inferred to be associated with the "South Khangai Hot-Spot" (Yarmolyuk *et al*., 1995), that formed a "giant geothermal field tapping into the lower mantle of Central Asia" (Dergunov, 2001).

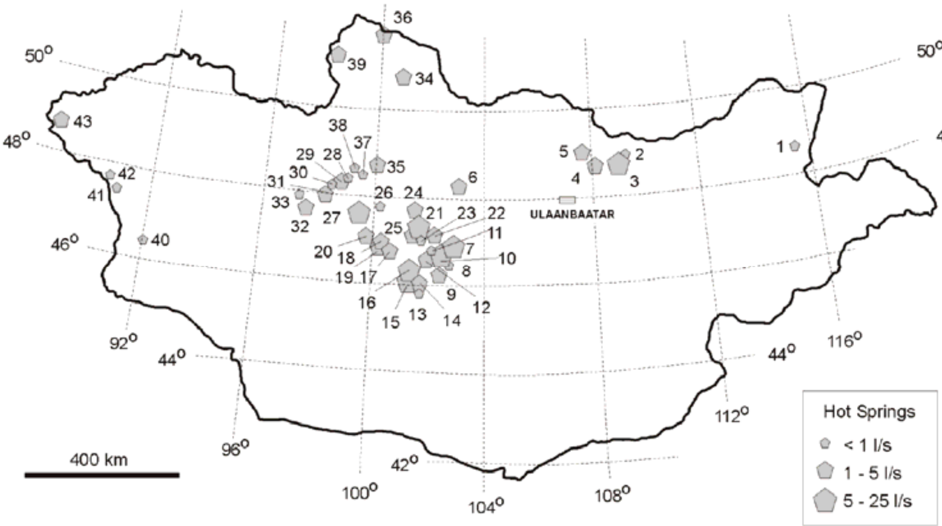

Fig 1. Location map of major geothermal areas in Mongolia (see also Table 1; after Tseesuren, 2001).

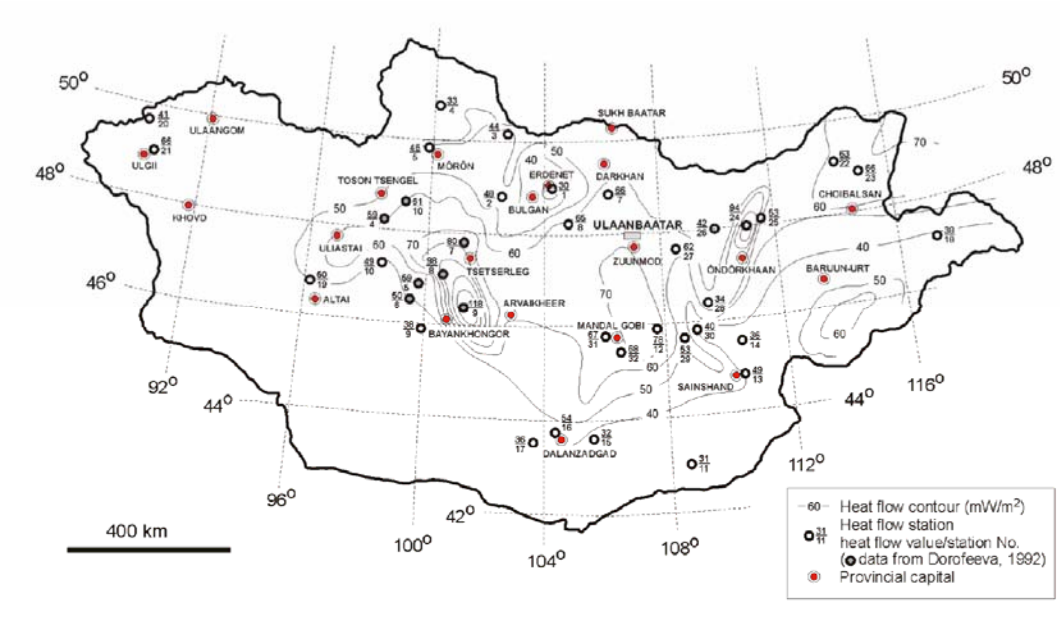

Fig. 2: Heat flow map of Mongolia, highlighting the area of anomalous heat flow over the Khangai area (from Tseesuren, 2001).

Gravity, seismic and electrical resistivity surveys point to a regional (mantle) anomaly in the Mongolian-Siberian mountainous (Zorin et al., 1990). Dorofeeva (1992) suggested that the lithosphere under the Siberian platform is ~200 km thick, thins to 55-75 km below the Baikal Rift Zone and thickens beneath the Trans-Baikal fold zone (to 120-170 km). Other surveys reveal anomalous heat flow values attributed to magmatic bodies beneath the Khangai-Khentii Mountain Ranges (Ministry of Agriculture and Industry of Mongolia, 1999). Heat flow measurements (Fig 2) obtained via shallow bores (150-200 m drilled depth), indicate average regional values of: Mongolian Altai, 54 ± 24 mW/m^2; Khangai region, 52 ± 6 mW/m^2; Khentii region, 65 ± 10 mW/m^2; Khuvsgul nuur region, 60 ± 12 mW/m^2; and Dornod Mongolian region, 44 ± 6 mW/m^2.

GEOTHERMAL RESOURCES

Mongolian people have used hot springs for many centuries, for bathing and small scale heating, as well as agricultural and medicinal purposes (e.g. treatment of high blood pressure, rheumatism, disease of the nervous system etc. using geothermal water). To date, however, there has been no comprehensive study of the geothermal resources in Mongolia or their resource potential (either for electric power generation, agricultural uses and/or district heating, etc). In the past couple of decades a few studies have been undertaken to record the nature of geothermal activity, spring chemistries etc, but only recently has there been strong signs of new research and exploration initiatives (Lkhagvadorj and Tseesuren, 2005; these proceedings).

Table 1: List of major geothermal areas in Mongolia (compiled by Tseesuren, 2001).

No. (Fig 1)	Spring Name	Province	Latitude	Longitude	Total Flow (l/s)	Mineral. (mg/l)	Max. Temp (°C)	Heat >35°C (kW)
1	Utaat Minjuur	Dornod	48º43´	115º50´	-	-	67	
2	Baga Onon	Khentii	48º56´	108º00´	0.1	-	73	16
3	Ikh Onon	“	48º56´	108º49´	11	-	88	2443
4	Eustii	Tuv	48º35´	107º50´	3	239.4	34	
5	Eruu	Selenge	49º00´	107º33´	3	226.8	43	101
6	Saikhan khulj	Bulgan	36º16´	102º58´	2.3	744.5	55	193
7	Khujirt	Uvurkhangai	46º54´	102º46´	16	-	55	1341
8	Emt	“	46º26´	102º47´	0.5	-	39	8
9	Khuremt	“	46º16´	102º46´	5	-	55	419
10	Mogoit	“	46º45´	102º15´	7	-	72	1085
11	Khamar	“	46º43´	102º00´	4	-	39	67
12	Gyatruun	“	46º36´	102º00´	5	200.6	36	21
13	Sharga	“	45º50´	101º40´	1	-	30	
14	Taats	“	46º10´	101º38´	2.5	-	55	210
15	Baga Shargaljuut	Bayankhongor	46º13´	101º15´	10	37.3	58	964
16	Shargaljuut	“	46º13´	101º15´	25	259	92	5971
17	Uheg	“	46º48´	100º52´	5	-	57	461
18	Örgööt	“	47º15´	100º05´	5	364.3	40	105
19	Teel	“	46º51´	100º02´	5	-	32	
20	Tsokhiot	“	47º00´	99º45´	5	-	23	
21	Tsenkher	Arkhangai	47º20´	101º39´	10	239.9	86	2137
22	Tsagaan Sum	“	47º40´	102º00´	8	-	69	1140
23	Gyalger	“	47º12´	101º33´	1	221.6	52	71
24	Shivert	“	47º38´	101º31´	4	24.8	55	335
25	Bor tal	“	47º12´	101º36´	4.5	258.9	46	207
26	Chuluut	“	47º55´	100º15´	1.2	250.5	45	50
27	Noyon	“	47º55´	99º25´	6	-	38	75
28	Tsetsuuh	Zavkhan	48º21´	98º30´	0.2	231.2	36	1
29	Zaart	“	48º21´	98º46´	2.8	247	44	106
30	Khaluun us	“	48º15´	98º24´	1	236	35	0
31	Khojuul	“	48º12´	98º08´	4	181	45	168
32	Otgontenger	“	47º45´	97º30´	1.7	223	56	150
33	Ulaan khaalga	“	47º55´	97º20´	0.2	340.6	37	2
34	Bulnai	Khuvsgul	50º48´	100º48´	5	501.2	47	251
35	Salbart	“	48º35´	99º37´	6	-	44	226
36	Urtrag	“	51º45´	99º42´	3.1	-	21	
37	Tsuvraa	“	48º30´	99º39´	0.1	-	35	
38	Khunjil	“	48º34´	99º22´	0.1	214.8	62	11
39	Jalga	“	51º20´	98º01´	5	-	40	105
40	Bulgan	Khovd	46º36´	91º23´	0.6	306.2	29	
41	Gants mog	Bayan-Ulgii	47º35´	91º31´	1	139.3	31	
42	Chihert	“	47º48´	90º28´	0.5	-	25	
43	Tsagaan gol	“	48º40´	88º12´	3	-	32	

Geothermal resources in Mongolia mainly occur in the Khangai, Khentii, Khuvsgul Mongol Altai, Dornod-Dariganga and Orkhon-Selenge regions. Forty three hot spring areas have been identified (Table 1, Fig 1). Tseesuren (2001) calculated the thermal energy of the springs, based on their natural flow, temperature and cooling the discharge water to 35^{o}C (shown in Table 1). Of the areas listed, the Khangai geothermal region has attracted most interest from potential developers, with several areas having potential for electricity development, including Shargaljuut (~5,970 kW; #16 in Fig 1), Tsenkher (2,137 kW; #21), Khujirt (1,341 kW; #7) and Mogoit (1.085 kW; #10), whilst Ikh Onon (#3) in the Khentii area has 2,400 kW potential.

In Mongolia, some geothermal resources may be developed for electric power generation (e.g. Shargaljuut, #16), whilst others are likely to be utilised for direct use applications. Worldwide, the use of low-moderate (<150^{o}C) temperature geothermal resources have increased, and the Mongolian Government has recognized the potential of direct use technologies, including house/district heating, cooling and industrial processing, space conditioning and agricultural applications (e.g. greenhouse development, wool washing and drying etc). At present, only a few areas are utilised for greenhouse projects: Khuremt hot springs (#9 in Fig 1), Teel (#19), Baga Shargaljuut (#15) and Tsenkher (#21).

Here, three active geothermal fields are briefly described, which have potential for resource utilisation:

<u>Shargaljuut – Power generation</u>

The Shargaljuut Hot Springs (#16 in Fig. 1) are located ~680km west of Ulaanbaatar in the Khangai Mountain Range. Each year, several thousand people visit the area to enjoy the thermal waters, which are reportedly effective for a variety of health problems (Bignall et al, 2003; Lkhagvadorj, 2003). Thermal features at Shargaljuut include steaming ground, and springs that discharge near boiling (to 90.5^{o}C), 8.2-8.7 pH, low Cl, weakly mineralised (<44mg/kg SiO_2, <13mg/kg HCO_3(T)) waters (Bignall et al., 2004). Drilling of 9 shallow wells (to a maximum depth of 90m) for the Shargaljuut Sanatorium and greenhouse complex, tapped hot water (up to 48^{o}C) with quartz, chalcedony, NaK and NaKCa geothermometry pointing to a fluid source of <130^{o}C. The source of the geothermal energy is likely to be conductive heat from volcanic events associated with the "South Khangai Hot Spot". Upwelling waters are channeled to the surface via NE-SW and cross-cutting NW faults, where they discharge from cracks in metamorphosed Palaeozoic rocks (~50 l/sec over the entire thermal area).

Resource assessments conducted at Shargaljuut reveal that the area has potential for small scale geothermal power generation, possibly by installation of a binary-cycle geothermal power plant (Dorj, 2001). It was estimated 2-3 wells would be required to produce 60 t/h fluid (with power plant inlet temperature of 120^{o}C) to generate 300 kW of electricity (Tseesuren, 2001). The electricity generating cost for the project was estimated to be 10-15 c/kWh. Worley International (1995) estimate a 300kW binary cycle plant would be sufficient for the existing demands of the 2,500 (est) people who live in the Shargaljuut area.

<u>Shivert Hot Springs – Direct Use</u>

The thermal area at Shivert (#24 in Fig 1) is located about 35 km NE of Arkhangai, and was explored in the early 1980's, and again more recently, for direct geothermal utilisation. Five geothermal exploration bores were drilled in 1980, which encountered steam-heated hot water (described as "hydrocarbon-sulphuric sodium water, with mineralization of 0.35-0.36 g/l, by Dorj et al., 2003), up to 57^{o}C (at about 40 m depth in Borehole 1 – the well discharges water at 5 l/s). Some aquifer fluids are hosted by sedimentary units, but primary permeability is provided by interconnected fracture networks, which channel fluids to the surface.

In 1967, the Shivert Sanatorium was established, with a 150-bed winter facility and a 300-bed summer building (the sanatorium was closed for financial reasons). Dorj *et al* (2003) suggested the Shivert area has considerable resource potential, especially as a tourist centre, and that the geothermal area could be developed for year-round, district floor heating. It has been proposed that future drilling of a 80-100m deep borehole, designed to intersect permeable fracture zones in basement, fractured Paleozoic granite, could tap 70^{o}C fluids suitable for a hot water heating system.

<u>Tsenkher Hot Springs – Direct Use</u>

The Tsenkher Hot Springs, located 30km from Arkhangai in the central part of Mongolia (#21 in Fig 1), has potential for the design of a domestic geothermal heating system. The hot springs at Tsenkher have a high flow rate, with a maximum spring temperature of 86^{o}C. Spring waters at Tsenkher are characterized by their alkalinity (pH ~9.4) and high fluoride content (25 mg/l). The springs were analysed by the Chemical Institute of Mongolia (in Tseesuren, 2001), and have a composition of 54.6 mg/l CO_2, 45.3 mg/l SO_4, 128 mg/l SiO_2, 84.3 mg/l Na, 2.9 mg/l K and 17.7 mg/l Cl), and more recently by Gendenjamts (2003). Chalcedony and NaK solute geothermometry point to reservoir temperatures of < 120^{o}C (Tseesuren, 2001).

Reconnaissance surveys have concluded that the Tsenkher area has potential to supply sufficient hot water for a geothermal heating scheme for the approx 2500 inhabitants of the Tsenkher area (these typically require hot water at about 80^{o}C), as well as use in greenhouses and for bathing. In addition, there is potential direct use of the geothermal resource at Tsenkher for wool (cashmere) washing and drying (e.g., the latter, perhaps, using a geothermal net conveyor belt dryer; after Xing and Wu, 2000).

DISCUSSION / TABULATED DATA

Mongolia has vast land area and a large number of small, isolated settlements. In the future, it is likely that an off-grid solution will prove the most economic means of solving the country's problem of providing electricity to the rural areas.

At present, there are three electricity markets in Mongolia. The largest is the urban market (comprising, for the most part, three independent transmission grids; the Central (CES), Eastern (EES) and Western (WES) Energy Systems, which supply a total load of about 560MW). The second market is non-connected regional centres, comprising stand-alone diesel generator systems, which account for ~3% of the overall electricity supply to the country, but is the primary supply for most small towns. The biggest problem with the existing diesel system, however, is the pressure of ongoing costs for operation and maintenance, which often causes interruptions to power supply. The third market consists of individual electrification solutions for rural areas (~82% of the non-electrified population live in rural areas).

There are three heating systems in Mongolia. About 30% of the population obtains heat from a central source, through a district heating system. Another 10% obtain heat through a non-centralized system, such as small-sized boilers. The vast majority of the population, however, provide their own heat,

either by the use of coal in stoves (urban centres) or by bringing wood and/or dried dung (rural areas).
Mongolia is in transition from a centrally planned to a market oriented economy (supported by private sector investment). There are, however, factors that have had a negative impact on direct private investment, such as slow economic growth, low returns on investment, dependence on foreign capital, limited domestic markets, increasing poverty, difficult property and land rights issues etc). In this climate, the Mongolia Government has set aside funds for research and development activities (including geothermal projects, and other forms of renewable power generation including solar, wind energy) that will further the development and management of its natural resources.

In the near to medium term, the Mongolian Government will be reliant on external assistance to alleviate its energy problems, and solve issues related to rural development. There are projects in the energy sector, including Egiin hydropower plant (to meet peak demand and expand the current grid system - a feasibility study was completed in 1996, installed capacity would be 220MW), Orkhon hydropower plant, and Shargait Hydropower plant, ~40 km from Murun. The Murun aimag (provincial centre) was connected to the power grid in 2004, and although current electricity demand is 2.5 MW, it could substantially increase if phosphate mining operations begin at Khuvsgul-Dulaankhaan. Other projects include Liquefied Petroleum Gas (LPG) development, exploitation of Mongolian oilfields (estimated to contain 300-500 million barrels of oil), and other energy enterprises, including the development of renewable energy programmes (e.g. wind generation systems, and development of existing geothermal resources).

To date, however, little work has been undertaken to assess the geothermal energy potential of Mongolia. The following tables summarise the present state of geothermal development and utilisation in Mongolia:

Table 2: Present and planned production of electricity (*from Rentsen and Enebish, 2003). No information = x

	Geothermal		Fossil Fuels		Hydro Electric		Nuclear		Renewables		Total	
	Capacity MWe	Prod. GWh/y	Capacity MWe	Prod. GWh/y	Capacity MWe	Prod. GWh/y	Capacity MWe	Prod. GWh/y	Capacity MWe	Prod. GWh/y	Capacity MWe	Prod. GWh/y
In operation	0	0	>1000*	2,355	3.28	x	0	0	0.5	x	>1000	>2,350
Under construction	0	0	x	x	0.57	x	0	0	x	x	x	x
Funds committed	0	0	x	x	18	x	0	0	x	x	x	x

Table 3: Present utilisation of geothermal energy for electric power generation

Locality	Power Plant Name	Year Commissioned	No. of Units	Status	Type of Unit	Total Installed Capacity (MWe)	Annual Energy Prod. (GWh/y)	Total under Const. (MWe)
No geothermal electric power generation at present (to September 2004)								

Table 4: Utilisation of Geothermal Energy for Direct Heat

		Maximum Utilisation						Annual Utilisation		
Locality	Type (1)	Flow rate (kg/s)	Temp. Inlet (ºC)	Temp. Out (ºC)	Enthalpy Inlet (ºC)	Enthalpy Out (ºC)	Capacity (2) (MWt)	Av. Flow (kg/s)	Energy (TJ/y)	Capacity Factor
Shargaljuut	H, G	25	88-89	72	369-373	301	1.7	25	54	1.0
Shargaljuut	B	25	40	x	168	x	x	25	x	x
Tsenkher	H,G	10	86	x	360	x	x	10	x	x
Tsenkher	B	10	x	x	x	x	x	10	x	x
Khuremt	G	5	55	x	230	x	x	5	x	x
Teel	G	5	32	x	134	x	x	5	x	x
Baga Shargaljuut	G	10	58	x	243	x	x	10	x	x
Zaart	B	2.8	44	x	184	x	x	2.8	x	x
Shivert	B,H	4-15	55	x	230	x	x	4-15	x	x
Khujirt	B	2.3	55	x	230	x	x	2.3	x	x
Eruu	B	3	43	x	180	x	x	3	x	x

NB : (1) I = Industrial process heat, C = Air conditioning, A = Agricultural drying, F = Fish farming, K = Animal farming, S = Snow melting, H = Individual space heating (not heat pumps), D = District heating, B = Bathing and swimming, G = Greenhouses/soil heating. (2) Capacity = Max. flow rate (kg/s) x [inlet temp. (ºC) - outlet temp. (ºC)] x 0.004184 . Annual Utilisation, Energy Use (TJ/yr) = Av. flow rate (kg/s) x [inlet temp. (ºC) - outlet temp. (ºC)] x 0.1319. Capacity factor = [Annual Energy Use (TJ/yr) / Capacity (MWt)] x 0.03171. No information = x

Table 5: Geothermal (ground-source) heat pumps.

Locality	Ground/water Temp. (ºC)	Heat Pump Rating/Capacity	No. of Units	Type (1)	COP (2)	Heating Equiv.(3) Full Load (Hr/y)	Thermal Energy (TJ/y)	Cooling Energy (TJ/y)
No geothermal heat pump utilisation at present								

NB: (1) Type of installation. (2) COP = output thermal energy/input energy of compressor. (3) Heating equivalent full load operating (hours/year).

Table 6: Geothermal direct heat use (to Dec. 2004).

Use	Installed Capacity (MWe) (1)	Annual Energy Use (TJ/y) (2)	Capacity Factor (3)
Individual space heating	0	0	0
District heating	0	0	0
Air conditioning (cooling)	0	0	0
Greenhouse heating	0.18	5.6	x
Fish farming	0	0	0
Animal farming	0	0	0
Agricultural drying	0	0	0
Industrial process heat	0	0	0
Snow melting	0	0	0
Bathing and swimming	x	x	x
Subtotal	>0.18	>5.6	x
Geothermal heat pumps	0	0	0
Total	>0.18	>5.6	x

(1): Capacity (MWt) = Max. flow rate x [inlet temp. - outlet temp.] x 0.004184. (2) Annual Utilisation, Energy Use = Av. flow rate x [inlet temp. - outlet temp.] x 0.1319. (3) Capacity factor = [Annual Energy Use/Capacity] x 0.03171. No information = x.

Table 7: Wells drilled for electrical, direct and combined use of geothermal resources (to Dec. 2004).

Purpose	Well Temp. (°C)	Number of Wells Drilled between Jan 2000 & Dec 2004				Total Depth (km)
		Electric Power	Direct Use	Comb -ined	Other	
Exploration	(all)	None				0
Production	(all)	None				0
Reinjection	(all)	None				0

Table 8: Personnel involved in geothermal activities

Year	(1)	(2)	(3)	(4)	(5)	(6)
2000	2	-	1	-	-	2
2001	2	-	-	-	-	
2002	-	-	2	-	-	-
2003	2	-	-	3	3	-
2004	2	-	-	-	-	-

(1) Government; (2) Public Utilities; (3) Universities; (4) Foreign Consultants; (5) Foreign aid programmes; (6) Private industry

Table 9: Total investment in geothermal activities.

Period	Res & Devel. (1) US$.10^6	Field Devel. (2) US$.10^6	Direct Util. (3) US$.10^6	Elec. Util. (4) US$.10^6	Private Funding %	Public Funding %
2000-4	0.22	-	-	-	-	100

(1) Research and development (incl. surface exploration/exploration drilling; (2) Field development (incl. production drilling & surface facilities; (3) Direct Utilisation; (4) Electrical Utilisation.

FUTURE GEOTHERMAL DEVELOPMENT

The previous tables (2-9) show the present state of geothermal utilisation in Mongolia, and demonstrate that coordinated development of geothermal resources in the country is still in its infancy. At present, there is no use of geothermal resources for electricity generation, with future development projects still only in exploration, planning and pre-feasibility stages. Never the less, there is potential for geothermal resource utilisation, particularly for small-scale power generation projects, which target the energy (electricity) requirements of remote, sparsely populated settlements (it is suggested the Mongolian Government is thinking along similar lines). It seems likely, that several thermal areas may be explored in detail in the near future, and perhaps developed, with the construction of binary-type geothermal power plants to supply electricity to isolated parts of the country.

The Ministry of Agriculture and Industry of Mongolia advocated the "Geotherm" sub-programme of the "Mineral Resource" Programme, to establish geothermal exploration in 1999., which complemented resolutions from the Mongolian Government for "Development of Spring Research". It is envisaged, as a consequence of these recent developments that, by the time of the NEXT Mongolia country update, in ~2010, the geothermal community will be able to see positive outcomes of the Mongolia' commitment to develop the country's geothermal potential.

Although it may take some time for geothermal resources in Mongolia to be utilised for electricity (power) generation, the prospect of direct use applications (using thermal fluids in the 50-150°C temperature range) is much more advanced. In fact, the first use of geothermal waters for space heating was undertaken at Ikh Shargaljuut in 1973, with 720-750 m^3/day water now used for heating the nearby sanatorium, hotel, cultural centre, restaurant, balneology and greenhouses. The success of that geothermal resource utilisation has promoted studies elsewhere (including Shivert, Khujirt and Tsenkher) for direct (geothermal) industrial applications (as well as tourism, health spa and recreational uses - >200,000 tourists visit the thermally active central and western parts of the country each year). Indeed, several low-moderate temperature geothermal systems, most applicable for direct utilisation, are close to potential users and could be developed for a variety of uses.

Mongolia has a harsh winter climate, with large seasonal variation in temperature. Several centres, such as Tsetserleg, Bayankhongor or Arvaikheer, in the geothermally prospective Khangai area, are potential sites for the introduction of geothermal district space heating systems.

Direct geothermal resource utilisation in Mongolia, for industrial purposes, have been outlined by Lkhagvadorj and Tseesuren (2005, these proceedings) and include washing of cashmere and wool; use of water-air heat exchanger system(s) for drying wood, cashmere or wool and various food products; processing, sterilizing and packing milk products. Greenhouse applications (e.g. at Shargaljuut and Tsenkher) is expected to include soil heating (especially during winter months, when mean soil temperature is <0°C).

CONCLUSIONS

At present, there is no geothermal resource utilisation in Mongolia for electricity (power) generation, although the Government is exploring potential uses of its geothermal resources to meet the energy requirements of its rural communities. In the foreseeable future, despite renewed research programmes (highlighted in these proceedings) and investment, most geothermal resource utilization is anticipated be for direct use applications, which are expected to include district heating schemes, cashmere and wool processing, horticultural applications, and balneological and therapeutic purposes, and development of the country's tourism industry.

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REFERENCES

Asian Development Bank, 2002. Technical Assistance to Mongolia for renewable energy Development in small towns and rural areas. Uunpubl. Report.

Bignall, G., Batkhishig, B., Tsuchiya, N., 2003. Taking the waters? - Shargaljuut Hot Springs (Mongolia). 25th NZ Geoth. Workshop, 15 - 20.

Bignall, G., Batkhishig, B., Tsuchiya, N., 2004. Character of surface thermal manifestations and spring waters at the Shargaljuut Hot Springs, Mongolia. Geothermal Resources Council. Transactions, 28, 449-453.

Dergunov, A.B., (Editor), 2001 Tectonics, Magmatism, and Metallogeny of Mongolia. Routledge, London and New York. 228p. (Translated from Russian by Sorkina, R.E., Fursenko, R.V., Miloradovskaya, E.A)

Dorj, P., 2001. Design of small geothermal heating systems and power generators for rural consumers in Mongolia. Report 3, in Geothermal Training in Iceland 2001. The United Nations University, Geothermal Training Programme, Iceland, 27-57.

Dorj, P., Galsantseren, P., Tseesuren, B., Ovgor, B., 2003. Future geothermal survey – Study in Mongolia. Proc. IGC2003, Multiple Integrated Uses of Geothermal Resources. Reykjavik, Iceland, S10, 15-19.

Dorofeeva, R.P., 1992. Geothermal regime of east Siberia and Mongolia. Intl. Conf. on Industrial Uses of Geothermal Energy. Reykjavik, Iceland. 9pp.

Gendenjamts, O-E., 2003. Interpretation of chemical composition of geothermal fluids from Árskógsströnd, Dalvik, and Hrisey, N-Iceland and in the Khangai area, Mongolia. Report 10, in Geothermal Training in Iceland 2003. The United Nations University, Geothermal Training Programme, Iceland. 219 – 252.

Lkhagvadorj, I., 2003. The use of geothermal energy in a low-temperature field with a case study from Shargaljuut, Mongolia. Report 16, in Geothermal Training in Iceland 2003. The United Nations University, Geothermal Training Programme, Iceland. 385 – 405.

Lkhagvadorj, I., Tseesuren, B., 2005 (these proceedings.). Geothermal energy resources, present utilization and future developments in Mongolia. World Geothermal Congress (WGC-2005), Antalya, Turkey, 24 – 29 April, 2005.

Ministry of Agriculture and Industry, 1999. Geotherm – Sub-programme of the mineral resource programme, Mongolia. Mongolian Ministry of Agriculture and Industry report. Ulaanbaatar, Mongolia, 25pp.

Rentsen, B., Enebish, N., 2003. Mongolia. Renewable Energy Corporation of Mongolia (REC) 2004: renenergy.com. International Cooperation on Energy/Electrification Sector Rehabilitation and Development, Energy Co-operation in North-East Asia. Vladivostok, Russian Federation, April 08-10, 2003.

Tseesuren, B., 2001. Geothermal resources in Mongolia and potential uses. Report 15, in Geothermal Training in Iceland 2001. The United Nations University, Geothermal Training Programme, Iceland, 347-374.

World Bank, 2002. Mongolia sustainable energy sector strategy plan (2002-2010), Unpublished report, http://www.worldbank.org.mn/sector/infras/plan.htm.

Worley International, 1995. Power system master plan interim report. Asian Development Bank and Government of Mongolia. Project Report TA No. 2095-MON, 423p.

Xing, B., Wu, Y., 2000. Drying wool and other direct uses of geothermal energy in Heibei, China. Proc. World Geothermal Congress (WGC-2000), Kyushu-Tohoku, Japan. 3589-3592.

Yarmolyuk, V.V., Kovalenko, V.I., Ivanov, V.G., Samoylov, V.S., 1995. Dynamics and magmatism of late Mesozoic-Cenozoic mantle hot spot, southern Khangai (Mongolia). Geotectonics, 28 (5), 391-407 (translated from Russian: Geotectonika 28 (5) 28-45, 1994).

Zorin, Y.A., Novoselova, M.R., Turtanov, E.Kh., Kozhevnikov, V.M., 1990. Structure of the lithosphere of the Mongolian-Siberian mountainous province. J. Geodyn., 11, 327-342.