Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Geothermal Possibilities in Kazakhstan

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Keywords: Kazakhstan, sedimentary resources, direct use, WB, ICEIDA

ABSTRACT

The key objectives of a study conducted by a team of Icelandic geothermal specialists in 2018/2019 were to review available information on geothermal resources in Kazakhstan, assess technically and economically viable applications, and make recommendations on next steps for possible deployment of geothermal resources in the future. Kazakhstan is believed to hold considerable low-temperature geothermal resources, mainly of the sedimentary type. This information is acquired from deep wells, mostly petroleum and gas wells that have yielded hot water and a few wells drilled specifically for geothermal exploration. Surface manifestations (hot springs) also provide evidence of such resources. Furthermore, there are parallels between the geological conditions (deep sedimentary basins) in parts of Kazakhstan and the geological conditions of sedimentary basins in other parts of the world with extensive low-temperature geothermal utilization, for example in Eastern Europe and in China. Hot water from springs and wells is already being used on a very limited scale in certain areas in Kazakhstan. There is significant need for adequate heating services for the Kazakhstan population and therefore an opportunity to identify whether and how the geothermal resources can be harnessed to meet some of the household energy needs. Based on an initial review of available information, the study focused on two hypothetical case studies of geothermal application: geothermal district heating in the town of Zharkent in southeast Kazakhstan and a 10 MW_e binary power plant in the Zharkent sub-basin, to give an indication of the technical and economic viability of such applications. A set of recommendations to the Government of Kazakhstan on the next steps for possible deployment of geothermal utilization in the country was provided as part of the study. It is recommended that Kazakhstan primarily aim for direct use of geothermal resources: house heating, greenhouse heating, fish farming and other direct use applications. Moreover, the development of an efficient and comprehensive regulatory framework for geothermal utilization and district heating in Kazakhstan is among the highest priorities.

1. INTRODUCTION

A study aimed at assessing potential utilization of geothermal resources in Kazakhstan was conducted in the fall 2018. It was carried out for the Ministry of Energy in Kazakhstan in response to a request by the World Bank (WB) to the Directorate for International Development Cooperation (ICEIDA) within the Ministry for Foreign Affairs in Iceland (IMFA), under the framework of on-demand technical support from IMFA to the WB and its clients. The key objectives were to review available information on geothermal resources in Kazakhstan, assess technically and economically viable applications, and make recommendations to the Government of Kazakhstan (GoK) on next steps for possible deployment of geothermal resources in the future.

Energy use in Kazakhstan is quite intensive due to energy-intensive industries, adverse climate conditions (requiring space heating) and low energy efficiency. Despite energy resource abundance and low energy prices, energy poverty is an issue in Kazakhstan and 2/3 of rural households still use coal as a primary energy source. The predominantly fossil-fuel based energy economy also causes environmental pollution and considerable CO_2 emissions. Therefore, the GoK has adopted ambitious targets and policy measures on renewable energy development focused on increased renewable energy utilization. This includes the target that the share of renewables in electricity production will not be less than 30% by 2030 and 50% by 2050. Targets and policies regarding household heating are no-less important (World Bank, 2018).

Kazakhstan is believed to hold considerable low-temperature geothermal resources, mainly of the sedimentary type. This information is acquired from deep wells, which have mainly been drilled as petroleum and/or gas wells and have yielded hot water. Surface manifestations (hot springs) also provide evidence of such resources. Furthermore, there are parallels between the geological conditions (deep sedimentary basins) in parts of Kazakhstan and the geological conditions of sedimentary basins in other parts of the world with extensive low-temperature geothermal utilization, e.g. in Eastern Europe and in China. Information on the geothermal resources of Kazakhstan in international science and technology literature is very limited, but more extensive literature exists, mainly in Russian.

Low-temperature geothermal resources are especially suitable for household heating and other direct utilization purposes such as industrial application, balneology, etc. There is an opportunity to assess the potential and characteristics of geothermal energy resources in Kazakhstan, and identify whether and how they can be harnessed to meet some of the household energy needs. Hot water from springs and wells is already used on a very limited scale in certain areas in Kazakhstan, for direct purposes.

This paper summarizes the results of the Kazakhstan study. It starts out by reviewing briefly knowledge on geothermal resources in Kazakhstan as a whole and then continues by discussing more specifically geothermal resources in South- and SE-Kazakhstan with special emphasis on the Zharkent sub-basin of the Ily sedimentary basin. Consequently, the paper moves on to presenting general aspects of geothermal utilization, with emphasis on direct use and the associated surface technology, after which a basic technological and financial analysis of hypothetical case studies of utilization in the Zharkent sub-basin is presented. The paper is concluded by a summary of the main recommendations on the way forward towards successful large-scale geothermal utilization in Kazakhstan.

2. GEOTHERMAL RESOURCES IN KAZAKHSTAN

The information compiled during this study mainly consisted of reports in Russian, some translations thereof, as well as very limited information available internationally, e.g. on the web. However, comprehensive data related to the geothermal resources is known to exist in the archives of Kazakhstan, data which should be compiled and evaluated.

Some geothermal research was conducted in Kazakhstan during the Soviet period, including comprehensive studies in the 1980's of geothermal resources in the most promising regions of South Kazakhstan. At that time the results already indicated considerable geothermal reserves. Geothermal research after independence has included three main studies: a) In 2006, forty existing deep wells in the south and southeast parts of the country were inspected and a feasibility study presented, identifying the most promising areas for further prospecting and exploration (Kasymbekov, 2006), b) in 2008, prospecting and exploration was conducted in the Zharkent sub-basin in SE-Kazakhstan, and exploitable geothermal reserves assessed, including the study of a deep well (2800 m), producing 90°C water, which consequently has supplied a large greenhouse complex with thermal energy and c) in 2015-2016, deep exploration drilling for geothermal energy at the Zharkunak site in the Zharkent sub-basin was carried out for the purpose of assessing whether sufficient geothermal reserves for direct use existed in the area (The Ministry of Energy and Mineral Resources of the Republic of Kazakhstan, 2016). This project was successful and hot water from 2 – 3 wells is now used for space heating, hot water supply, greenhouse heating, fish-farming and other needs.

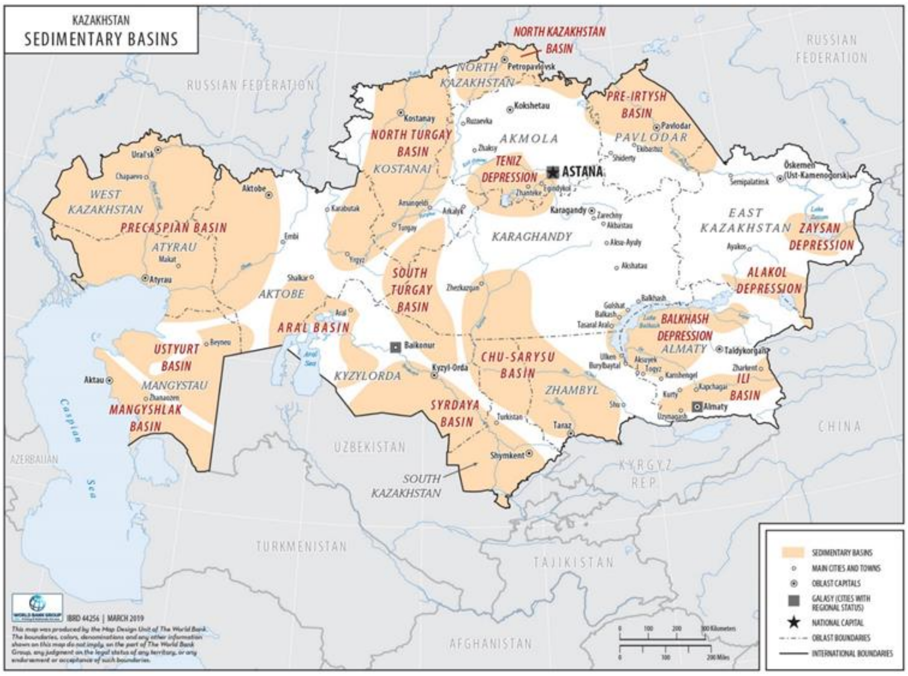

Figure 1: The main deep sedimentary basins of Kazakhstan classified by their hydrocarbon exploration/exploitation status (based on KazEnergy Association, 2015).

Kazakhstan is believed to possess considerable low-temperature geothermal resources, as already mentioned. These are mainly of the sedimentary type (Saemundsson et al., 2009). This is based on knowledge from deep wells drilled in sedimentary environments that have yielded hot water from permeable sedimentary layers at great depth, where temperature is sufficiently high by virtue of the geothermal gradient in the region. Some surface manifestations (hot springs) also exist in the country. This belief is also supported by clear parallels between geological conditions (deep sedimentary basins) in parts of Kazakhstan and the geological conditions of sedimentary basins in other parts of the world with extensive low-temperature geothermal utilization, e.g. in Eastern Europe and in China.

Fifteen sedimentary basins in Kazakhstan that have been identified as bearing hydrocarbon resources, or prospects thereof, are presented in Figure 1. These are also expected to hold geothermal resources, due to their nature, to a variable extent. The sedimentary basins that are believed to contain the greatest potential for geothermal resource utilization are: Mangyshlak and Ustyurt-Buzashin basins in the southwest, Syrdaria Basin in the south and the Ily Basin in the southeast. Generally, the resource formations are either composed of sandstone or carbonate rocks, which are however quite different in nature.

Some assessments of the potential of different parts of the sedimentary geothermal resources of Kazakhstan exist in the local literature. These mainly use the volumetric assessment method, or variants thereof. These show variable results, which are difficult to discern but most likely result from a variability in basic parameters such as surface area and thickness (hence volume) as well as temperature conditions and recovery factor. Evaluating these assessments was beyond the scope of the present study. All these assessments demonstrate great production potential for the main sedimentary basins of the country, even though the results are variable. In addition, some assessments have been made on the basis of well discharge data, adding to the volumetric assessment results, including well assessments presented by (The Ministry of Energy and Mineral Resources of the Republic of Kazakhstan, 2016).

The most comprehensive, country-wide assessment available is the one presented by Boguslavsky et al. (1999). Their work presents an estimate of geothermal energy in 12 of the 15 sedimentary basins of Kazakhstan, at up to 5,000 m depth (depending on basin) and for different temperature ranges. Table 1 presents the results of Boguslavsky et al. (1999) with the estimates for resource temperature above 40°C summed up, in the table's second column (energy density). The results of Boguslavsky et al. (1999) were taken further to estimate extractable energy per km^2. In doing this, a recovery factor of only 1% was assumed, as only a small part of the total thickness will constitute permeable reservoir layers and only a small fraction of the energy in these layers will be extractable, during a 100-year utilization period (column 3). Column 4 shows the estimated surface area of a few of the most significant sedimentary basins and finally, column 5 shows the estimated extractable energy per year for the 12 basins.

Table 1: Estimates of geothermal energy content in sedimentary basins of Kazakhstan for the resource temperature range above 40°C according to (Boguslavsky et al., 1999), along with further estimates done as part of the study.

Basin	Energy density PJ/km^2	Extractable per km^2 and year TJ/km^2/yr	Area km^2	Total extr. energy EJ	Extractable per year PJ/yr
Prikaspiy	184	18	380 000	690	6 900
Ustyurt-Buzashin	475	48	85 000	410	4 100
Manguyshiak	509	51	59 000	300	3 000
Aral	264	26	61 000	160	1 600
Syr-Daria	86	8.6	135 000	120	1 200
S-Torgay	68	6.8	86 000	59	590
N-Torgay	-	-	188 000	-	-
N-Kazakhstan	-	-	60 000	-	-
Teniz	-	-	61 000	-	-
Shu-Sarysuy	213	21	185 000	390	3 900
W-Ily	382	38	(19 000)	(71)	(710)
E-Ily	577	58	(19 000)	(110)	(1 100)
Balkhash	26	2.6	91 000	24	240
Alakol	56	5.6	31 000	18	180
Zaisan	54	5.4	28 000	15	150
Priirtysh	155	16	101 000	160	1 600

Note that EJ = 10^{18} J, PJ = 10^{15} J and TJ = 10^{12} J. Note that numbers in parenthesis are relatively more uncertain estimates.

The results in Table 1 demonstrate the following:

- The greatest extractable energy per km^2 is estimated for the Ustyurt-Buzashin and Mangyshlak basins in SW-Kazakhstan and in the W-Ily (Almaty) and E-Ily (Zharkent) basins in SE-Kazakhstan (see Figure 1). This is mainly due to the likely existence of higher temperature resources in these basins relative to the other basins.
- The Ustyurt-Buzashin and Mangyshlak basins are also amongst the basins with the greatest extractable energy per basin, as a result of their relatively great surface area. In addition, the table shows that the Prikaspiy basins in NE-Kazakstan and the Shu-Sarysuy in S-Kazakhstan are also amongst the basins with the greatest extractable energy per basin, simply because of the great surface area of these basins.

Here it should be noted that basins with high extractable energy density (per km^2) are generally the most interesting concerning geothermal potential, as they should require less wide-spread production well drilling.

Even though the focus of this study was on the geothermal resources of SE-Kazakstan, information was provided verbally (during final work-shop) on two regions with promising potential, where some utilization has been ongoing in the past and interest exists in reviving and expanding the utilization. These are firstly in the Ustyurt-Buzashin basin in SW-Kazakhstan where petroleum exploration wells have demonstrated resource temperature as high as 150 – 160°C at 4 – 5 km depth. Secondly, resources exist in the Prikaspiy basin in NE-Kazakhstan where some wells were drilled to approximately 1.5 km depth in the 1970's. Many of these wells have been utilized, yielding water at a temperature of 40°C approximately.

3. SEDIMENTARY GEOTHERMAL RESOURCES IN ZHARKENT SUB-BASIN

3.1 Zharkent sub-basin

In South and South-East Kazakhstan, the geothermal resources in the Zharkent sub-basin of the Ily-basin appear to be most promising, based on resource temperature, low concentration of dissolved solids and powerful natural recharge through precipitation. Further research may locate other promising geothermal resources in the South and South-East region. The sedimentary formations of the Ily-basin are generally of Mesozic to Cenozioc age and composed of sequences of sandstone with interlayers of carbonate rocks. Geothermal waters in the Cretaceous complex are widespread in the basin and appear the most favourable resource for utilization. The estimated temperature at the bottom of the thermal aquifer systems, depending on depth, are believed to vary between 40–75 and 155–165°C (Kasymbekov, 2006). Tectonic fractures also play a role in the geothermal hydrology of some parts of the Zharkent sub-basin. Figure 2 shows an example of a cross-section (approximately N-S) through the sub-basin.

Out of 11 deep geothermal wells drilled in the Zharkent sub-basin, four wells encountered geothermal water at 2,800 m to 3,200 m depth; their artesian flow rates range from 11 to 50 l/s, with pressure head corresponding to +195 to +360 m, at a discharge temperature of up to 103°C. Wells where temperature is higher than 60°C are located in the central part of the sub-basin where depth to the aquifer formations is greatest. Other wells show lower discharge temperatures. Hot water from at least 3 wells in the Zharkent sub-basin is currently used for space heating, hot water supply, greenhouse heating, fish-farming and other local needs.

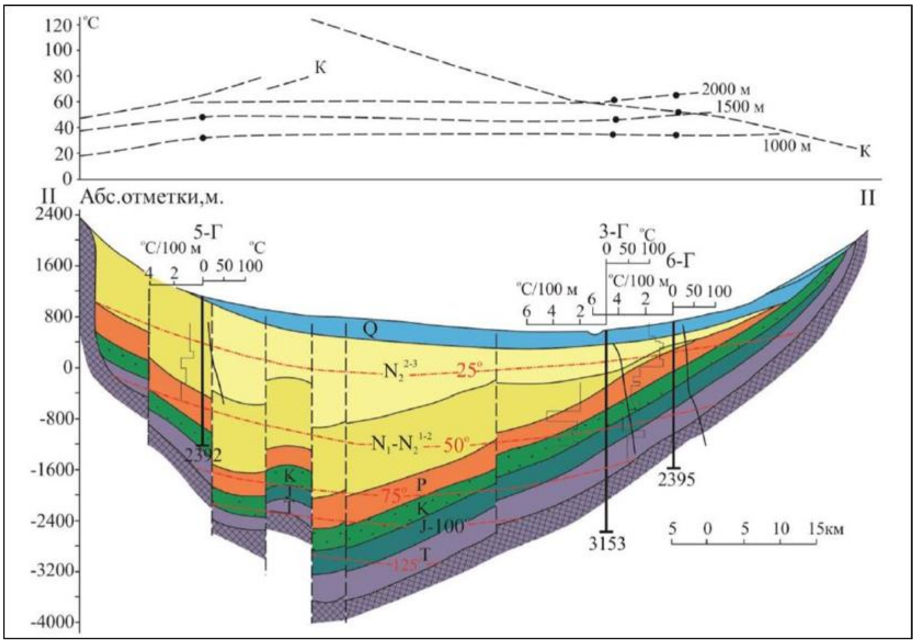

Figure 2: An approximately N-S cross-section through the central part of the Zharkent sub-basin showing age of different formations, faults, location of wells and thermal gradient (Ministry of Energy and Mineral Resources of the Republic of Kazakhstan, 2016).

Geothermal conditions in the Zharkent sub-basin are in several ways quite favourable, as compared to other sedimentary resources, both in Kazakhstan as such and worldwide. The reservoir formations discovered reaching great depth outcrop at the surface in mountainous regions on the margins of the sub-basin. Thus, the formations are provided with substantial recharge through precipitation. This recharge is also demonstrated by high well-head pressure and artesian flow. Information provided also indicates that this well-head pressure and artesian flow had not declined with time as far as the limited available information indicates, which is normally expected however.

Figure 3 shows an example of temperature logs from wells in the Zharkent sub-basin and diagrams of geothermal gradient plotted with depth. They show that the temperature gradient is as high as 40°C/km, or even higher, in some depth intervals. In addition, a maximum temperature of about 100°C is observed at about 2 700 m depth in well 1-Γ.

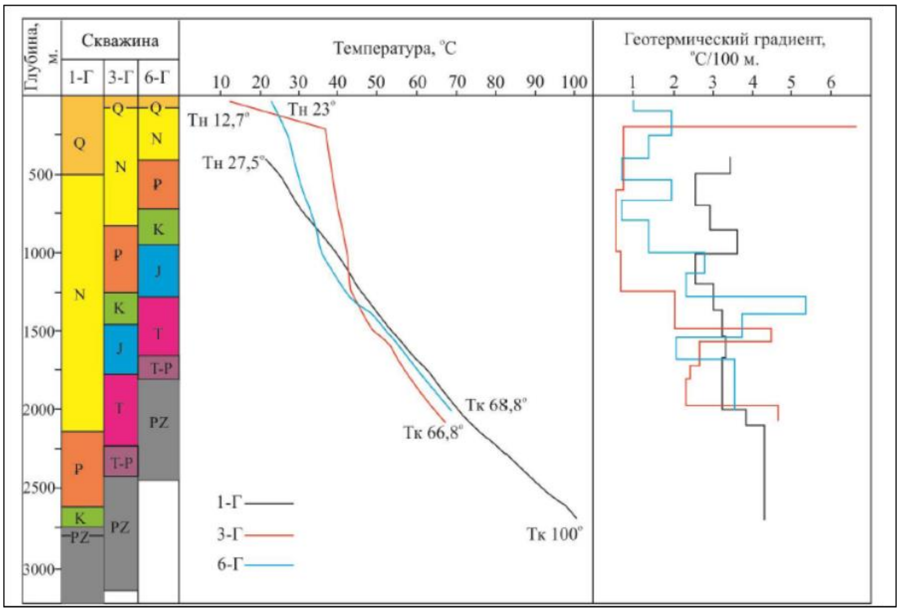

Figure 3: Temperature logging results and estimated geothermal gradient (°C/100m) for wells 1-Γ, 3-Γ and 6-Γ in the Zharkent sub-basin (Ministry of Energy and Mineral Resources of the Republic of Kazakhstan, 2016).

Figure 4 presents the results of a simple analysis of temperature conditions in the Almaty and Zharkent sub-basins of the Ily basin. It shows the well-head temperature of several productive geothermal wells in these sub-basins plotted as a function of well-depth. Even though well-head temperature is usually somewhat lower than reservoir temperature, the figure demonstrates clearly higher resource temperatures found in the Zharkent sub-basin. These results are partly caused by deeper wells and partly by higher temperature gradient.

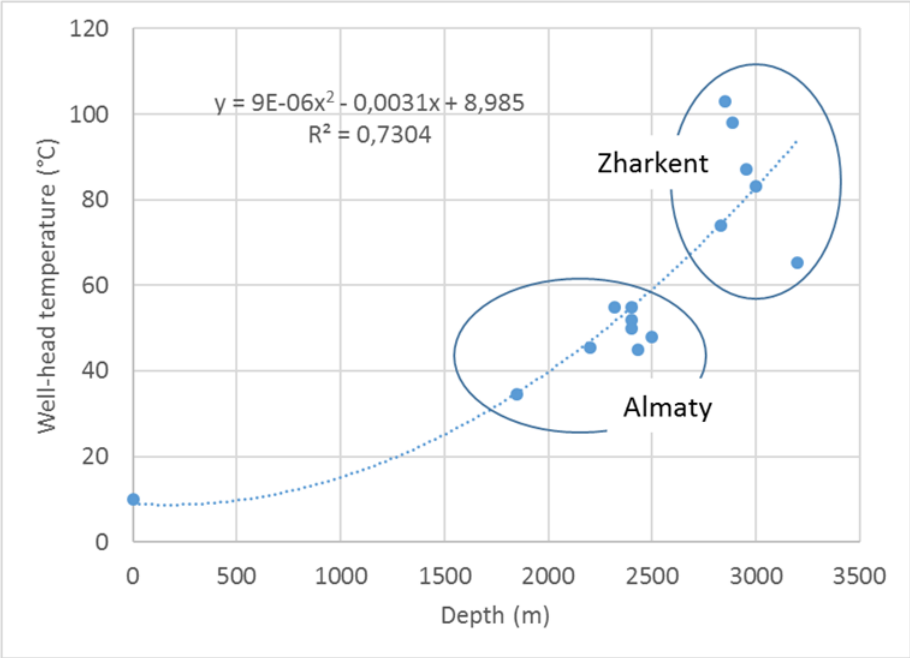

Figure 4: A view of temperature conditions of wells in the Zharkent sub-basin presented by plotting well-head temperature as a function of well depth. Note that well-head temperature is considerably lower than resource temperature and that the inflow into the wells may not always be at their bottom.

3.2 Hypothetical case study of resource assessment

Table 1 above presents estimates of the extractable energy for all the main sedimentary basins of Kazakhstan, including the Zharkent sub-basin. As these constitute single values for the whole sub-basin, a more detailed assessment was performed specifically for the Zharkent sub-basin by using the volumetric assessment method. The results are presented in Figure 5 where the extractable energy per km^2 is presented as a function of reservoir temperature, which in turn depends on depth and local temperature gradient. The following key parameters were used:

- Reservoir thickness = 500 m
- Energy recovery factor = 10%
- Utilization period = 50 years
- Reference temperature = 30°C

The results as presented in Figure 5 indicates that the extractable energy for the Zharkent sub-basin is in the range of 20 to more than 260 TJ/km^2/yr, depending on resource temperature, and assuming a utilization period of 50 years. The significance of this regarding utilization are discussed later, but hypothetically each km^2 could provide space heating for 200 to 1,600 inhabitants[1]. The whole basin could similarly provide heat for roughly 1.5 million inhabitants (based on Table 2). These numbers should not be taken literally, however, they're only presented to demonstrate the potential.

Figure 5 can further be used to estimate approximately the surface of the drilling area needed to sustain certain utilization schemes, based on an expected average flow-capacity of production wells drilled in the area. As an example, the 2,360 TJ/year needed to heat the town of Zharkent would require a drilling area of about 15 km^2, which is somewhat less than the area of the town. This estimate assumes a resource temperature of about 100°C. A similar resource area can be calculated for 10 MW_e electrical plant, utilizing 125°C geothermal water. About 3,000 TJ/yr will be needed or an area about 14 km^2.

Because of the closed nature of most sedimentary geothermal reservoirs, also most likely in Kazakhstan, reinjection is essential for their sustainable use. Otherwise water-level in the reservoirs will decline continuously with time and the hot water extraction can't be maintained in the long-term. This may not be immediately necessary in all locations in the Zharkent sub-basin, because of the natural recharge, but will become so with time and increased geothermal development. It will certainly be required from the beginning of large-scale utilization of most other sedimentary geothermal resources in Kazakhstan.

Reinjection is associated with some risks and challenges, the main risk being possible cooling of near-by production wells. The most efficient way of assessing the danger of cooling of production wells due to reinjection is to perform so-called tracer tests and associated cooling modelling. The main challenge associated with reinjection into sedimentary geothermal reservoirs is the clogging of sandstone layers next to reinjection wells. A solution to this problem was developed in Germany/Denmark in the 1990's. An updated version of the European solution is now successfully being adapted on a large scale in China, to name an example (Seibt and Kellner, 2003; Axelsson, 2012).

[1] Assuming that approximately 1 TJ/yr is sufficient heat for 10 individuals under conditions in Kazakhstan.

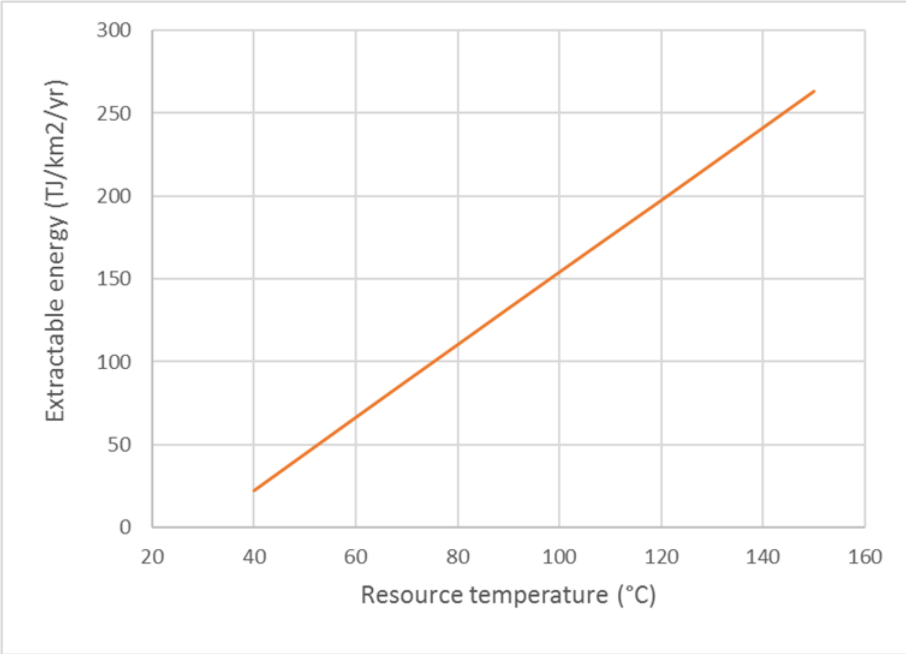

Figure 5: Extractable thermal energy per km^2 presented as a function of reservoir temperature (which in turn depends on depth and local temperature gradient) estimated by the volumetric assessment method for the Zharkent sub-basin.

4. GEOTHERMAL UTILIZATION POSSIBILITIES

Finding an adequate application for geothermal resources is not always a straightforward task since utilization possibilities will highly depend on various factors such as:

- The characteristics of the resource such as temperature, flow, chemistry and other parameters related to its sustainable utilization; and
- Economic considerations related amongst other things to the potential market for the product resulting from the resource utilization or how easily available the resource is.

The utilization possibilities of geothermal energy depend highly on the resource temperature as is shown in Figure 6 below.

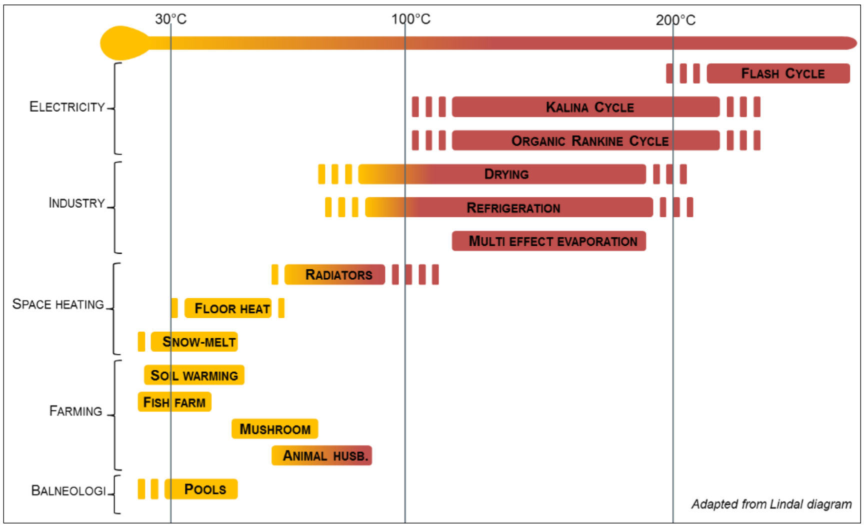

Figure 6: Geothermal utilization (adapted from the Lindal diagram).

The temperature of Kazakhstan geothermal resources is not suitable for production of electricity with steam turbines. This is not unusual. Many places around the world apart from Kazakhstan have low and medium temperature geothermal systems with temperature between 40°C and 160°C. Such systems may be suitable for production of electricity with binary power cycles and/or various direct heating applications.

4.1 Power generation with binary power cycle

The binary technology allows for production of electricity from low temperature resources that could otherwise not be used for such purpose. In a conventional steam power plant, the turbine is driven directly by the steam for power production whereas in a binary plant, the geothermal fluid is used indirectly. It vaporizes a working fluid in a closed-loop that is then used to drive the turbine for power generation. Various working fluids are available and are presented further in the section on cycles.

Typical heat sources suitable for electricity production with binary plants are:

- Geothermal two-phase resource 180°C;
- Geothermal resource between 100 - 180°C; and
- Waste heat from industrial processes.

Utilization of the binary technology for production of electricity from geothermal energy is therefore an option worth assessing for project developers with low temperature geothermal resources in their portfolio.

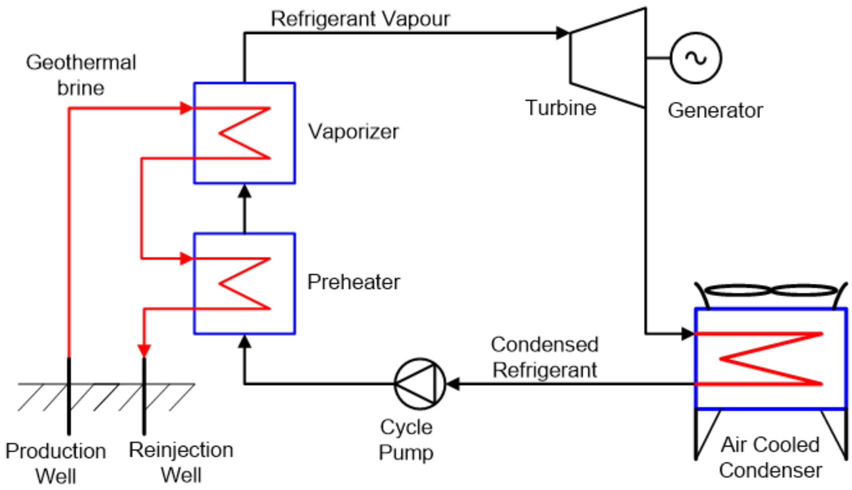

Figure 7: Simplified single stage ORC Cycle.

As an example, the authors have calculated and set forth simplified table showing how much geothermal water flow is needed for 3 different temperatures in the range of 100 – 150°C (Table 2). The parasitic power only includes the process internal use, like cycle pump power and fans, but excludes all external power consumptions, like well pump power, which can be significant

Table 2: Geothermal water temperature, heat input, net power output and conversion ratio.

Resource Temperature, °C	Geothermal water flow, kg/s	Re-injection temperature, °C	Heat input kW	Net power output, kW	Net conversion ratio %
150	20.3	59.9	7,618	1,000	13.0
125	32.9	57.0	9,396	1,000	10.6
100	59.5	51.5	12,120	1,000	8.2

4.2 Direct use of geothermal resources

Direct use of geothermal resources is usually a very efficient process and it makes sense to investigate such utilization when local markets are available. Replacing conventional heat sources like fossil fuel or coal with geothermal is considered to have a positive impact on climate change, improve air quality and enhance energy independence of the local community.

The potential market for direct use of geothermal is vast. Most direct use applications can be applied for geothermal fluids in the low to moderate temperature range 40 - 160°C. Direct use of geothermal for district heating and industrial purposes should therefore be a priority for developers during the planning stage of a project. It is also a good way to distribute risk by having revenues not only dependent on the length of the heating season and coming from various economic sectors. If already existing potential users are not available, this would translate into the planning of an industrial or eco-park at early stage of the project, in collaboration with the local community to create room for potential users served by a transmission pipe, like a district heating system.

From a historical point of view, the most widespread forms of direct use are space heating, balneology, horticulture, aquaculture and some industrial uses. These applications are usually simple and concern mainly thermal utilization, although some applications also deal with chemicals, gases or minerals contained in the geothermal fluid.

District heating systems supply thermal energy to a community for space heating and in some cases for domestic hot water as well. Geothermal district heating system harness most of their energy from geothermal resources. For various economic reasons, peak power can in some cases be supplied by other sources of energy.

Geothermal district heating systems usually combine wells, gathering, transportation and distribution systems, heat centrals and peak load equipment to supply heating or cooling to a group of buildings.

A simplified scheme featuring the main components of a geothermal district heating is presented in Figure 8.

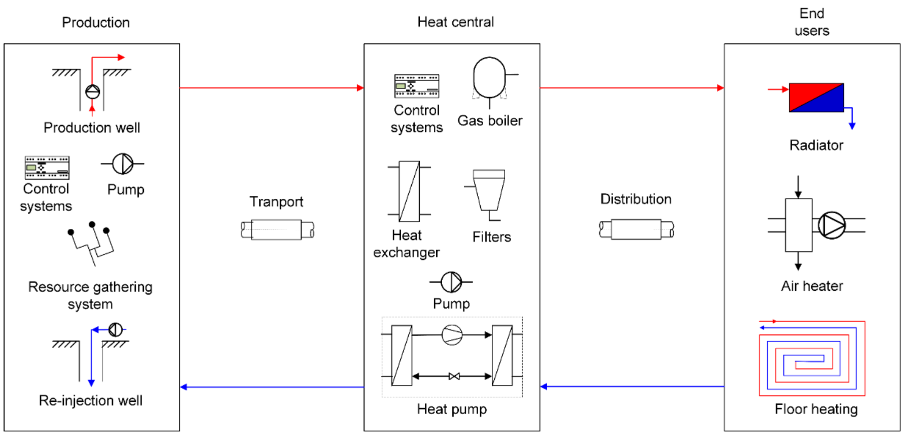

Figure 8: Main components of geothermal district heating project.

Various concepts may be applied to use geothermal resources for space heating, depending on the characteristics of the geothermal fluid, the elements of the system already in place or other technical or economic aspects. Transport of the energy between the geothermal production and the heat central is usually done with large mains. The distribution on the other hand is more extensive and with smaller diameters to reach each single end-user.

5. HYPOTHETICAL GEOTHERMAL UTILIZATION CASE STUDIES IN THE ZHARKENT SUB-BASIN

5.1 Binary power generation

The authors of the report assumed the following parameters for a hypothetical case study analyzing binary power generation applications as follows:

- Net power output: 10 MW_e
- Resource temperature: 125°C.
- Outdoor temperature: 7°C

Based on available information on the geothermal resource, a temperature of 125°C would be available at 4,000 m depth in the Zarkhent basin. A binary plant would require three large geothermal doublets at 4,000 m depth and able to supply altogether 330 kg/s of 125°C geothermal fluid. Table 3 below presents a preliminary cost estimates for the proposed geothermal power plant. Drilling cost and well field development, including well pumps and resource gathering systems have been adjusted to Kazakhstan.

Table 3: Preliminary CAPEX for the proposed 10 MWe geothermal power plant in Zharkent sub-basin.

	Units	Quantity	Unit price, MUSD	Total cost MUSD
Geothermal production system [1]	Number of doublets	3	10	30
Power plant	MW (net)	10	3.0	30
Total CAPEX				**60**

1: Production and re-injection wells including resource gathering system for 330kg/s of 125°C geothermal fluid to at least 4 000 m depth.

Regarding the operation cost, it is foreseen that the geothermal loop will require pump of 330 kg/s at a depth of 200 m, resulting in a power request of 1.3 MW. The estimated operation and maintenance costs are estimated to be 3% of CAPEX or 1.8 MUSD and total of 2.3 MUSD when adding other cost such as billing etc. In this case study a detailed financial and economic analysis was not applied. However, it is possible to establish a preliminary estimate based on the following premises:

- Powerplant operating: 8300 hours pr. year on rated output
- Annual net energy from the Binary Cycle: 83 GWh/year;
- Annual electricity for well pumping: 11 GWh/year;
- Annual electricity sold to the grid: 72 GWh/year;
- Discount period 25 year;
- IRR 8% project IRR;
- Calculated energy price: 11 US¢/kWh.

The calculated energy price resulting from this preliminary estimate is 0.11 USD per kWh and is provided here for the sole purpose of giving an order of magnitude of the price of electricity from geothermal with the setup proposed here.

5.2 District heating of Zharkent town

Zharkent is a small town in the center of the E-Ily basin. The surface area of the town is estimated to be around 2,000 ha (20,000,000 m2). The population is close to 35 000 or 17.5 persons per ha of land. It is difficult to estimate how much floorspace must be heated without access to real building data. Evaluating the heat demand is also challenging with existing buildings of different age and type resulting in energy efficiency spanning the entire scale. The building density is low since buildings are quite sparse, but a rough estimate based on site visit and assessment of the maps provided give a building density of 0.2. On this basis, the heated floorspace in the town is assumed to amount 4 Mm^2.

5.2.1 Power and energy demand

To secure at least an 18°C indoor temperature, the heating system must be able to provide enough power to maintain 15°C. The remaining 3°C are emitted from people, lighting, cooking and other internal heat.

The assessment of power and energy demand is generally based among other things on data from the local construction standards. As this information was not accessible for this work, the authors have assumed the power and energy demand based on weather data from nearby weather stations and typical heat loss coefficient of buildings of 2.3 W/m^2 °C, which is not very efficient insulation and deemed to reflect the age and conditions of the buildings in Zharkent. Based on these premises, the peak heating power demand is estimated to be 70 W/m^2. For comparison the heat loss coefficient for buildings in Reykjavík, Iceland is around 1.8 W/m^2 °C. Many new modern large apartment buildings in China have reported heat requirement as low as 1.6 W/m^2 °C.

Figure 9 shows the duration curve for heating in Zharkent, based on outdoor temperature profile and building heat loss coefficient. The area under this curve is proportional to the number of degree-hours required for heating and gives a measure of the amount of energy required for space heating.

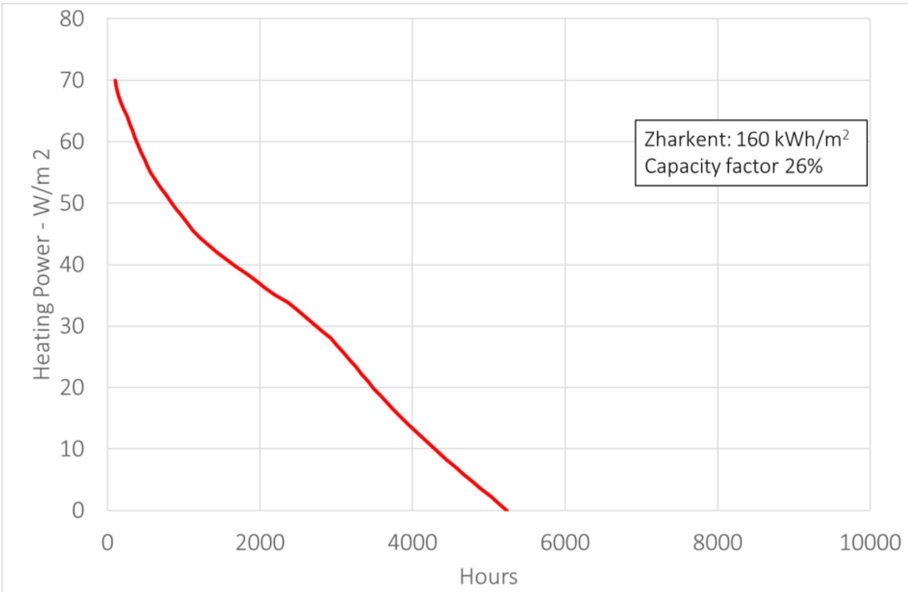

Figure 9: Load duration curve for Zharkent, net heating power and energy.

This curve enables to assess the total energy requirements for the system which is also an important element for the financial analysis because it indicates the energy that can be sold to the end users. The annual heating energy demand is represented by the area under the load duration curve, or 160 kWh/m^2.

The capacity factor is calculated as 26% for the town of Zharkent. The fact that this value is low has an impact on how the energy combination will be planned for. It will hardly be feasible to provide energy solely from geothermal in these conditions because this would imply drilling many wells, resulting in high investment cost compared to their overall use over the year.

5.2.2 Heat Central Concept

A geothermal district heating system is usually composed of a combination of primary geothermal, secondary geothermal with heat pump and gas boilers to extract as much from the geothermal fluid before re-injection. A correct combination of the above is influenced by the load duration curve, the capacity factor and the cost of the various heat sources.

The temperature of the geothermal fluid is assumed to be 100°C @ 4,000 m depth near Zharkent. The geothermal flow is 40% of the secondary district heating flow. At maximum power the geothermal flow is cooled directly from 100°C to 40°C by heating 50% of the secondary distribution water from 35°C to 83°C. It is then further cooled to 10°C in a loop connected in serial where a heat pump is used to transfer the 40/10°C drop to a 35/67°C temperature increase in the secondary loop. The secondary fluid of 83°C is mixed with this 67°C flow from the heat pump resulting in 75°C secondary fluid upstream of a gas boiler. Finally, the gas boiler is used to raise the supply temperature up to 85°C.

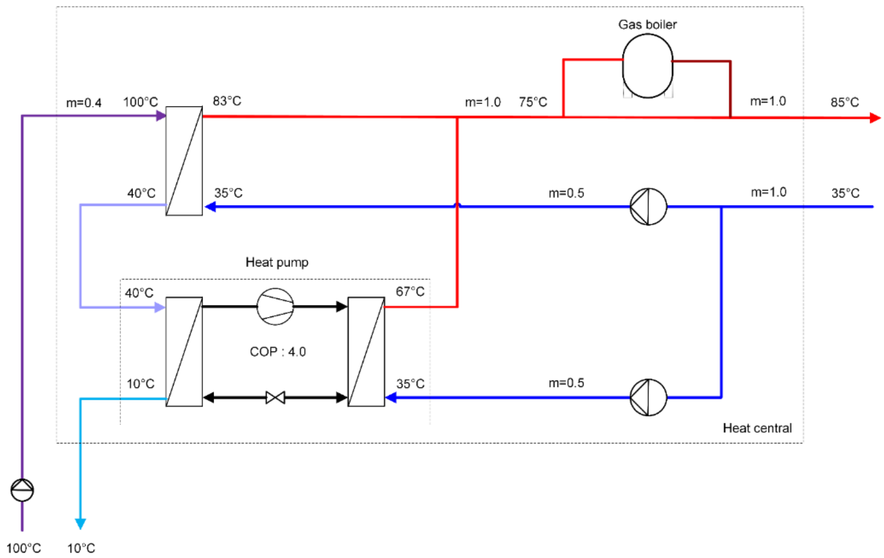

Figure 10: Heat Central Concept for a hypothetical case of a geothermal district heating in Zharkent.

The proposed concept enables to make the most of the geothermal wells without compromising the sustainable use of the resource. The gas boiler is only intended for the coldest weather period, to boost the temperature of the system without increasing the amount of geothermal fluid extracted from the system. Return temperature of a district heating system cannot be much lower than 30-35°C but the installation of a heat pump on the return pipe main enables to optimise the energy extraction from the geothermal fluid and return it to the geothermal system at about 10°C. The main goal of such a setup is to squeeze as many degrees from the geothermal fluid as possible before reinjecting it.

Table 4: Power and energy for a hypothetical case of heat central in Zharkent.

	Heating power W/m^2	Power %	Energy kWh/m2 pr. y	Energy %
Primary geothermal loop (100°C to 40°C)	37.8	48	133	73
Secondary geothermal loop (40°C to 10°C)	18.9	24	31	17
Electrical energy from heat pump	6.3	8	10	6
Peak load boiler, gas	15.4	20	6	4
Total	**78.4**	**100**	**180**	**100**

It should be noted that on top of the net power and energy set forth in Figure 9, the heat central will have to be able to cover the heat losses in the distribution system. The heat losses have been assumed to be 12%, a rather high value compared to other places in the world mainly because of the local weather conditions. The maximum power is thus 78.5 W/m2 at heat central level, or 314 MW for Zharkent. Based on this, the circulation flow is thus about 1 500 kg/s.

5.2.3 Cost estimate end economy

In general, a geothermal district heating system will be optimal from the economical point of view with an installed geothermal power ranging from 40 to 80% of the total peak power. This mainly depends on the type of additional energy and on the local conditions (drilling costs among other things). Nevertheless, since geothermal energy is always used for the base load, the share of energy provided by the geothermal system can turn out to be rather high, from 70 to 90%, depending on the shape of the load duration curve.

Based on the cost information provided, preliminary cost estimates of the proposed geothermal district heating in Zharkent is set forth in Table 5.

Table 5: Preliminary CAPEX estimate for the proposed geothermal district heating in Zharkent

	Units	Quantity	Unit price, MUSD	Total cost MUSD
Geothermal production [1]	Number of doublets	5	8.25	41.3
Pipe main/transport [2]	km	5	2.2	11.0
Heat centrals	MW	314	0,12	37.7
District heating system	ha	2,000	0,05	100
Total CAPEX				**190**

1: Drilling wells including resource gathering system for 600 kg/ of 100°C geothermal fluid assuming large wells at 3 600 m depth.
2: Transport of fluid from well field to heat central(s)

The total investment cost is estimated to be 190 MUSD for the whole system. This results in 47.5 USD per square meter of heated floorspace or 5,000 USD per household.

As discussed before, there are two major variable operational cost parameters involved, cost of electricity and natural gas. Peak load boilers using conventional sources of energy such as natural gas or coal are well known technologies. In terms of investment, they are among the cheapest technologies available on the market today to produce heat at large scale. Their maintenance cost is usually low. However, their operational cost will highly depend on the gas price that may fluctuate depending on the international market. The same goes for heat pumps powered by electricity. It is assumed here that the electricity price and gas price are according to information provided by MoE.

Table 6: Annual OPEX estimate for the proposed geothermal district heating in Zharkent.

	Units	Quantity	Unit price, USD	Total cost MUSD
Gas for peak load boilers	kWh/year	24,000,000	0.018	0.43
Electricity for heat pumps	kWh/year	40,000,000	0.054	2.16
Electricity for well pumping	kWh/year	5,000,000	0.054	0.27
Electricity for DH pumping	kWh/year	3,000,000	0.054	0.16
Maintenance cost, 2 % of CAPEX	2.0%	-	-	3.80
Other cost, billing etc	-	-	-	1.00
Total annual OPEX				**7.82**

No detailed financial and economic analysis is available for the time being. However, it is possible to establish a preliminary estimate based on the following assumptions:

- Capital cost: 190 MUSD;
- Annual operating cost: 7.82 MUSD, starting from year 2 for 24 years;
- Annual energy sold to end-users: 160 kWh/m2 x 4 Mm2= 640 GWh;
- Energy price: 4.5 US¢/kWh (calculated based on the below IRR);
- IRR: 10% project IRR requirement over 25 years.

The energy price of 4.5 USD US¢/kWh sold to the end users is provided here for the sole purpose of giving an order of magnitude of the geothermal energy district heating energy price. It should be noted that this value is comparable to the price of local house heating with gas. Heating with gas locally costs 1.80 US¢/kWh according to MoE. Geothermal has the advantage of being a cleaner and local source of energy, with minimum impact in terms of greenhouse gases than gas and contributing to enhancing energy independence of the local community.

5. PROPOSED IMPLEMENTATION STRATEGY AND RECOMMENDATIONS

A set of recommendations to the GoK on the next steps for possible deployment of geothermal utilization in the country was provided as part of the Kazakhstan study. It is recommended that Kazakhstan primarily aim for direct use of geothermal resources; house heating, greenhouse heating, fish farming and other direct use applications. It is also recommended that a comprehensive country-wide compilation and evaluation of data regarding resource assessment be undertaken. Data is believed to exist in the archives of Kazakhstan, mainly from wells drilled for petroleum exploration, having hydrothermal indications. Following this, further exploration should be planned, to fill in gaps in the existing data for selected resource areas. Conceptual models should then be developed, followed by drilling of exploration wells. These wells should be subjected to logging, testing, monitoring following resource assessment and modelling.

An evaluation of present legal-, institutional-, regulatory- and permit-framework with suggestions for improvements is recommended. This should also involve an evaluation of possible support and tariff-framework as well as data management. The development of geothermal utilization will benefit from the review of components of the legal and regulatory framework such as the National Energy Policy and various regulatory provisions on i.e. electricity, district heating, environment, water and agriculture, rural development, finance, land and property, mining, procurement and foreign investment. The GoK is advised to consider establishing an entity with the authority necessary to manage geothermal permitting and licensing as well as monitoring. Specific attention should be paid to the management of concessions and the decisions related to electric production. For long-term sustainable utilization of geothermal resources, comprehensive resource management must be applied.

General risk assessments should be conducted on the different aspects of geothermal development, e.g. on risks associated with exploration, drilling, public or private sector development, risks associated with tenders for international markets, environmental issues etc.

It is critical for the GoK to design a pricing mechanism that attracts investors and enables at the same time affordable energy prices for the users. Various mechanisms are currently used for electricity production from geothermal, such as feed-in-tariffs, energy auction tariffs, negotiated prices, etc.

As may be expected in a country with few projects in operation, there are currently very few clearly identified institutes and companies with experience in the field of geothermal in Kazakhstan. The set of basic competence required for developing geothermal projects includes major scientific and technical competence in disciplines such as geology, geochemistry, geophysics, reservoir engineering, environmental science, geothermal drilling and geothermal engineering. It is therefore recommended that the strategy for implementation of geothermal utilization in Kazakhstan is done in such a way that the GoK receives support and training from experienced partners in this field worldwide.

6. CONCLUSIONS

The discussion above shows that Kazakhstan holds considerable low-temperature geothermal resources, mainly of the sedimentary type. Hot springs and hot water from wells are already used for direct purposes on a very limited scale in certain areas in Kazakhstan. There is significant need for adequate heating services for the Kazakhstan population, provided in a sustainable manner with limited CO_2 emissions. There is therefore an opportunity to identify whether and how the geothermal resources can be harnessed to meet some of the household energy needs. The parallels between sedimentary resources in Kazakhstan and e.g. China and Europe, where they are extensively utilized, should be employed during future geothermal development in Kazakhstan. It is recommended that Kazakhstan primarily aim for direct use of geothermal resources; house heating, greenhouse heating, fish farming and other direct use applications. Moreover, the development of an efficient and comprehensive regulatory framework for geothermal utilization and district heating in Kazakhstan is among the highest priorities.

The greatest extractable energy per km^2 is estimated for the Ustyurt-Buzashin and Mangyshlak basins in SW-Kazakhstan and in the W-Ily (Almaty) and E-Ily (Zharkent) basins in SE-Kazakhstan, according to a simple countrywide evaluation performed. This is mainly due to the likely existence of higher temperature resources in these basins relative to the other basins. Currently, the geothermal resources in the Zharkent sub-basin appear most interesting of potential resources in S- and SE-Kazakhstan because of higher resource temperature, low concentration of dissolved solids and powerful natural recharge. It is therefore suitable for demonstration projects. The Zharkent geothermal resources were also the focus of a comprehensive geothermal assessment study during 2015 – 2016; thus, more geothermal information/data is available there than for other locations in Kazakhstan. It should be pointed out, however, that even though this appears most promising now, further research may locate other promising geothermal resources.

The estimated extractable energy for the Zharkent sub-basin is in the range of 20 to more than 160 $TJ/km^2/yr$, depending on resource temperature (depends on depth) and assuming a utilization period of 50 years. Hypothetically, each km^2 could provide space heating for 200 to 1,600 inhabitants. Based on these assumptions, the whole basin could thus provide heat for roughly 1.5 million inhabitants.

Because of the closed nature of most sedimentary geothermal reservoirs, reinjection is essential for their sustainable use. This may not be immediately necessary in all locations in the Zharkent sub-basin, because of the natural recharge, but will become so with time and increased geothermal development. It will certainly be required from the beginning of large-scale utilization of most other sedimentary geothermal resources in Kazakhstan.

Various benefits would be associated with the introduction of geothermal district heating systems in Kazakhstan. The main advantage would be the reduction of air pollution and greenhouse gas emission. Using geothermal with full reinjection will allow for considerable reduction of greenhouse gas emission. Furthermore, geothermal energy is an indigenous source of clean energy and can contribute as such to "clean energy" independence of Kazakhstan.

Two hypothetical case studies in the Zharkent sub-basin are presented and analyzed. One involving space heating for the 35,000 inhabitants of Zharkent town and the other involving a 10 MWe binary electrical power plant utilizing the deepest part of the sub-basin, containing the hottest resources (125°C assumed). The 2,300 TJ/year needed to heat the town would require a drilling area of about 15 km^2, which is somewhat less than the area of the town. A similar drilling area can be estimated for the 10 MW_e electrical plant. About 3,000 TJ/yr will be needed or an area about 14 km^2.

From the technical point of view, the feasibility of the case studies presented here will highly depend on the quality of the geothermal resource. Nevertheless, built on assumptions that are deemed prudent based on information readily available, the heat price with geothermal district heating at end-user level is estimated at 4.5 US¢/kWh and the electricity price from a geothermal binary plant at 11 US¢/kWh. It should however be pointed out that the prices shown here would appear to be high compared to energy prices in Kazakhstan, as far as they were available for this study, likely due to the current energy policy.

The implementation of a geothermal district heating will also be highly dependent on the ability to achieve an energy density as high as possible with a massive connection to the users nearby the distribution system. This is considered a critical issue together with the energy efficiency of the buildings and their modernization. In this regard, the authors consider that metering and tariff will be critical tools to promote sustainable use of the resource and ensure that a large part of the community can be supplied with energy from the geothermal system.

A carefully planned geothermal project aiming at integrating the resource exploitation activities in a community can potentially create more jobs than just of the power and/or district heating operators. An eco-park close to a geothermal project can create a variety of local jobs, such as food production and food processing, tourism, well-being industry, etc. The diversity of activities that may result from the utilization of geothermal resources is an important factor to be considered by policy makers and project developers.

However, various barriers can affect the successful implementation of geothermal projects. Considerable risk is associated with the development of geothermal resources, including drilling, and is greater than the risk associated with other renewable energy resources. This risk is variable and is often higher in fracture-controlled systems than in sedimentary systems such as identified in Kazakhstan. The risk can be minimized by comprehensive research, both prior to drilling and during the drilling phase of the development of a geothermal project.

There are also risks associated with the well-drilling itself and the assessments of the capacity of geothermal resources. The best way to avoid overexploitation associated with the resource risk is stepwise development. i.e. developing a resource in relatively small steps over a longer period. The first step should be well below the estimated capacity as well as providing essential and more accurate additional information on the resource capacity as the first step progresses.

No specific legal framework appears to be in place in Kazakhstan concerning the utilization of geothermal resources. This could be a serious barrier for investors wishing to develop projects in this field in the country, due to the resulting uncertainty on issues such as ownership, licensing, fees, monitoring, etc.

ACKNOWLEDGEMENTS

The authors of this paper would like to acknowledge the following individuals in Kazakhstan for readily providing variable information and data on geothermal resources in Kazakhstan: Ms. Ainur Sospanova, Head of the Renewable Energy Resources Department, Ministry of Energy; Ms. Leila Omark of the same department; Mr. Aitmurat Issayev, Deputy Chairman, Committee of Geology and Subsoil Use, Ministry of Investment and Infrastructure Development; Mr. Sergei Khan, Director of the Institute of Hydrogeology and Geoecology in Almaty, Mr. Valeriy Vyalov, Chief Hydrogeologist of the same institute; and Ms. Bakhyt Yessekina, Head of the Green Academy. The same applies to various other local geological and geothermal experts met during the site visit of this study. Additionally, the authors would like to thank the staff of the World Bank Country Office for their valuable assistance, in particular Ms. Yelena Yakovleva and Ms. Olga Besedina, and finally our main interpreter and guide, Ms. Oxana Miller.

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