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GEOTHERMAL PROJECT DEVELOPMENT WITH A CASE STUDY FROM TSETSERLEG, MONGOLIA

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ABSTRACT

This report describes geothermal project development issues in Mongolia and economic feasibility of a geothermal pilot project in the town of Tsetserleg. Mongolia has 43 hot springs, mainly distributed in the central and western provinces. The hot springs are used for bathing and traditional balneological purposes. There is presently no geothermal electric power generation in Mongolia. The methods most commonly adopted in exploring for geothermal energy, financing aspects and risks for geothermal projects are reviewed. Tsetserleg town is located at N47º28′ and E101º27′ in the central-west part of Mongolia. There are three types of heat consumers in Tsetserleg, those supplied by central boiler stations, individual boilers or individual stoves. In 2002, the central boiler stations in Tsetserleg produced 51,739 GJ (14.38 GWh) of thermal energy, consuming 7,600 tons of coal.

To start a geothermal pilot project in Tsetserleg, it is suggested that a separate geothermal company be formed. Maximum geothermal water flow in the new suggested district heating system is 60 l/s, the peak load will be served by coal-fired boilers and the heating season will be 9 months a year. IRR of the project is calculated to be 14%, ROE is 41% and NPV at 8% inflation rate is 1.65 million USD. Feasibility of the project is most sensitive to the heating tariff, meaning that the feasibility of the project greatly depends on the customers' payment abilities and the existing tariff system. Feasibility of the project would be enhanced by cost optimization.

1. INTRODUCTION

1.1 World-wide direct utilization of geothermal energy

Geothermal energy has been used for bathing and washing since the dawn of civilization in many parts of the world. The heated groundwater can be used for the heating of homes and greenhouses, for bathing, vegetable drying, fish farming, and for a number of other uses. Geothermal energy is also used for electricity production, but this requires a good, high-temperature geothermal resource.

Geothermal resources have been identified in over 80 countries and there are quantified records of geothermal utilization in 71 countries in the world. An estimate of the world-wide installed thermal power for direct-use at the end of 2004 is 27,825 MWt, almost a two-fold increase from the year 2000, growing at a compound rate of 12.9% annually. The thermal energy used is 261,418 TJ/year or 72,622 GWh/year, almost a 40% increase from the year 2000, growing at a compound rate of 6.5% annually (Lund et al., 2005). The distribution of thermal energy use by category is approximately 33% for geothermal heat pumps, 29% for bathing and swimming (including balneology), 20% for space heating (of which 77% is for district heating), 7.5% for greenhouse and open ground heating, 4% for industrial process heat, 4% for aquaculture pond and raceway heating, and less than 1% each for agricultural drying, snow melting and cooling, and other uses.

Production costs for geothermal heating are highly variable, ranging from 1.4-14 USD/GJ (Turkenburg et al., 2000), but commonly lower than 6 USD/GJ. The cost is highly dependent on the quality of the geothermal resource and the investment needed for recovery, especially the number and depth of wells required and the distance from the wells to the point of use.

1.2 Mongolia - an overview

Mongolia is situated in the northern part of the Asian plateau, where the mean elevation is 1500 m above sea level, covering an area of 1.57 million km^2. The northwest and central parts of Mongolia are mountainous, the eastern part is a vast steppe plain and the southern part is a semi-desert area. The population of Mongolia totals 2.4 million, 45% rural, 55% urban, and 30% of the total population lives in the capital city. The present yearly rate of population growth is estimated as 2.8%.

The climate is continental with a monthly mean temperature of -12°C in January and +25°C in July, with large daily and seasonal variations. The annual mean precipitation ranges from 38 to 389 mm depending on the region. The territory of Mongolia is administratively divided into 21 provinces (aimag) and a capital city. Each province is generally divided into 12 - 22 counties (soum) and the capital city is divided into districts.

The centralized electricity network in Mongolia consists of western, central and eastern grid systems, where electricity is produced by coal-fuelled combined heat and power (CHP) plants or is imported. These serve 50% of the total population or 40% of the land area. District heating systems in major cities are based on CHP plants or coal-fuelled boilers serving 40% of the total population. Other local centres are in critical need of an energy supply; diesel power stations and five small hydro power plants are currently supplying domestic consumers with electricity for mainly 4-5 hours daily, with the exception of two provincial centres which are supplied round the clock. Some major institutions such as hospitals, primary schools, telecommunication and governmental offices are supplied by small photovoltaic systems and wind turbines. Heating demand is covered by small boilers and simple household stoves fired by coal, firewood, agricultural waste, animal dung etc. Nomadic families, 45% of the total population, are partially self-sufficient with small-sized photovoltaic, wind electric systems, but most of them have no reliable access to modern electricity and space heating systems. This situation encourages increasing the efficiency of existing energy systems and investigating alternative and renewable energy sources such as solar, wind, hydro, as well as geothermal energy.

The Mongolian government has actively considered geothermal development in the country. The Ministry of Food and Agriculture have intentions to develop geothermal research activity in the country and a "Geothermal" sub-programme of the "Mineral Resources" programme was asserted by the Government of Mongolia in 1999 (Ministry of Food and Agriculture of Mongolia, 1999). Additionally, a "National Programme for Sanatorium Development during 2003-2010" was asserted by the Government of Mongolia in 2002 (Ministry of Health 2003).

Regional surveys have identified 5 areas with anomalous heat flow characteristics and geothermal resource potential in the 1) Mongolian Altai (54±24 mW/m^2); 2) Khangai region (52±6 mW/m^2); 3) Khentii region (65±10 mW/m^2); 4) Khuvsgul nuur region (60±12 mW/m^2); and 5) 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 the most interest for future geothermal development.

Mongolia has 43 hot springs, mainly distributed in the central and western provinces. The hot springs are mainly used for bathing and traditional balneological purposes. Small-scale greenhouse and space heating systems are used in some places. There is presently no geothermal electric power generation. The main geothermal activity is in the Khangai area, which has a population of approximately 241,000 in the centres of Arkhangai, Uvurkhangai and Bayankhongor aimags and 44 soum (Tseesuren, 2001).

1.3 Tsetserleg - an overview

Arkhangai aimag is situated in the central part of the Khangai mountain range. In the centre of Arkhangai aimag is the town of Tsetserleg, N47º28′ and E101º27′, at an elevation of 1691 m above sea level, 470 km east of the capital city, Ulaanbaatar. The location of Tsetserleg is shown in Figure 1. The number of inhabitants in Tsetserleg is 18,100, with a 25% increase in the population during the winter months (MNSO, 2000). The number of employed residents, aged 15 and over, is 4650 and unemployed 1600. A household's average income in Tsetserleg is 165.8 USD/month or 1989.7 USD/year and is higher than in most comparable towns in Mongolia (ADB, 2002). Tsetserleg is connected to a centralized electricity network and electricity distribution covers the whole town. The total number of households is 4373, divided into 2565 conventional houses and 1808 conventional nomadic dwellings, called Gers (MNSO, 2000).

FIGURE 1: Map of Mongolia showing the location of Tsetserleg town

1.4 Existing heating systems in Tsetserleg

There are three types of heat consumers in Tsetserleg, those supplied by central boiler stations, individual boilers or individual stoves. "Ilch-Arkhangai", a state-owned district-heating company in Tsetserleg, operates 8 coal burning boiler stations which provide heating to a total of 57 public-service buildings such as administration, schools, kindergartens, hospitals, shops and apartments (Ilch Arkhangai, 2003a). A good quality sub-bituminous coal is transported from the Bayanteeg Mine, which is located 201 km away from Tsetserleg. In 2002, the district heating company produced 51,739 GJ (14.38 GWh) of thermal energy, consuming 7,600 tons of coal and spending 210,744 USD for coal transportation costs alone. In 2002, the district heating company consumed 924 MWh of electricity as pump power and paid a total of 43,400 USD for electricity, at a price of 4.7 USc/kWh (Rafhonnun, 2004). Information on the district-heating company's performance is shown in Table 1.

TABLE 1: Information on the district heating company in Tsetserleg

Item	Unit	Information
Coal consumption	tons/year	7,600
Heat production	Gcal/year	12,366
	GJ/year	51,739
Coal transportation cost	USD/year	210,744
Electricity cost	USD/year	43,400
Total revenues	USD/year	341,025
Energy price	USD/GJ	6.31

Estimated total carbon dioxide (CO_2) emission by the district heating company is 12,069 tons per year, while the energy content of sub-bituminous coal is 18.4 MJ/kg. Individual boilers at private office buildings consume approximately 3,040 tons of coal and the resulting CO_2 emissions are 4,828 tons per year. Individual Ger and private-housing household's coal consumption is approximately 21,865 tons per year. The CO_2 emissions in Tsetserleg total 51,621 tons per year (Rafhonnun, 2004). The annual coal consumption and carbon dioxide emissions in Tsetserleg are shown in Table 2.

TABLE 2: Annual coal consumption and carbon dioxide emissions in Tsetserleg

Heating system	Number	Coal consumption (tons)	Cost (USD)	CO_2 emission (tons)
Central boilers	8	7,600	304,000	12,069
Individual boilers	-	3,040	121,600	4,828
Gers	1,808	9,040	361,600	14,356
Houses	2,565	12,825	513,000	20,367
Total		32,505	1,300,200	51,621

The total coal consumption of heat consumers in Tsetserleg is 32,505 tons per year and costs USD 1,300,200 or EUR 1,085,490, based on the purchase of coal at 40 USD/ton or 33 EUR/ton, including transportation costs (Ilch-Arkhangai, 2003b). Costs spent for heating per household in Tsetserleg are shown in Table 3.

TABLE 3: Heating costs in Tsetserleg

Consumers	Amount	Unit
Families residing in apartments which are connected to DH	1.13	USD/(m^2·year)
Heating expenditure of families residing in houses	5.0	USD/(m^2·year)
Heating expenditure of families residing in Ger	5.5	USD/(m^2·year)

The heating tariff of the district heating company was asserted by the 22nd resolution of the Governor of Arkhangai aimag on January 21, 2001. Consumers in government or business buildings pay 0.4 USD/m^3·month (without VAT) and consumers in private apartments pay 0.17 USD/m^2·month (without VAT). The tariff for private consumers is thus much lower than for consumers in government or business buildings. The heating tariff is exempt from VAT and it, therefore, seems that the Mongolian

Government subsidizes the district heating company. In 2002, 113,000 m^3 office buildings and 12,000 m^2 private apartments were connected to the district heating system.

Smoke from the polluting stoves hangs over the town all winter long. This is believed to be a cause of the respiratory complaints and diseases that account for half the mortalities of children and a majority of child and adult morbidity (Ministry of Nature and Environment of Mongolia, 2000).

2. GEOTHERMAL ENERGY DEVELOPMENT

2.1 Geothermal energy development in Mongolia

Geothermal energy development in Mongolia is currently in the reconnaissance study stage. But the Mongolian Government has actively considered geothermal development in the country. The Ministry of Food and Agriculture have intentions to develop geothermal research activity in the country and a "Geothermal Energy" sub-programme of the "Mineral Resources" programme was asserted by the Government of Mongolia in 1999. The "Geothermal Energy" sub-programme was devoted to geothermal exploration work and suggested the following stages:

1. Investigate available geological, geophysical and hydro-geological data of the Geo-Fund of Mongolia. Work with foreign specialists for further research (scheduled to start in 2000).
2. Estimate the capacity of the selected geothermal activity area using geophysical methods (scheduled for 2001-2004).
3. Make a feasibility study for industrial and agricultural use of geothermal energy on the selected sites.
4. Start exploration work on the nearest areas of Bayankhongor, Arvaikheer, Tsetserleg and Uliastai (scheduled for 2004-2008).
5. Start exploration work on the nearest areas of Ulaanbaatar, Erdenet, and Darkhan cities.

Unfortunately, the "Geothermal Energy" sub-programme has neither been financed nor implemented until now due to a lack of funding. Implementing a Master plan, which realizes above mentioned geothermal exploration works, would be the next approach to further developing geothermal energy in Mongolia. If such a Master plan is financed by the Government and implemented, it would give rise to commercial geothermal projects.

2.2 Phases of geothermal exploration

Geothermal energy development typically progresses through stages of study, design, construction and field development with various decision points along the way. A geothermal energy utilization process is defined as the process where geothermal energy is extracted from geothermal fluid and utilized for various applications. Therefore, the process depends heavily on the specific characteristics of the geothermal reservoir, chemical composition of the geothermal fluid, distribution and control systems, and characteristics of the applications intended for the geothermal energy.

The following outlines the methods most commonly adopted in exploring for geothermal energy, where the existence of such an energy source is anticipated. The type of methodology needed for the purpose is resource type (high or low enthalpy) and site specific.

2.2.1 Preliminary study

A preliminary study for geothermal exploration consists of 1) a reconnaissance survey to identify specific prospect areas and to assign them priorities for more detailed investigation 2) prospect investigations to locate drill sites within the prospect area and 3) exploratory drilling to discover a geothermal reservoir. All the data collected during the preliminary study are important when requesting financing for the next stages of the exploration work.

Reconnaissance survey

- Literature search - Critical review of available data by previous geological, hydro-geological, geophysical and geochemical studies.
- Maps and air photos - Aerial infrared imagery scan by satellite of a large geographical area using infrared photographic technology is a very useful first step. The scan locates areas with higher than normal thermal radiation images. The scan is filtered to exclude thermal phenomena other than subterranean heat flow and the most promising hot areas are identified.
- Hot springs and fumaroles - In numerous instances little or no manifestation of underlying geothermal reservoirs is visible on the surface, but more often thermal springs, steaming ground and fumaroles are evidenced. Where this is the case, an experienced geochemist is sent to collect water and gas samples from selected fumaroles, springs, and old wells found within the area being surveyed.
- Geothermometry - Calculating the likely temperature within the reservoir involves the use of methods such as silica, alkali, isotope and gas-geothermometers.
- Natural heat loss - Regional heat flow is mapped using shallow thermal gradient well logging and any existing information.
- Volcanism and regional geology. Two or more geologists, who are experienced in geothermal surveying, are subsequently sent to the identified areas to carry out a preliminary study of the predominant geological structures within the area. The purpose is to verify the existence of geothermal reservoirs in the areas identified, assess their likely extent and rate them in order of importance.
- Reconnaissance report - Reconnaissance reports should point out prospect areas, problems of access, logistics and environmental aspects.

Prospect investigation

- Volcanic and structural geology. A team of geologists is sent to the area to carry out a geological survey. Using aerial photographs and other means the team maps fractures and faults, active and/or extinct surface geothermal manifestations such as thermal springs, fumaroles, steaming ground, alterations and old wells, if any exist. Any existing sub-surface geological, hydro-geological and other data are collected and perused. A thermometer staff is sometimes used around surface geothermal manifestations to draw up isothermal contours. This work yields information about the predominant rock types, their ages and origins. Faults and fractures may be very important as geothermal fluid conductors and/or barriers. Detailed fracture and fault data are particularly important in a high-enthalpy (temperature) geothermal field. The information collected forms the basis for the conceptual hydro-geological and reservoir models and is important for selecting strategic locations of geothermal wells and in the drilling of such wells.
- Chemistry and isotopes of thermal fluids. The collected water and gas samples are analysed carefully and subjected to various evaluations that concern the age of the fluid, its potential for scaling and corrosion and the likely temperature within the reservoir. The last mentioned involves the use of silica, alkali, isotope, and gas-geothermometer methods.
- Heat flow studies - Local surface thermal distribution is mapped by means of surface measurements of soil temperature, snow-melt photography, airborne infra-red surveys and detailed mapping of thermal manifestations. Excessive values of conductive heat flow in the earth's crust show anomalous geothermal conditions in the subsurface.
- Resistivity survey - The common principle for all resistivity methods is to induce an electrical current in the earth and monitor signals at the surface, generated by the current distribution.
- Prospect report - Prospect reports should result in a conceptual model of the reservoir and prospective drilling sites

Investigation of drilling sites

At the start of this stage, sufficient evidence has been collected during previous stages to reveal the existence of geothermal reservoirs in the area and rate them in order of development potential. These need to be investigated further according to their order of potential. The characteristics and size of each reservoir, both as regards area and depth, must now be defined, preferably using surface surveying methods to hold down costs.

- Detailed structural mapping - Detailed mapping of geological formations in the area.
- Detailed resistivity surveys - The method selected depends very much upon the type of reservoir being studied, the local terrain and topography, the anticipated type of permeability (whether sedimentary or fracture-dominated), reservoir depth and closeness of manmade surface structures, etc. Most rocks are resistive and have high resistivity. Conduction of electricity is mostly through groundwater contained in the pores of the rocks and along surface layers due to water-rock interaction. The common principle for all resistivity methods is to induce an electrical current in the earth and monitor signals at the surface, generated by current distribution. Common electrical methods are DC profiling and sounding such as Schlumberger sounding, dipole sounding and profiling and head-on profiling. Electromagnetic methods include natural source electro-magnetic methods such as MT and AMT and controlled-source electro-magnetic methods such as TEM.
- Structural geophysical surveys - Magnetic surveys are widely used in geothermal exploration, often in conjunction with gravity and refraction in mapping geological structures. A magnetic anomaly is a local disturbance in the earth's magnetic field, caused by local change in magnetization. It is characterized by the direction and magnitude of the effective magnetization, the shape of the anomalous body and its position. Gravity surveys are used in geothermal exploration to detect geological formations with different densities. The method can be used to map various structures showing basement depth variation, intrusive rocks, alteration, cementation due to thermal effects, porosity variations, pore fluids, fault or dyke systems and also for monitoring mass extraction from a geothermal field.

Exploratory drilling

- The drilling of exploration wells combined with geo-scientific surveying gives excellent results in locating geothermal reservoirs and hot water up-flow zones, particularly in low-enthalpy geothermal fields. Mobile and small drilling rigs are used. Costs are usually comparable with the cost of resistivity surveying. Cores or cuttings are collected during drilling and analyzed. It gives information about lithology and alteration minerals. Reservoir temperatures and pressures are measured if the drilling leads to the discovery of a geothermal reservoir. Productivity of the geothermal reservoir is evaluated and slim- or production well design is envisioned. Fluid chemistry and isotopes of the geothermal water are analyzed and geophysical logs made.

Results of the preliminary study should include a structural model of the reservoir, drilling properties of the formation and casing programme, boundaries of the reservoir and excess heat stored in the reservoir, predicted temperature, pressure, and chemistry of potential aquifers, porosity and permeability, and estimated potential of the reservoir.

2.2.2 Appraisal study

An appraisal study for geothermal exploration consists of 1) appraisal drilling and reservoir evaluation to prove sufficient production and provide data for assessing the long-term production capacity of the reservoir and 2) an economic feasibility study to determine capital and operating costs for a geothermal energy system and to compare the cost with the cost of other available energy sources.

Appraisal drilling and reservoir evaluation

- The results from previous stages yield data on the reservoir size, likely fluid temperatures, bulk properties of the geological formations, fault/fracture directions, strike, angle and distribution, and fluid distribution within a given geothermal reservoir. Sufficient data has been collected to pinpoint one or more locations for the drilling of test wells. All the investigations carried out up to this stage are based upon indirect measurements and/or observations obtained above ground. They need verification based upon subsurface data collected via the drilling of strategically located test wells. Such test wells provide the necessary geological, geophysical, geochemical, and reservoir data. Moreover, they can yield data on potential fluid yield per well, well spacing and the drilling depth required for production wells in order to obtain geothermal fluid of exploitable properties.

- The results of the appraisal drilling and reservoir evaluation will be detailed mapping of the geological structures and lithology of the area, pressure potential of aquifers, temperature and chemistry of reservoir fluid, reservoir permeability and porosity, enthalpy and mass-flow of wells, production characteristics and its decline with time, corrosion and scaling problems associated with geothermal fluid properties, predicted spacing and minimum economic yield of wells and a revised reservoir model.

Revised reservoir model

- The data obtained from previous stages makes it possible to construct a model of the reservoir. This model combines the geo-scientific and reservoir data into an entity that forms the foundation of the mathematical model formulated to simulate the reservoir's capacity, its potential response to future fluid extraction scenarios, etc. The revised reservoir model gives a detailed structural model of the reservoir, understanding of the nature of aquifers and permeability, physical state and fluid properties, and predicted production capacity of the reservoir.

Economic feasibility study

- Review the well test data to verify production capacity and evaluate evidence for drawdown.
- Determine capital costs and running charges of the optimum-size plant which could be operated from proven well capacities on the basis of a preliminary plant design.
- Compare the costs with the cost of alternative energy sources.
- Determine possible economic uses of the resource for various purposes.
- Investigate the possibility of a long term Power Purchase Agreement (PPA).
- Assess the environmental impact of development - Environmental impact assessment report.

The above mentioned strategy for geothermal exploration assumes that the geothermal field is developed in one big step according to the philosophy borrowed from hydro projects. Consequently the production capacity must be known when plant size is determined. This results in a long exploration time in order to assess the production potential of the field, which also means that a large investment is necessary before money comes into the project, but on the other hand it minimizes risks to the lowest possible extent.

3. FINANCING A GEOTHERMAL PROJECT

Typically, small renewable energy projects, as well as geothermal projects, require equity sponsorship of at least 25% and often 50% of the total value of the project. As the real or perceived risk associated with a project increases, lenders require a larger equity component to finance the project. Equity investors take a greater share of the burden of capital investment and this is onerous for small-scale developers. In Table 4, types of possible financing of renewable energy projects, including geothermal projects, are shown (UNEP, 2004).

TABLE 4: Types of financing for renewable energy projects

Types of financing	Description
Private financing	Private financing from personal savings or bank loans secured by private assets.
Grants	Grants from the public sector are often designed to help a project developer share the costs of early stage development.
Risk capital	Risk capital is equity investment that comes from venture capitalists, private equity funds or strategic investors (e.g. equipment manufacturers)
Mezzanine financing	Mezzanine financing groups together with a variety of structures in the financing package somewhere between the high-risk/high-upside equity position and the lower-risk/fixed-returns debt position.
Corporate financing	Debt provided by banks to companies that have a proven track record, using "on-balance sheet" assets as collateral. Corporate sponsor required accepting risk and potential reward of a project in its entirety.
Project financing	Debt provided by banks to distinct, single-purpose companies, whose revenues are guaranteed by credit worthy off-take agreements. For renewable energy projects these are typically structured as Power Purchase Agreements.
Participation financing	Similar to project finance, but the "lender" is a grouping of investors, for example a cooperative fund, that often benefits from tax and fiscal incentives.
Risk financing / Insurance structures	Used to transfer or manage specific risks through commercial insurers and other parties better able to underwrite the risk exposures and "smooth" revenue flows.
Consumer financing	Often required for rural clients as a means of making modern energy services affordable. Once client credit worthiness is proven, the portfolio can be considered an asset and used as collateral for financing.
Third party financing	Independent party finances individual energy systems. This can include hire-purchase, fee-for-service and leasing schemes, as well as various types of consumer financing.

In developing countries, the financing of rural energy programmes is usually addressed through government subsidies, donor programmes and private cash sales of small systems adapted to local conditions. Quasi-equity or mezzanine finance has had some limited application in developing country situations. The 'burden of proof' requirements for off-balance sheet project financing are usually too onerous for projects in these locations because of real and perceived credit risks.

Methods for financing geothermal projects in developing countries commonly are based on preliminary investigations leading up to a pre-feasibility report, financed by local governments and supported by international agencies such as UNDP or under bilateral or multilateral aid agreements.

The project design and power plant construction are often financed by the World Bank or regional development banks, and by loans provided by the suppliers of plant equipment from export credit agencies and commercial banks.

The appraisal study with costly appraisal drilling is usually the most difficult phase of the project development to finance. Lack of funds for this phase has stopped the development of geothermal resources in several developing countries.

3.1 Private financing

A recent study by the World Energy Council indicates that the following key-elements must be satisfactorily resolved locally in order to attract private financing for energy projects. These include:

- The rule of law and contract enforceability;
- Credit worthiness both at macro-economic and energy enterprise levels;
- National sector policies including market related pricing based on reducing energy subsidies and ultimately reflecting full energy costs at the point of delivery;
- A transparent legal and regulatory framework that signals appropriate pricing and tariff policies;
- Bankability of investment via effective domestic capital markets and institutional capabilities;
- Government commitment to sustained action on reform, long term planning and change.

3.2 Commercial loans

Commercial loans are normally confined to financing largish energy projects because of the inherent high costs. Such loans may, however, be available for financing renewable energy projects such as for geothermal energy from major finance institutions such as the European Investment Bank, Nordic Investment Bank, the European Bank for Reconstruction and Development and the World Bank, at competitive international lending rates, grace periods and maturity periods. The terms available vary from project to project depending upon project size, aims and the structure of the capitalisation scenario proposed. To ensure favourable financial terms and conditions, the projects will have to satisfy the conditions set. The financing institutions all have high international credit ratings and can therefore. through inter-bank borrowing and other financial manoeuvring, ensure interests and other conditions that are favourable to the borrower.

3.3 Grants and development aid

The *Icelandic International Development Agency (ICEIDA)* is responsible for the implementation of official Icelandic bilateral development aid to developing countries. Iceland's contributions to bilateral developmental aid are expected to increase considerably over the next few years.

In the Agency's projects relating to resource utilisation in geothermal development, particular emphasis will be placed on environmental protection and sustainable development. The majority of international development agencies include environmental impact assessment in their preparation of developmental projects. ICEIDA plans to adapt to this policy in the coming years and have such assessments carried out in preparation for the Agency's projects, particularly in the field of geothermal energy.

Under the auspices of the *International Energy Agency (IEA),* the Geothermal Implementing Agreement (GIA) presents an important framework for international cooperation in geothermal research. Fostering collaboration on research and development, technologies and improving understanding of the benefits of geothermal energy are the main mandate of the GIA. The GIA is expected to develop a set of future "guidelines for market acceleration", addressing issues such as legislation, risk management, green power production credits and the development of geothermal energy. To this end, GIA recently administered a survey covering a broad range of countries (from Albania to Yugoslavia) and issues, including national acceptance, energy policies, licensing, promotional issues, and educational, media and marketing issues.

The *Danish Environmental Protection Agency (DEPA)* has initiated and/or co-funded 6 geothermal projects in the Central and Eastern European Countries (including Russia and Ukraine). In total, DEPA has invested more than USD 9 million in geothermal projects. This investment has generated co-funding, adding up to a total of USD 148 million from international finance institutions and national sources.

The *Nordic Development Cooperation Programmes* award bilaterally grants and/or concessionary financing for the incremental costs associated with environmental projects. The projects should be environmentally sound and economically viable and of significant Nordic interest.

3.4 Special purpose funds

There are a number of possibilities for obtaining partial financing of geothermal energy projects from special purpose financing sources.

Nordic Finance Group. The Nordic group of geothermal investors includes the Nordic Investment Bank (NIB), the Nordic Development Fund (NDF), the Nordic Environment Finance Corporation (NEFCO) and the Nordic Project Export Fund (NoPEF), all of which have contributed to the development of geothermal projects in the past. NEFCO participates in environmental investment projects as a risk capital financier, particularly in Central and East European countries. Projects should be both ecologically and economically sound, i.e. viable investment projects with a positive environmental effect. NEFCO provides equity investments covering 25-35% of the total project cost, at a minimum € 125,000 and a maximum of € 3 million. During the last decade the Nordic Investment Bank (NIB) has supported 4 geothermal projects, totalling € 1.4 million. The projects focused on direct use and had minor research and developmental components. In the same period, the Nordic Development Fund (NDF) has supported 2 geothermal projects, totalling € 0.7 million. These projects focused on the direct use of geothermal energy, with minor research and developmental components. The Nordic Environment Finance Corporation (NEFCO) has supported 3 geothermal projects, focused on the direct use of geothermal energy, totalling € 0.4 million. Finally, the Nordic Project Export Fund (NoPEF) supported 6 geothermal projects, totalling € 0.2 million.

The *Global Environment Facility (GEF)* helps developing countries fund projects and programmes that protect the global environment. GEF grants support projects related to biodiversity, climate change, international waters, land degradation, the ozone layer, and persistent organic pollutants. It provides grants and concessionary loans that fund agreed incremental costs associated with the above focal points. Since 1991, the Global Environment Facility has provided $6.2 billion in grants and generated over $20 billion in co-financing from other sources to support over 1,800 projects that produce global environmental benefits in 140 developing countries and countries with economies in transition.

GEF funds are contributed by donor countries. In 2002, 32 donor countries pledged $3 billion to fund operations between 2002 and 2006. GEF projects are managed by GEF Implementing Agencies, which are the United Nations Environment Programme, the United Nations Development Programme and the World Bank.

GEF's Strategic Partnership for *Geothermal Energy Development* is designed to promote the use of geothermal energy in the region by mitigating financial and resource-related risks, by providing financial support for some investment projects, and by providing capacity-building and technical assistance. Partners are the participating countries in the region, the World Bank, the United Nations Environment Programme, and various international financial institutions. The core innovation of this partnership is a partial risk guarantee window to militate against the geological risks of exploratory drilling - which often is a prohibitively large investment and a barrier to the wider market penetration of geothermal energy production.

3.5 Soft type loans

Soft type loans are available from International Financing Institutions (IFI), such as the Nordic Development Fund (NDF) and the World Bank. Soft type loans usually cover partial financing up to

40% of the total project costs. Therefore, co-financing, joint financing, bilateral parallel financing, project financing and a syndicate type of financial arrangement is necessary for a given project, depending upon the size of project and the wishes of the applicant.

In all cases, the project would have to fulfil the specific IFI conditions imposed, such as those of technical and economic feasibility, socio-economic and environmental significance, etc. Loan applications must be properly reinforced by documentation that is drawn up by accredited consulting companies and drawn up in a certain approved manner. They must contain the following:

- Clear well defined objectives;
- Project definitions - risk assessment;
- Demonstrable social benefits;
- Significant environmental benefits;
- Technical feasibility and good/fair viability;
- Well substantiated cash flow prediction.

A typical soft loan term contains zero interest, a 0.75-1% service charge, a 5-10 years grace period and a 25-40 years maturity period.

3.6 Export import loans

A significant barrier to the development of geothermal energy is financing the first project approach, which includes the exploration, reconnaissance and appraisal study phases. The International Finance Institutions demand that these be carried out by accredited consulting firms, which may not be so readily available at a location during the start of geothermal development.

Financing the exploration phase is very difficult and usually only possible through research co-operation programmes, “payment by result” type donations by consulting companies and bilateral-aid negotiated assistance. There may, however, be funds available that partially finance reconnaissance and feasibility investigations depending upon project and locality specifics. These are available from the Nordic Project Export Fund (NoPEF), the European Bank of Reconstruction and Development (EBRD), the European Investment Bank (EIB), the World Bank’s International Development Fund (WB-IDF) and possibly other local specific sources.

This type of funding is always only partial (up to 50%) and generally awarded only to the consulting company on the condition that either the company itself or the recipient country guarantees the remainder. The funding is typically all risk funding repayable on reasonable terms if the specified project gets implemented within a given timeframe (5-10 years) after completion of the pre-development study. Otherwise, the loan is written off as a grant to the consulting company that received the loan in the first place.

Loan applications must be properly reinforced by documentation that is drawn up by accredited consulting companies and drawn up in a certain approved manner. They must contain the following:

- Clear well defined objectives;
- Project definitions - risk assessment;
- Demonstrable social benefits;
- Significant environmental benefits;
- Technical feasibility and good/fair viability;
- Well substantiated cash flow prediction;
- Marginal or low viability without grant;
- Up to 50% of needed services and goods must be purchased from donor country;
- Participation of small and medium enterprises.

3.7 Carbon financing

Climate change and accompanying disrupted weather patterns - caused by the greenhouse effect through atmospheric loading of greenhouse gases (carbon dioxide, methane, etc.) could wreak havoc on the planet, particularly large parts of the developing world. The cost-effective reduction of greenhouse gas emissions to avert the most severe impacts of climate change remains one of the widely accepted priorities for global action.

Companies can supplement their commitments at home by purchasing potentially lower-cost emission reductions in developing countries and countries with economies in transition. As a result, projects in the developing countries can get a new source of financing for sustainable development in the energy, industrial and waste management sectors, land rehabilitation, and in the introduction of clean and renewable technologies. Industrialized countries can meet part of their Kyoto obligation, while the threat of climate change is reduced at a lower overall cost.

The price for carbon credit differs a lot between trading programs, and years will probably pass before a well functioning world market with more uniform prices is in place. Greenhouse gas credit prices for various carbon funds are shown in Table 5. For this study, 3 USD per ton CO_2 is assumed, referring to the prices of the World Bank Prototype Carbon Fund.

TABLE 5: Greenhouse gas credit price in 2002 (USD per ton CO_2 equivalent)

	USD
United Kingdom, Auction System	23
United Kingdom, Emissions Trading System	7-18
Dutch Government, ERUPT and CERUPT	4-5
World Bank, Prototype Carbon Fund	6
Denmark, Emissions Trading System	2-4
North America, Private Transactions	1-2
Other	0.5-5

The *World Bank Prototype Carbon Fund (PCF)* is a partnership between 17 companies and 6 governments, managed by the World Bank. The PCF became operational in April 2000 (PCF, 2006). The Prototype Carbon Fund (PCF) was created as a response to the need for understanding and testing the procedures for creating a market in project-based emission reductions under the Kyoto Protocol's flexible mechanisms. The PCF has played a pioneering role in developing the market for greenhouse gas emission reductions, while promoting sustainable development, and offering learning opportunities to its stakeholders.

The PCF will pilot production of emission reductions within the framework of Joint Implementation (JI) and the Clean Development Mechanism (CDM). The PCF will invest contributions made by companies and governments in projects designed to produce emission reductions fully consistent with the Kyoto Protocol and the emerging framework for JI and the CDM. Contributors, or “Participants” in the PCF, will receive a pro rata share of the emission reductions, verified and certified in accordance with agreements reached with the respective countries hosting the projects.

The Netherlands Clean Development Facility (CDF). The World Bank announced an agreement with the Netherlands in May 2002, establishing a facility to purchase greenhouse gas emission reduction credits. The Clean Development Facility (CDF) supports projects in developing countries that generate potential credits under the CDM established by the Kyoto Protocol to the UN Framework Convention on Climate Change.

The CDF has a particular interest in financing projects of the following types (in order of preference):

- Renewable energy projects (e.g. biomass, wind, geothermal) that displace the use of fossil fuels;
- Energy efficiency projects, supply side or demand side, that reduce the consumption of fossil fuels;
- Recovery and utilization of methane from, for example, waste landfills and coal mines; and
- Switching from fuels with greater to lesser GHG intensity (e.g., from coal to natural gas).

Until the Kyoto Protocol rules on land use and forestry projects are further clarified, the CDF will not be considering projects that sequester carbon in biomass.

If a project is approved, the CDF will make payments to the project over a period of 7-10 years upon annual certification of actual GHG emission reductions. In return for these payments, the Netherlands will receive certified emission reductions (CER) that can be used to meet its obligations under the Kyoto Protocol. The CDF may consider limited advance payments for reductions but only under unusual circumstances.

A contract with the CDF will specify:

- The volume of GHG emissions that are expected to be reduced, measured in metric tonnes of carbon dioxide equivalent (CO_2 equivalent);
- The price agreed per tonne of CO_2 equivalent; and
- The period over which payments will be made, typically through to 2012.

The *Community Development Carbon Fund (CDCF)* provides carbon finance to small-scale projects in the poorer rural areas of the developing world. The fund, which was designed in cooperation with the International Emissions Trading Association and the United Nations Framework Convention on Climate Change and became operational in July 2003, is a public/private initiative that has a target size of $100 million and that is still open to subscriptions. The CDCF supports projects that combine community development attributes with emission reductions to create "development plus carbon", and will use financial innovation to improve the lives of the poor.

The Italian Carbon Fund. In the fall of 2003, the World Bank entered into an agreement with the Ministry for the Environment and Territory of Italy to create a fund to purchase greenhouse gas emission reductions from projects in developing countries and countries with economies in transition that may be recognized under such mechanisms as the Kyoto Protocol's CDM and JI. The fund is open to the participation of Italian private and public sector entities.

4. PROJECT RISKS

Investors and lenders are naturally averse to risks that can give rise to unexpected negative fluctuations in a project’s cash flows or value. To attract financing, there is a fundamental requirement to manage risk in a way that minimizes the probability of an occurrence that could give rise to a negative financial impact on the project. Risk management instruments such as contracts, insurance and reinsurance, alternative risk transfer instruments, and credit enhancement products could, if used, transfer certain types of risks away from investors and lenders, reducing the costs of financing geothermal energy projects.

Geothermal projects face significant upfront capital investment for exploration, drilling wells and the installation of plants and equipment, and often employ some degree of public assistance. Due to the geothermal environment, drilling can be inherently expensive and risky, and the costs can vary depending on the geological nature of the reservoirs, the depth of the wells to be drilled, the local authorities and the available service industries involved. Due to the significant upfront capital outlay for geothermal projects and the potentially lengthy period before revenue generation, financiers are particularly concerned with any risks and/or expenses that may delay or prevent the project from meeting its debt obligations.

In the first project phases, in which questions of financing and acquisition of subsidies have to be solved, it is of utmost importance to provide a reliable business plan, which is created for the eyes of investors on the basis of the existing information. It is of enormous importance to name and analyze risks which are connected with project implementation. An identified and named risk, which was evaluated monetarily, is in the eyes of the investor, a barrier that can be estimated in terms of its consequences. If this risk is evaluated monetarily and action alternatives are shown, it provides the investor with a clear picture of the project. The World Bank supports this approach and demands it for any geothermal project.

In developing countries the World Bank is also confronted with the problem that existing structures of the administrative, legal and political conditions already make project realization difficult. A purely technical or geological approach may keep many factors out of focus which could result in a geothermal project's success or failure. In order to minimize the risk of investment from the angle of international financing institutes like the World Bank, a risk analysis in these countries is absolutely irreplaceable.

The available information about geological resources and the political, economic and administrative conditions are integrated in the system. A detailed risk analysis can result in a project, although technically, geologically and economically feasible, which cannot be realized. This does not mean that the project idea has failed completely, because conditions for the project realization can change quickly, reducing risks and the project as a whole could be feasible after a certain time. However, if a geothermal project becomes a poor investment, it can be presumed that it will produce a long-lasting negative image for the complete sector of geothermal energy production.

If the first phases of a geothermal project have been passed successfully, in most cases, drilling will be necessary in order to exploit the geothermal reservoir. During drilling, further decisions can influence the economic efficiency of the complete project. There is no way to avoid a strictly economic angle, as the costs connected with initial drilling can comprise a large part of the complete investment. The risks connected with this first drilling and its success, expressed in temperature and, above all flowrate, must be dealt with before beginning the project.

Calculating the risks and how to reasonably insure an economic project realization are dependent in part on the success of the drilling, i.e. partial flowrate. All possible risks must be considered in cooperation with the experts that made the monetary evaluation. The result of this risk evaluation is presented afterwards in an evaluation system integrating an already known classification of risks. Alternative strategies must be shown which help to achieve a reduction in or avoidance of risks. Risk features high in the cost and potential financial gains that may be expected from a given project. The higher the risk the higher becomes the project cost, consequently bringing about lesser return on investments. In Figure 2 a graph for expenditures and risks prior to geothermal development is illustrated.

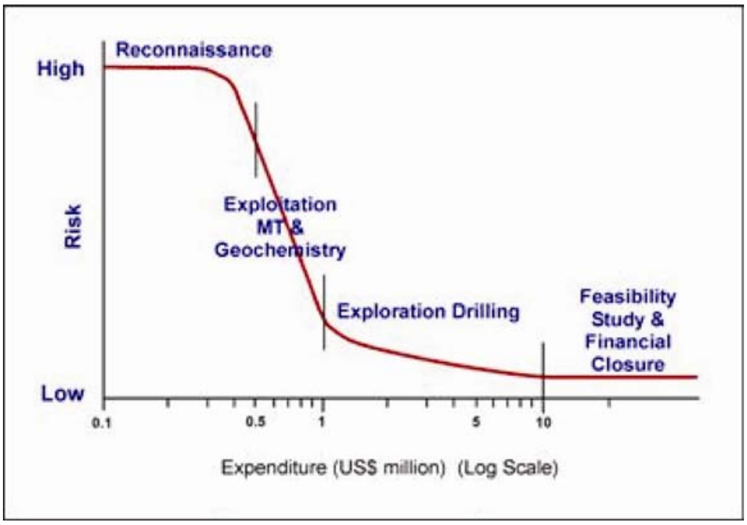

FIGURE 2: Expenditure and risk prior to geothermal development

4.1 Economy specific risks

The economic risk factors are many and varied. Some of the more obvious ones are generally of three distinct categories:

1. The financing arrangement available to and/or adapted for development are:
   - Loan and grace period;
   - Interest rates and loan servicing charges;
   - International currency trends.

2. Energy facility operating factors are:
   - Reservoir management parameters such as longevity, sustainable capacity etc.;
   - Plant maintenance needs, ease and accessibility to spare parts.

3. Energy market factors are:
   - Tariff policy, energy market stability, competing energy sources;
   - Energy purchase contracts - length and renewal terms;
   - Market forecasting and understanding of market development.

4.2 Locality specific risks

The locality at which the energy development is proposed may pose specific risk factors and affect the relative weight of others. The locality will also have a significant impact upon the countermeasures available and needed for a given development. Locality also greatly affects the ability and preparedness of entities to shoulder risks. All commercial entities demand return on their investment that is commensurate with the risk they take on.

Country specific risk factors are for instance:

- Political stability, legalistic and judiciary matters;
- The prevailing national economic and financial situation and the country's international credit rating;
- Environmental constraints specific to the country and the specific locality within the country;
- Public and political attitude to the development of a given energy source and how it is utilised.

All these and many more may pose a significant barrier to the available financing possibilities and the cost of financing.

4.3 Project specific risks

Some of the risks associated with a project, the resource type and the utilisation scenario proposed, are in the case of geothermal energy quite specific to the actual geothermal field in its own right.

a) Specific to the geothermal resource are such aspects as:
   - Reservoir characteristics;
   - Physical and chemical properties of the fluid to be utilised;
   - Natural hazards associated with the area and its utilisation, e.g. steam cap formation, subsidence, earthquakes (normally not fluid withdrawal induced or enhanced).

b) Specific to the project owners are such factors as:
   - Financial status and credibility of the consortium and each of the partners individually;

- Technical and operating experience available within the consortium;
- Marketing experience of same.

c) Risks specific to project completion and the post-implementation stage include:
   - Due cost and/or time overruns;
   - Due overestimated or not realised profit margins.

d) Risks associated with the technological solutions adopted are chiefly related to the use of novel technologies, lack of care in the selection of materials, insufficient attention to scaling and corrosion causes, and overambitious automatic control features.

5. ECONOMIC FEASIBILITY ANALYSIS

5.1 Methodology

The following financial models are used for economic feasibility analysis of a project:

Payback period: The payback period for a project is the initial fixed investment in the project divided by the estimated annual cash inflows from the project (Equation 1). The ratio of these quantities is the number of years required for the project to repay its initial fixed investment. This method assumes that the cash inflows will persist at least long enough to pay back the investment, and it ignores any cash inflows beyond the payback period. The method also serves as an inadequate proxy for risk. The faster the investment is recovered, the less the risk to which the project is exposed.

$$Payback\ period = \frac{Initial\ fixed\ investment}{Estimated\ annual\ cash\ inflows} \tag{1}$$

Average rate of return: The average rate of return is the ratio of the average annual profit (either before or after taxes) to the initial investment in the project (Equation 2). Because annual average profits are usually not equivalent to net cash inflows, the average rate of return does not usually equal the reciprocal of the payback period.

$$Average\ rate\ of\ return = \frac{Average\ annual\ profit}{Initial\ fixed\ investment} \tag{2}$$

Neither of these evaluation methods is recommended for project selection, although a payback period is widely used and does have a legitimate value for cash budgeting decisions. The major advantage of these models is their simplicity, but neither takes into account the time-value of money. Unless interest rates are extremely low and the rate of inflation is nil, the failure to reduce future cash flows or profits to their present value will result in serious error.

Discounted cash flow: Also referred to as the net present value method, the discounted cash flow method determines the net present value of all cash flows by discounting them by the required rate of return and predicted rate of inflation, as follows:

$$NPV\ (project) = -A_0 + \sum_{t=1}^{n} \frac{F_t}{(1+k+p_t)^t} \tag{3}$$

A_0 = Initial cash investment;
F_t = Net cash flow in period t;

k = Required rate of return; and
p_t = Predicted rate of inflation during period t.

Early in the life of a project, net cash flow is likely to be negative, the major outflow being the initial investment in the project A_0. If the project is successful, however, cash flow will become positive. The project is acceptable if the sum of the net present values of all estimated cash flows over the life of the project is positive.

Internal rate of return: The internal rate of return is the discount rate that equates the net present values of the expected cash inflows and expected cash outflows. If A_t is an expected cash outflow in the period t and R_t is the expected cash inflow for the period t, the internal rate of return is the value of k that satisfies the following equation (the value of k is found by iteration):

$$A_0 + \frac{A_1}{1+k} + \frac{A_2}{(1+k)^2} + \ldots + \frac{A_n}{(1+k)^n} = \frac{R_1}{1+k} + \frac{R_2}{(1+k)^2} + \ldots + \frac{R_n}{(1+k)^n} \quad (4)$$

5.2 Base-case economic feasibility analysis of geothermal pilot project in Tsetserleg

To start a geothermal pilot project in the town of Tsetserleg in the Arkhangai province of Mongolia, it is suggested that a separate geothermal company or a geothermal project implementation unit, which employs Mongolian and international experts, be formed with participation of the Mongolian Government authorities, and possibly some environmental and developing funds. The proposed new geothermal company would be responsible for developing the financial basis for the project using commercial loans, possible grant support from the World Bank, Nordic Funds, UN institutions and the Mongolian Government, together with private funds and CO_2 credits. The creation of the geothermal company would greatly facilitate the advancement of the project. A proposed stake-holder chart for the geothermal company is shown in Figure 3.

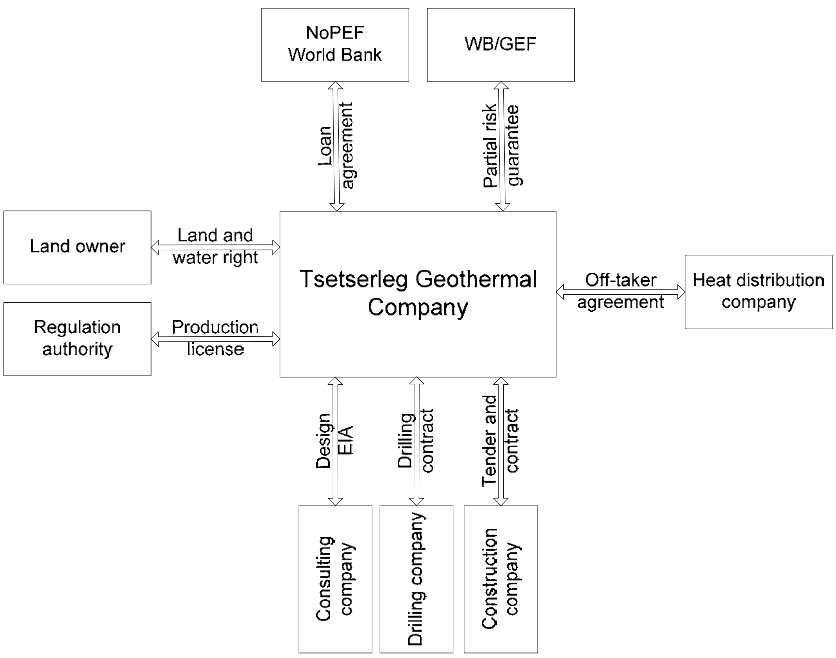

FIGURE 3: Stakeholder chart for the proposed geothermal company in Tsetserleg

The following assumptions are made for the financial calculations. The existing DH consumers' heat load is increased by 20 percent, because hot tap water will be supplied and some minor buildings will be connected to the new geothermal DH system. Existing small individual boiler heating systems will be integrated into the geothermal DH system.

Maximum geothermal water flow is limited to 60 l/s and average flow is 45% of the maximum flow. Peak load will be supplied by one of the existing coal-fired boilers. The heating season will be 9 months a year. The heat load duration curve for the geothermal district heating system is shown in Figure 4.

Temperature of the geothermal water is assumed to be 80ºC and temperature drop in the radiator system is 40ºC. Base-case characteristics assumed for the geothermal district heating system are shown in Table 6.

The financing of the Tsetserleg geothermal pilot project has been split into the following stages:

- Geothermal exploration and drilling of exploration wells;
- Design of geothermal heating system and eco-nomic feasibility study;
- Drilling of production wells and construction of geo-thermal district heating system.

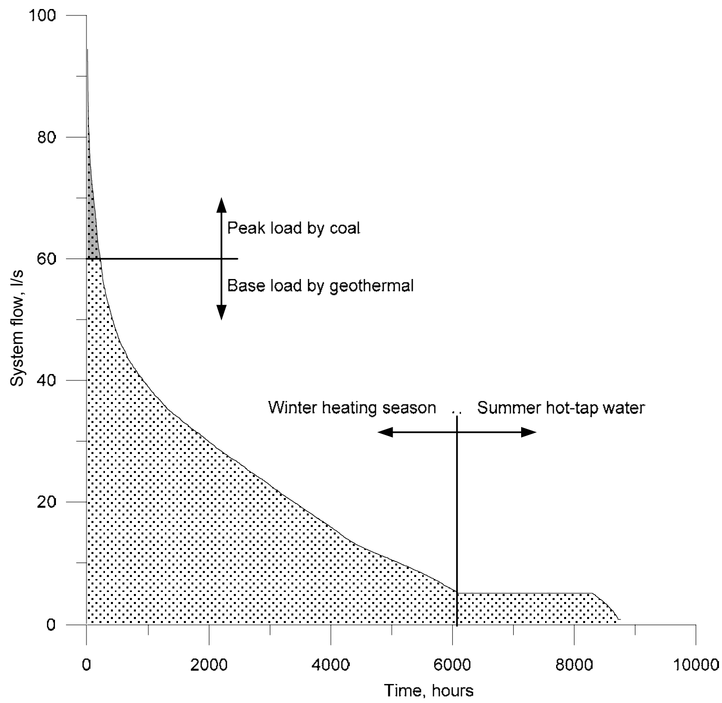

FIGURE 4: Heat load duration curve for the geothermal district heating system in Tsetserleg

TABLE 6: Geothermal district heating system size

Maximum system flow	60	l/s
Average system flow	27	l/s
Well max output	30	l/s
Number of wells	2	
Re-injection	No	
Transmission pipeline	5	km
Yearly energy	103,669	GJ/year
Yearly energy	28,797	MWh/year

Geothermal exploration: The results of the exploration and exploration drilling are highly uncertain and this is therefore the riskiest part of the project. The project must be managed from a strictly economic angle, as the costs connected with the first drilling comprise a large part of the complete investment. The risks connected with the initial drilling and its success, expressed in temperature and above all flowrate, must be dealt with. Costs are therefore envisioned being met through Mongolian Government financing, and possibly partially by environmental or development grants or all-risk capitals. In this calculation, costs for geothermal exploration works with exploration drilling is lump-summed to USD 0.7 million.

Drilling of production wells: The results of the drilling of the exploration well are most often quite uncertain; this is, therefore, the risky part of the project. Consequently, financing for the drilling of production wells must be insured; the insurance is assumed to be given by the Global Environment Facility (GEF). GEF's Strategic Partnership for Geothermal Energy Development is designed to promote the use of geothermal energy by providing a partial risk guarantee to militate the geological risks of exploratory drilling, often a prohibitively large investment and a barrier to wider market penetration of geothermal energy production.

The cost of drilling in Mongolia is assumed to be similar to the cost of drilling in China. In China, the initial investment in a geothermal well is 157.2 USD/m ($13^3/_8$" - $9^5/_8$" - 7") for production or injection wells for an average well depth of 2000-3500 m, not including wellhead equipment (Wang, 2005). In this calculation, the cost of a production well with a depth of 2000 m is assumed to be 450,000 USD, including wellhead equipment and a submersible pump. Two production wells with a maximum yield of 30 l/s and no re-injection wells are assumed.

Tsetserleg geothermal project: It is envisioned that the Tsetserleg Geothermal Company (TGC) will be responsible for developing the financial basis for the project using commercial loans, possible grant support, Mongolian government support, together with private funds and CO_2 credits. In this calculation, the total cost for the geothermal district heating system is assumed to be 12,000 USD per unit system flow (l/s). The length of the transmission pipeline is assumed to be 5 km and the total cost of the transmission pipeline is 100,000 USD/km.

Here, 20% equity financing and 80% soft-type loans are envisioned for financing the drilling of production wells, the construction of the transmission pipeline and the distribution system. Cost estimation of the geothermal pilot project in Tsetserleg is shown in Table 7. Operating and energy costs of the geothermal district heating system are shown in Table 8.

TABLE 7: Geothermal project costs

Cost of preliminary study	0.70	M USD
Cost of wells and pumps	0.90	M USD
Cost of transmission pipeline	0.50	M USD
Cost of distribution system	0.72	M USD
Cost of contingency work	0.56	M USD
Upfront fees for loan	0.03	M USD
Interest during construction	0.30	M USD
Total investment cost	**3.71**	**M USD**

Energy costs or heating tariffs are set at 5.5 USD/GJ or 19.8 USD/MWh, which is lower than the existing heating tariff (6.31 USD/GJ) in Tsetserleg by coal-fired district heating system. The annual increase in energy cost is assumed to be 2% and the annual increase in operating costs is assumed to be 2%.

TABLE 8: Operating and energy costs of the geothermal district heating system

Annual operating cost	0.20	M USD
Annual increase in operating cost	2.00	%
Energy cost (tariff)	5.50	USD/GJ
Energy cost (tariff)	19.80	USD/MWh
Annual increase in energy cost (tariff)	2.00	%

Carbon financing is included in the calculation and CO_2 payback is 6 USD per ton CO_2 equivalent according to the World Bank - Prototype Carbon Fund. Yearly GHG emission reduction and yearly CO_2 payback are shown in Table 9.

TABLE 9: Yearly GHG emission reduction and yearly CO_2 payback

Yearly CO_2 reduction	23,401	ton
Yearly CO_2 payback	0.14	M USD

TABLE 10: Feasibility indicators of the Tsetserleg project

IRR	14	%
ROE	41	%
NPV @		

The internal rate of return for the project is 14% and the return on equity is 41%, which are satisfactory. The net present value at 8% inflation rate is calculated to be 1.65 million USD. Feasibility indicators of the geothermal pilot project are shown in Table 10.

The proposed geothermal district heating system in Tsetserleg is, thus, economically feasible.

5.3 Sensitivity analysis

Feasibility of the project is most sensitive to the heating tariff, meaning that project feasibility greatly depends on the customers' payment abilities and the existing tariff system. The second major contribution to the economic feasibility of the project is the well cost, the cost of district heating system installation and the length of transmission pipelines. Project feasibility would be enhanced by cost optimization. The sensitivity of the internal rate of return for the project to the design variables is shown in Table 11 and illustrated in Figure 5.

TABLE 11: Sensitivity of IRR to the design variables

Cost of Well		Length of pipeline		Cost of DH system		Tariff	
	IRR		**IRR**		**IRR**		**IRR**
	14.24%		**14.24%**		**14.24%**		**14.24%**
50%	17.72%	50%	15.72%	50%	16.56%	50%	2.98%
60%	16.94%	60%	15.41%	60%	16.06%	60%	5.71%
70%	16.20%	70%	15.10%	70%	15.58%	70%	8.10%
80%	15.50%	80%	14.81%	80%	15.12%	80%	10.29%
90%	14.85%	90%	14.52%	90%	14.67%	90%	12.32%
100%	**14.24%**	**100%**	**14.24%**	**100%**	**14.24%**	**100%**	**14.24%**
110%	13.65%	110%	13.96%	110%	13.81%	110%	16.07%
120%	13.10%	120%	13.69%	120%	13.40%	120%	17.84%
130%	12.57%	130%	13.42%	130%	13.01%	130%	19.56%
140%	12.07%	140%	13.16%	140%	12.62%	140%	21.23%
150%	11.58%	150%	12.91%	150%	12.25%	150%	22.87%

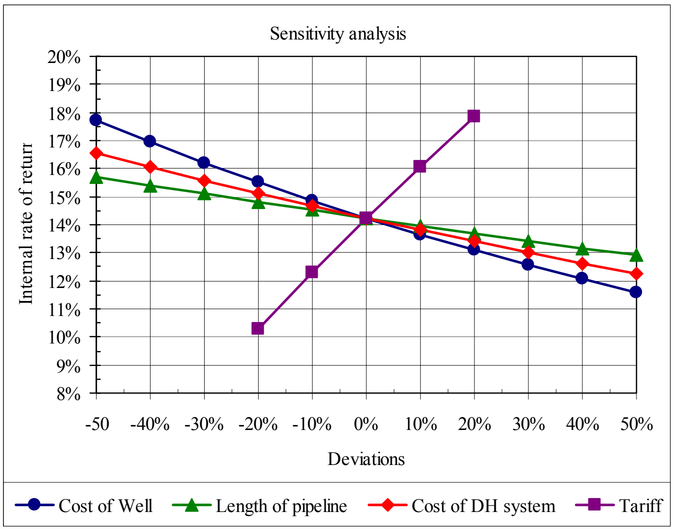

FIGURE 5: Sensitivity of IRR to the design variables

6. CONCLUSIONS

Implementing a master plan, which realizes the first stages of geothermal exploration work, would be the next approach to further development of geothermal energy in Mongolia. If such a master plan is financed by the Government and becomes implemented, it would give rise to commercial geothermal projects. To start a geothermal pilot project in Tsetserleg, it is suggested that a separate geothermal company be formed;

The internal rate of return of a new geothermal district heating system is calculated to be 14% and the return on equity 41%. The net present value at 8% predicted inflation rate is calculated to be 1.65 million USD. The proposed geothermal district heating system in Tsetserleg is, thus, economically feasible.

Project feasibility is most sensitive to the heating tariff, meaning that project feasibility greatly depends on the customers' payment abilities and the existing tariff system. Feasibility of the project would be further enhanced by cost optimization.

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