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Possibility of Geothermal Heating System in Arkhangai Province Centre, Mongolia

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ABSTRACT

This paper highlights building heating system difficulties facing provincial centres in Mongolia and possibilities of using of alternative energy sources such as geothermal energy. Mongolia has one of the highest greenhouse gas (GHG) emissions per capita and GHG emissions per $GDP in the world (Improved Urban Stoves 2000). Based on a recent study (2003), for example the DH company of Arkhangai province centre had spent US$ 220,152 as coal transportation cost alone which is the most common typical picture of heating systems expenses of rural locations in Mongolia. The geochemical exploration studies of the Khangai geothermal area showed no scaling tendency (Gendenjamts 2003). Further detailed geological and geophysical exploration works are next plan for the geothermal development of Arkhangai province centres to define the exact locations for exploration drilling. A modelling of Arkhangai geothermal heating system will be based on the existing heating system distribution pipeline networks and will incorporate future heat demands. Techno-Economic feasibility study for heating and electrification for consumers using geothermal energy is a fundamental aspect of the future geothermal development in Mongolia.

1. INTRODUCTION

The improvement of living conditions of the urban population of province centre in Mongolia is the aim of this project through the examination of coverage of basic heating needs with the use of the domestic resources such as geothermal potential.

1.1. Arkhangai Province

Mongolia is divided into the capital city and the provinces, with further division of provinces into soums (like villages). There are 21 provinces (The Ministry of Foreign Affairs of Mongolia 2004).

Arkhangai province was established in 1931, territory 55.3 thousand square km and population 103.6 thousand. Centre of province is Tsetserleg town (Erdenebulgan soum), located 468 km away from Ulaanbaatar (capital city). Arkhangai province divided into 19 soums.

Arkhangai province is situated in the central part of the Khangai mountain range and its territories consist of mountain, wooded steppe and plain. The average altitude of the province is 2414 meters above sea level. The highest point is Kharalagtai peak clad in eternal snow at 3539 meters above sea level, while the lowest point is the area of the confluence of the Orkhon and the Tamir rivers at 1290 meters above sea level. There is mainly scattered grey and black soil of mountain meadow and forest. Over 70 per cent of the territory of the province is pasture land, almost 2 per cent with hay-fields, about 1 per cent with sown area, and 15 per cent of the territory is covered with broadleaved and coniferous forest. There are several peaks in the eternal snow at the four seasons of the year such as Suvraga, Noyon, Khan-Undur, and rapid rivers of Khanui, Khunui, Orkhon, Chuluut, South and North Tamir gushed from high mountain range of the Khangai and the fresh water lakes are Ugii, and Terkh. These rivers and lakes teem with taimen, grayling, scale, perth. There are seven hot springs (see Figure 1) such as (1) Noyon khangai, (2) Chuluut, (3) Shivert, (4) Gyalgar, (5) Bor tal, (6) Tsenher, (7) Tsagaan sum, and youngest volcanic crater Khorgo erupted 10 thousand years ago.

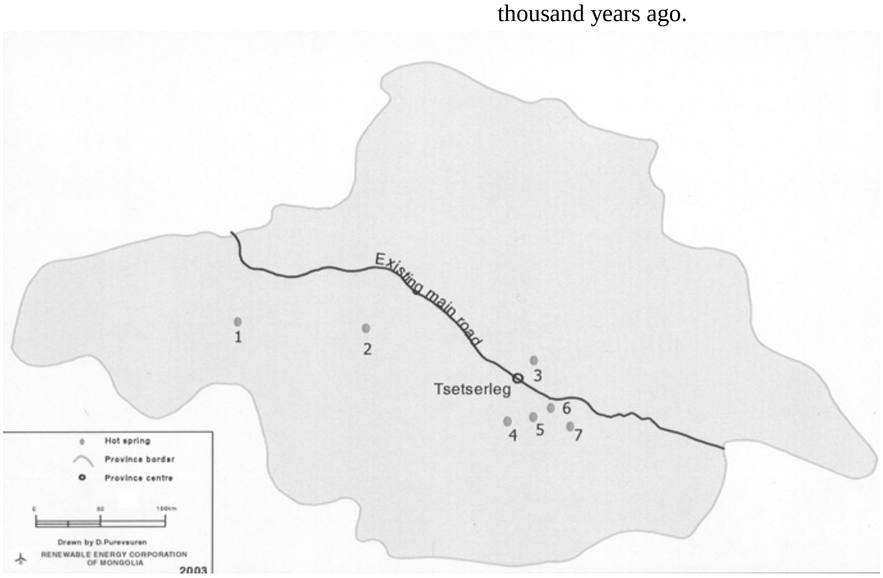

Figure 1: Hot springs of Arkhangai Province.

2. HEATING SYSTEMS: PRESENT SITUATION IN MONGOLIA

Two major urban and rural heat applications predominate in Mongolia. The urban heat applications are subdivided within centralized district heating and individual gers (primarily the traditional felt tents see Dorj, P., 2001) and conventional housing, which are cook and heat their gers and homes by the coal stoves.

There are three combined heat and power plants in the capital Ulaanbaatar. These power plants consume about 5 million tons of coal per year. In addition, 250 heat-only boilers provide heating for individual buildings. They use about 400 thousand tons coal per year.

Ger areas are found primarily around built-up urban areas. However, ger areas also include wooden houses in which the same types of stoves are used.

Mongolia has one of the highest greenhouse gas (GHG) emissions per capita and GHG emissions per $GDP in the world (Improved Urban Stoves 2000). During the bitterly cold and long winter, smoke sits over the towns and is the major cause of the respiratory complaints and diseases that account for half of the child deaths and a major part of child and adult morbidity. The primary sources of CO_2 emissions and air pollution are:

- The 70,000 coal-fired urban stoves concentrated in the poor ger areas in Ulaanbaatar (UB) accounting for about 300,000 of the city's 700,000 population; and
- The combined heat and power (CHP) stations.

The stoves are estimated to contribute 30-65% of Ulaanbaatar's air pollution. It is estimated that indoor cooking stoves consume about 350,000 tons of coal each year, with corresponding annual emissions of about half a million tons of CO_2. Each winter, each ger household consumes about 5 ton of coal and 4-7 cubic meter of wood, thus making a major contribution to overall CO_2 emissions and air pollution.

2.1 Heating System in Arkhangai Province Centre

The number of inhabitants living in Erdenebulgan soum is 18136 (Statistical Booklet 2000). Three types of heating consumers are in Tsetserleg, these are supplied by:

- A central boiler stations;
- Individual boilers;
- Individual coal stoves.

Central boiler stations. Since 1995, the "Ilch Arkhangai" a state-owned company has been managing the central heating system in Tsetserleg town. The company possesses eight boiler stations, which provide heating water (including tap water for specific consumers) covering a total of 57 public buildings (such as administration, schools, dormitories, hospitals et al) and some private apartments. In 2002, the company produced thermal energy of 51.739 GJ (14.3 GWh) and consumed 7600 tons of coal (Ilch Arkhangai 2003).

As an example, based on a recent study (2003), the Erdenebulgan soum had spent approximately US$ 220,152 on coal transportation cost alone, which is the most common typical picture of heating system expenses of rural locations in Mongolia. In 2002, total revenues of the "Ilch Arkhangai" company 399 million tugrug (tugrug – bank note of Mongolian) or US$ 341.025 (a rate of $1.00=MNT1,170 has been used). Figure 2 shows the smoky by-product from Boiler Station No 14. After the coal has burned within stove, 22 percent of the coal remains as ash and the remainder rises up to the sky as smoke.

Figure 2: Smoke comes from Boiler Station No 14

Individual boilers. There are several individual boiler heating systems serving individual private office buildings (such as banks, shops and other companies etc).

Individual coal stoves. Individual coal stoves for cooking and heating are used by families living in Gers and individual family houses. Ger and house areas are found primarily around built urban areas. 4373 total households are divided 2565 living in conventional housing and 1808 living in ger (Statistical Booklet 2000). Both conventional houses and ger households consume about 5 ton of coal and 4-7 cubic meter of wood, thus making a major contribution to overall CO_2 emissions and air pollution.

Following problems are faced to the present heating systems in Tsetserleg:

1. Boiler Heating system effectiveness is low due to age of boilers, approximately 50 percent. Coal consumption is therefore high. The boilers have been in use for 12 -24 years and are old technology, except boiler No 1, which was renovated in 2000.

2. Indoor air temperature drops down to unacceptable levels in winter due to insufficient DH system capacity, which can be traced to limited boiler output and heat losses in the distribution system. This results in uncomfortable living conditions for DH consumers. Sometimes indoor temperature goes down below 15 °C.

3. GHG emissions are high, for example, total CO_2 emissions in Tsetserleg due to coal burning for heating, based on our estimation is 51.621 tons per year.

4. Domestic Hot water service is limited. Hot water for bathing etc is limited to Saturdays between 14 and 16 h. Hospitals are supplied with hot domestic water twice a week.

Annual coal consumption and CO_2 emissions for different heating consumers is listed in Table 1.

Table 1. Annual coal consumption and CO_2 emission in Tsetserleg

#	Heating system	Number	Coal consumption, tons	Cost, $	CO_2 emission, tons
1	DH company	8	7.600	304.000	12.069
2	Individual boilers	-	3.040	121.600	4.828
3	Gers	1.808	9.040	361.600	14.356
4	Houses	2.565	12.825	513.000	20.367
	Total		32.505	1.300.200	51.621

3. GEOTHERMAL RESOURCES

According to geothermal studies, Arkhangai province has seven hot springs as mentioned in Section 1.1 (see Figure 1). The locations and general features of the seven hot springs are summarized in below items and Table 2.

- The Noyonkhangai hot springs (1) are located at 47°45’N and 99°25’E in the Khangai soum of the Arkhangai province at an elevation of 2370 m a.s.l. The hot springs are located 17-18 km southwest of the Khangai soum centre, (233 families in 2000) and 240 km of northwest of the Tsetserleg province center. The average surface temperature is 37°C, and the flow rate is 6 l/s (Namnandorj 1966). According to resent analysis average surface temperature is 36°C in 2002 (Dolgorjav, 2002). The hot springs consists of ten springs as source, and flow into the river of Noyonkhangai (Namnandorj 1966).
- The Chuluut hot springs (2) are located at 47°5”N and 100°15’E, and is 25-30 km north of the Chuluut soum centre (267 families in 2000) in Arkhangai province at an elevation of 2190 m a.s.l. The average surface temperature is 44°C, and the flow rate is 2.5 l/s (Namnandorj 1966). According to Dolgorjav average surface temperature was 44°C in 2002. The hot springs consist of five springs.
- The Shivert hot springs (boreholes) (3) are located at 47°39’49”N and 101°31’15”E and 21 km northeast from the Tsetserleg province centre of the Arkhangai, at an elevation of 1710 m a.s.l. (Namnandorj 1966). About 40 km north-east of Shivert there is the soum centre Battsengel (325 families in 2000). About 28 km southeast of Shivert is the soum centre Tsenkher. There have been five geothermal prospecting boreholes drilled by Mongolian and Russian scientists in 1980 (Dorj et al., 2003). The borehole depth is in the range of 26-40 m. The average surface temperature is 55°C, and the flow rate is 4 l/s (Tseesuren 2001). According to Dolgorjav, average surface temperature was 57.5°C in 2002. The hot springs consists of five springs
- The Gyalgar hot springs (4) are located at 47°11’19”N and 101°32’54’’E in the Tsenkher soum of the Arkhangai province. It is 30-32 km south of the Tsetserleg province centre, with an elevation of 1900 m a.s.l. (Namnandorj 1966). The average surface temperature is 52°C, and the flow rate is 1 l/s (Tseesuren 2001).
- The Bor tal hot springs (5) are located at 47°10’19’’N and 101°36’58’’E in the Tsenkher soum of the Arkhangai province. It is 34 km southeast of the Tsetserleg province centre, with an elevation of 1880 m a.s.l. (Namnandorj 1966). The average surface temperature is 52°C, and the flow rate is 1 l/s (Tseesuren 2001).
- The Tsenkher hot springs (6) are the largest of the Mongolian hot springs and are located at 47°19’28”N and 101°39’00”E in the Tsenkher soum of the Arkhangai province. It is 25 km southeast of the Tsetserleg province centre, with an elevation of 1860 m a.s.l. (Namnandorj 1966). The hot springs consist of six springs. The average surface temperature is 85°C, and the flow rate is 10 l/s (Tseesuren 2001). According to Dolgorjav average surface temperature is 84.3°C in 2001.
- The Tsagaan sum hot springs (7) are located at 47°04’12’’N and 102°04’48’’E in the Tsenher soum of the Arkhangai province. It is 25 km southeast of the Tsetserleg province centre, with an elevation of 1840 m a.s.l. The average surface temperature is 69°C, and the flow rate is 8 l/s (Tseesuren 2001). According to Dolgorjav, average surface temperature is 69.1°C in 2001.

3.1 Properties of Geothermal Fluids

In Mongolia, the “Institute Chemistry and Chemical Technology” and “Spring Research Institute” are both analysing cold and hot springs distributed in Mongolia. Balneology was main purpose of the analysis. This discipline is developed very much in Mongolia. Also the National Program “Development of Spring Research” was initiated by the 251st resolution of Mongolian government on 13 December, 2002.

After first two fellows who are the research worker of Renewable Energy Corporation of Mongolia had graduated UNU Geothermal Training Programme (UNU GTP) in Iceland in 2001, geothermal research activity started on the heating and electric purposes. The research workers at the Institute Chemistry and Chemical Technology had done “The hydrochemical properties of some hot and cold hot springs of Khangai area” M.Sc. thesis by Dolgorjav, O in 2002 and “Interpretation of geochemical data from geothermal fluids at Arskogsstrond, Dalvik, and Hrisey, N-Iceland and in the Khangai Area” report by Gendenjamts, O in 2003. Chemical composition of five hot springs (Noyon khangai, Chuluut, Shivert, Tsenher and Tsagaan sum) are available into both materials.

Subsurface temperatures of the five hot springs discussed in Section 3 have been estimated by chemical geothermometry (Gendenjamts 2003). The chalcedony, quartz, Na-K, and Na-K-Ca geothermometer temperatures were calculated. The Na-K geothermometer gives very high and sometimes unrealistic temperatures for all hot springs, whereas results for the Na-K-Ca geothermometer indicate that this empirical geothermometer appears to be applicable to the low-temperature waters. Quartz geothermometer temperatures are realistic for hot springs in this area compared to estimated mineral-equilibrium temperatures. But the chalcedony geothermometer provides the most reliable temperatures for these fields, with predicted temperature values ranging from 69 to 123°C.

Table 2. General features of the seven hot springs

#	Name of hot springs	Elevation (m)	Flow rate (l/s)	Mineral (mg/l)	Temperature (^{0}C)
1	Noyonkhangai	2370	6	-	36
2	Chuluut	2190	2.5	250.5	44
3	Shivert	1710	4	24.8	55
4	Gyalgar	1900	1	221.6	52
5	Bor tal	1880	4.5	258.9	52
6	Tsenher	1860	10	239.9	86
7	Tsagaan Sum	1840	8	-	69

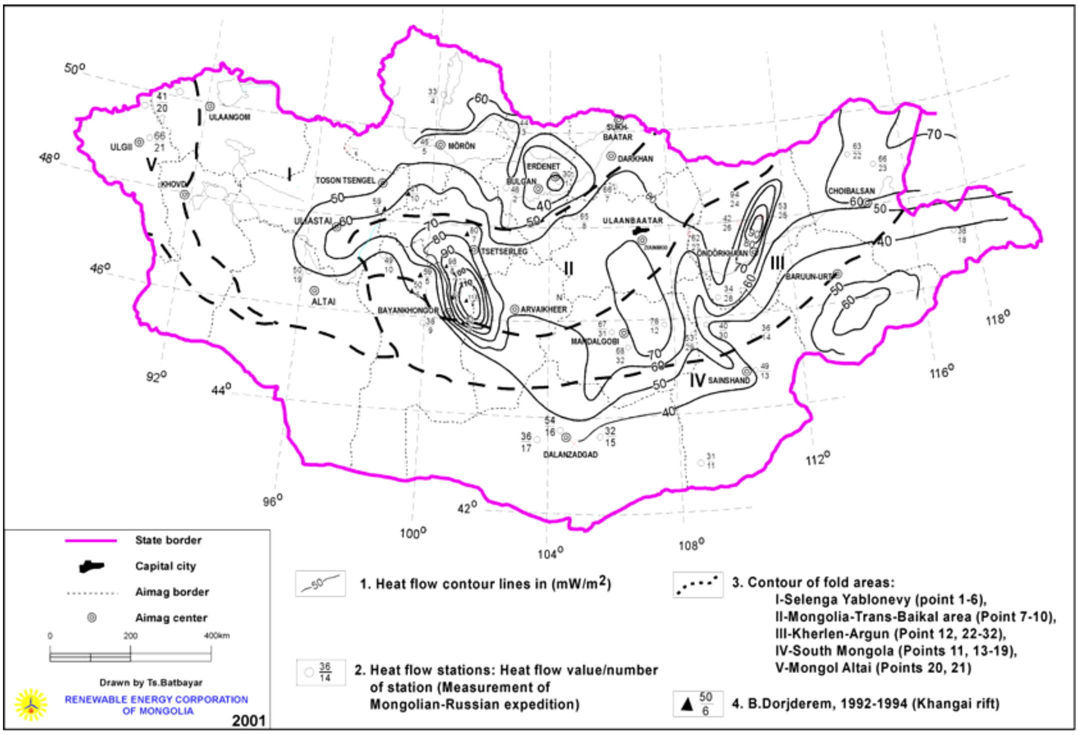

Figure 3: Heat flow map of Mongolia

The silica-enthalpy warm spring mixing model handles non-boiled and boiled mixed waters separately with mixing occurring after boiling, and the boiling hot spring waters indicate enthalpies from 908 to 1142 kJ/kg for the hot water component (212-261°C).

3.2 Geothermal Structure of Arkhangai

The 32 heat flow stations are basis for the Mongolian heat flow map presented in Figure 3. The map published here is based on previously works (Ministry of Food and Agriculture of Mongolia 1999 and Dorofeeva 1992). It highlights the area of anomalous heat flow over the Khangai area (with a highest heat flow 110 mW/m^2) in the central part of the country and shows a geothermal gradient of 45-80 °C/km. The Khangai geothermal system covers 3 aimag centres and 44 soum centres with approximately 241,000 people. The natural cumulative flow of hot springs of usable heat (>35°C) in Bayankhongor aimag 13.5 MWt, Arkhangai aimag 4.0 MWt, and Uvurkhangai 3.2 MWt.

3.3 Brief Description on an "Pre-feasibility Study – Geothermal Project in Tsetserleg Mongolia"

Resently in August 2004, the pre-feasibility study was written by ÍSOR – Iceland Geosurvey, Fjarhitun Geothermal Consultants and Rafhönnun Consulting Engineers in Iceland. The editors are Einar Tjörvi Elíasson from Kreta Geothermal Consulting on behalf of ÍSOR, Jóhann Thor Magnússon from Rafhönnun, Purevsuren Dorj from the Renewable Energy Corporation of Mongolia and Thorleikur Jóhannesson from Fjarhitun.

The conclusion of the report was that there are highly significant indications that geothermal energy can be economically developed in Tsetserleg and several other towns in the Khangai area where the main geothermal activity is.

4. CONCLUSION

Further detailed geological and geophysical exploration works are planned next for the geothermal development of Arkhangai province centre to define the exact locations for exploration drilling. A modelling of Arkhangai geothermal heating system will be based on the existing heating system distribution pipeline networks and will incorporate future heat demands.

A techno-economic feasibility study for heating and electrification for consumers using geothermal energy is a fundamental aspect of the future geothermal development in Mongolia.

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