GEOTHERMAL DEVELOPMENT
KECSKEMÉT

FEASIBILITY STUDY

January, 2014

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1 Introduction

According to the Hungarian National Renewable Energy Action Plan, it is forecasted that the country can reach 14.7% renewables in gross energy consumption by 2020. The heating and cooling sector is seen as the biggest contributor with 18.9% of renewable energy sector in consumption, and electricity sector meeting about 11% of consumption with renewables. The Hungarian government has published a ‘National Energy Strategy until 2030 that defines geothermal energy use as a priority renewable energy resource.

Geothermal energy has been used successfully for district heating in many parts of the world including Central Eastern Europe. Successful harvesting of the resource from various geological types of aquifers has been proven there inclusive the Pannonian basin which Kecskemét is a part of.

Kecskemét is the commercial and cultural centre of the region. The most developed industrial sectors are: IT, machine industry, printing industry, plastics and food processing. During the last two decades, nearly one hundred industrial operations have settled in Kecskemét. Amongst these are international companies. The permanently settled operations are mainly focused on the production of components parts, equipment, and accessories for machine and electrical installations. German carmaker Mercedes-Benz raised a plant nearby Kecskemét. The plant was opened on 29 March 2012. The Stuttgart-based company invested €800 million to build the new plant, which is expected to create 3000 new jobs in the region.

In the region there is a traditional industry of stock raising, vegetable production and food processing. One of Hungary’s largest food manufacturing companies is based here; the Univer-Group which has become famous for its food flavouring products and baby food. Fornetti is market leader in Hungary for the production of frozen bakery products. Another well-known branded food product is the mineral water bottler Szentkirályi Ásványvíz.

One of the main assumptions in this Study is to utilise the existing heating systems and connecting additional new consumers directly to the geothermal system. It is a step on the path to increased utilisation of renewable energy resources in Hungary with a sustainable emission free energy providing increased standard of living at a lower cost compared to present fossil fuels.

The project will contribute significantly to an increased use of geothermal energy for district heating, benefitting both the general public and private companies. Many of the buildings in Kecskemét are now heated with individual gas boilers, which are more expensive and less environmental friendly than geothermal district heating. After extension of the geothermal it will be possible to connect additional users as residential, commercial and industrial.

Data available for the Study was provided by Kecskemét municipality during personal meetings and through emails. All other data used in this report come from public sources. The well database (basic parameters, geology of drilled layers, hydraulic data, well log data, etc.) was gathered at the data room of the Hungarian Mining and Geological Authority (www.mbfh.hu), the Mining Property Utilization Company (www.bvh.hu) from the final well reports and from hydrogeological diaries stored at the Environmental and Hydrological Research Institute (VITUKI).

2 Background

The Municipality of Kecskemét has applied to the Intelligent Energy – Europe (IEE) program with the project “Geothermal District Heating in the City of Kecskemét” with the intention to finance the preparation of the project. The main goal of the project is to change the present gas source based district heating to a sustainable green geothermal district heating system. The application was successful and the project had been deemed worthy of support.

The Municipality of Kecskemét has held a restricted public procurement with the subject of compiling a Feasibility Study. The main scope of the work is to investigate the possibility of establishing a geothermal district heating system from the environmental, licensing, legal engineering and financial point of view.

Aquasoft has been invited and chosen as the winner to carry out the above detailed work.

It is a step on the path to the increased utilization of renewable energy resources in Hungary with a sustainable emission free energy providing increased standard of living at a lower cost compared to present fossil fuels.

A positive outcome of the study and the execution of the project would help to meet the energy needs of Hungary and contribute to eliminating dependence on foreign supplies of gas and the economic pressures associated with fossil fuels.

2.1 General

Heat is naturally present everywhere in the earth. For all intents and purposes, heat from the earth is inexhaustible. Geothermal energy is based on exploiting the earth’s internal heat supply and is used in several cities across Hungary. These geothermal projects have been implemented in several versions with different investment schemes and owner structures.

In Hungary there are 220 district heating systems in operation today. The current up and running district-heating systems supply approximately 650,000 homes with heat and hot water. Natural gas is the main source of district heating, supplying 75-80% of Hungary’s energy demands. In total 12 Hungarian cities run their district heating systems on geothermal energy. That leaves 208 cities that have the possibility to further explore the feasibility of using geothermal energy for district heating.

Many of the 220 district heating systems in over 90 municipalities have a favourable possibility of being run on renewable, emission-free geothermal energy. Geothermal energy could locally generate much of Hungary’s energy needs, while considerably eliminating dependence on foreign supplies of gas and the economic pressures associated with fossil fuels.

2.2 Legal Background

Hungarian government has published a ‘National Energy Strategy until 2030 which defines geothermal utilisation as a prioritized renewable energy source. According to the strategy, geothermal energy is a valuable contribution to increase the share of renewables in energy consumption. The project is in line with EU´s 2020 objectives as well as Hungary´s targets of cutting CO_2 emissions by 5,65 million tons/year and increasing the use of renewables to

14,65% of total energy consumption by 2020. Hungary has prioritised increased use of geothermal resources in their National Energy Strategy, and in the ‘Renewable Energy Action Plan’ geothermal energy is highlighted for direct use in district heating systems. The project is in line with 2009/28/EC Directive on the promotion of the use of energy from renewable sources.

The use of reinjection originates from the implementation of Water Framework Directive (2000/60/EC). According to article 4 Member States shall protect, enhance and restore all bodies of groundwater, ensure a balance between abstraction and recharge of groundwater, with the aim of achieving sustainability.

Based on the Danube River Basin Management Plan issued by Hungary, December 2009 there are three porous thermal groundwater bodies which have poor status, because of significant pressure drop hence lack of re-injection. All three bodies are located on the Great Hungarian Plain (refer **Figure 1**, areas with light orange/pink color).

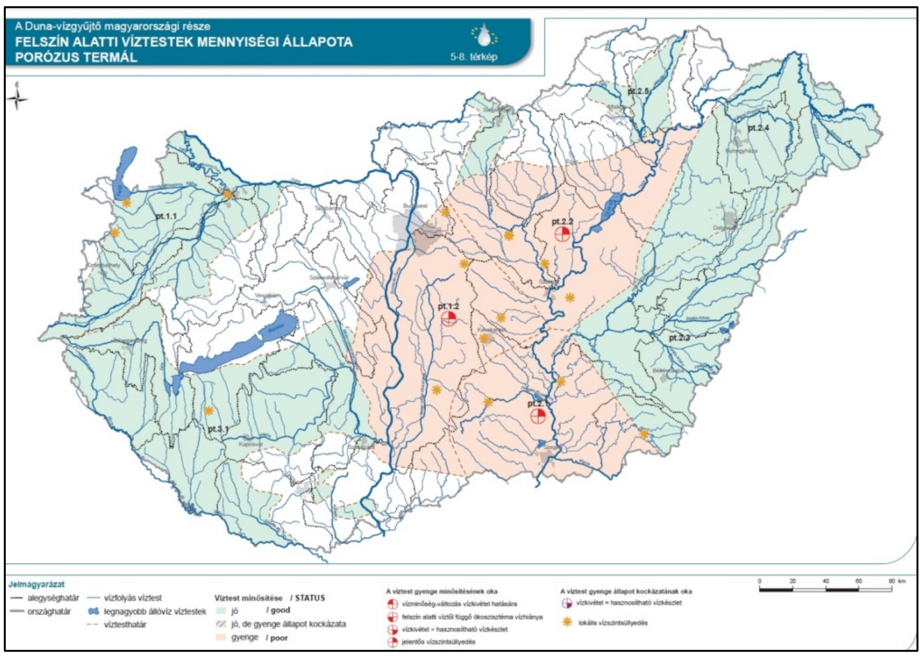


Figure 1: Status of porous thermal groundwater bodies of Hungary based on quantitative point of view, source: Danube River Basin Management Plan issued by Hungary, December 2009

Furthermore the development of the District Heating Development Action Plan is under progress, where it is also stated that the possibility of changing from gas to renewable geothermal or biomass should be assessed from technical and economical point of view.

Geothermal energy could have enormous potential to be an important contributor to the Hungarian energy portfolio as a source of clean and renewable energy, and thereby facilitating the EU goal of 2020 that 20% of the energy use to be from sustainable renewable energy sources. Geothermal systems have the ability to produce energy consistently and around the clock.

3 Basic Information

3.1 Geographical Location

Kecskemét is a city in the central part of Hungary, situated at 46.54° N; 19.41° E. It is the 8th largest city in the country and the shire-town of the territory wise biggest county, Bács-Kiskun. As of 1st January 2012 the city had a population of 114 226 in 47 040 flats. The total area of the city is 322.57 km^2. Kecskemét lies halfway between the capital Budapest and the country's third-largest city, Szeged, 86 kilometers from both and almost equal distance from the two biggest rivers of the country, the Danube and the Tisza. The location of Kecskemét is shown in **Figure 2**.

The city lies on the Great Hungarian Plain and its altitude is 120 meters above sea level. The area west of the city is covered by wind-blown sand, characterized by the almost parallel northern-southern sand dunes and the plane lands among them.

Figure 2: Location of Kecskemét

3.2 Meteorological information

The characteristic weather of the Kecskemét region is continental warm, dry, sometimes extreme. The amount of sunlight makes it possible for the region to produce agricultural products such as wheat, apricots, red peppers or tomatoes. The warmest month in Kecskemét is July, with an average temperature of 20.9°C; the coldest is January, with −1,9°C.

Early spring and late autumn frosts are frequent in the Great Hungarian Plain. The tendency of frost usually disappears only from the middle of April. After the third week of October, the temperature is frequently below 0°C. Monthly average temperatures are shown in **Table 1**.

Table 1: Climate in Kecskemét in centigrade

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average. Temperature	0	1	5	10	16	19	21	20	15	10	4	-1
Average Max Temperature	2	6	10	16	21	25	27	27	21	16	8	2
Average Min Temperature	-3	-2	0	4	9	12	14	13	10	5	0	-3

3.3 Introduction of the Town

3.3.1 General

The northern part of the city is mainly residential area, whereas the southern and south-western parts are suitable for industrial developments. In the north-west part of the town a recreation zone is just being shaped. Alongside the internal and external traffic rings, the town is surrounded by industrial areas, forming a semicircle. These are: the western, the eastern and the southern industrial areas. Within the industrial zone of Kecskemét, a rather spacious and under-utilized strip of land is wedged into the texture of the town. There is an ever-increasing demand to rejuvenate the so-called “brownfield” locations and the suburban industrial zones.

The most developed industrial sectors are: IT, machine industry, printing industry, plastics and food processing. During the last two decades, nearly a hundred industrial operations have settled in Kecskemét. Amongst these are international companies such as MAG (Thyssen) Production Systems, Knorr-bremse Brake Systems, Phoenix Mecano, Hilti, DD K-Digital-Disc Drivers, Freudenberger Simmeringe and Mercedes Benz. The permanently settled operations are mainly focused on the production of component parts, equipment, and accessories for machine and electrical installations. These are mainly German companies.

In the region there is a traditional industry of stock raising, vegetable production and food processing. One of Hungary’s largest food manufacturing companies is based here; the Univer-Group which is famous for its food flavouring products and baby food. Fornetti is market leader in Hungary for the production and distribution of frozen bakery products. Another well-known brand from the food industry is the Szentkirályi Ásványvíz mineral water which has a large bottling plant in the area.

Construction companies based in Kecskemét are operating nationally and internationally in the building industry. KÉSZ, with headquarters in Szeged, operates its production facility and own industrial park in the area. VERBAU is specialized in industrial flooring and external concrete surfaces, but also acts as main contractor for constructions. Freeline is developing fast, and Beton Star produces and installs reinforced concrete structures.

North from Kecskemét there is an agricultural area with small gardens, vegetable and grain lands, small greenhouses.

3.3.2 Industrial Parks

The industrial parks operating at present within the industrial zones are the Kecskemét Industrial Park, the KÉSZ Industrial Park, the Heliport Industrial Park and the Mercedes factory in the southern part of the town, outside the built-up industrial zones.

3.3.2.1 Kecskemét Industrial Park, Phase I.

The construction of the Kecskemét Industrial Park started in 1996. It is located in the Southern Industrial Zone and its total area is 27 hectare. The number of the settled companies is 11; the number of employees is around 720. The settled companies are dealing with food, electronic and precision mechanics production.

3.3.2.2 KÉSZ Industrial Park

In 1998 the KÉSZ Ltd. has bought all equipment and facilities of the TRAVERZ Inc. that was earlier a big state company, but later went into liquidation because of the changed economic situation. Total area of the Industrial Park is 13 hectare, the existing buildings have been constructed in very different times, but all provide civilized circumstances for production and logistics. The KÉSZ Industrial Park in Kecskemét is a construction engineering logistic center. This center provides services for construction engineering, the adjoining research and development, different architectural, electro technical, and vehicle production, the full scope of logistics. The Industry Park is equipped with telecommunications network and public utilities. The KÉSZ Industrial Park has own gas engine power plants that supply electric power.

3.3.2.3 Technik Park Heliport

The first industrial park of Kecskemét, Technik-Park Heliport was established in Kecskemét-Kadafalva in 1995. The territory of the industrial park is 51 hectare, 21 companies have settled in it; the number of employees is around 2100. The industrial park is developed and operated by Technik-Part Heliport Kft. The parent company is ElringKlinger AG of Germany, one of the largest subcontractors of car industry in the world, specializes in manufacturing engine sealers.

3.3.2.4 Mercedes Factory

German carmaker Mercedes-Benz raised a plant nearby Kecskemét to manufacture the new Mercedes-Benz B-Class. The plant was opened in March 2012. The Stuttgart-based company invested 800 million EUR to build the new plant, and by the end of the year the factory had over 3000 workers. Ever since Mercedes Benz has opened up in Kecskemét it keeps developing the factory and the production.

4 Market Analysis

4.1 Market Size

4.1.1 District Heating System

In the city of Kecskemét up until today there have been two independent district heating systems operating with two independent heat plants. The city has won a grant to complete the connection of the two systems which has been planned for some years now. With the accomplishment of the connection the efficiency of the heat and electricity production shall improve and the operation safety shall be at a higher level. The constructional works have been started in March 2013 and are planned to be finished in October 2013.

Characteristic Data of the Heating System:

- Volume of the heated residential space: ~ 1.500.000 m3
- Volume of the heated non-residential space: ~ 500.000 m3
- Supplied amount of heat: ~ 540.000 GJ
- Supplied hot water: ~ 300.000 m3

4.1.1.1 Heat Plants

The total number of flats in Kecskemét is 47 040 of which 11 234 are connected to the district heating network. The district heating network areas are shown in Figure 3.

Figure 3: Heat plants and district heating network areas

One of the heat plants is located in the north-western part of the city in the district of Széchenyiváros at 4. Akadémia St. It was constructed in 1975 and has been supplying heat to almost 66% of the district heated buildings, including the biggest residential area in Kecskemét with 7471 flats. The required heat is generated 100% by own resources with the aid of gas boilers which have a total capacity of 62.5MW and three gas engines which have a thermal capacity of 5MW and an electrical capacity of 4.7MW.

The other heat plant is located in the southern-center of the city in the district of Árpádváros at 1. Szultán St. Total 3763 flats and numerous non-residential consumers are connected to this district heating system. The heat plant was built in 1898 originally with the purpose of producing electricity but over the years the heat production became priority. The heat plant is running on five gas boilers with the total capacity of 31.2MW and one gas engine with thermal capacity of 1.6MW and electrical capacity of 1.5MW, see Table 2.

Table 2: Main distribution network heating parameters

Heat Plant	Total Capacity	Gas Boilers	Gas Engines	Heat Requirement	Hot Water Requirement
Széchenyiváros	67.5 MW	62.5 MW	5.0 MW	~35 MW	~3.0 MW
Árpádváros	32.8 MW	31.2 MW	1.5 MW	~19 MW	~1.5 MW

In 2013 the primary loops of the two district heating networks were connected to each other by a pair of DN300 pipeline. Heat is produced in Széchényiváros heat plant until the combined heat demand reaches ~15MW capacity, then extra gas boilers enters into operation in both heat plants. Circulation is ensured also in Széchenyiváros heat plant.

4.1.1.2 Heat Transfer Stations

The primary heating fluid is pumped to the heat transfer stations, which are accepting, converting and transferring the heat further to the secondary heating fluid. The system has 131 bigger and 178 smaller stations. 40 buildings already have independent heat transfer station in the town.

4.1.1.3 Control and Automation

The continuous running of the heating system is assured by automated heat control and electronic data processing system. The hot water supply is according to the pre-programmed algorithm and the heat energy is set up according to the ambient temperature.

4.1.1.4 District Heating Network

The heat plants are connected to several heat transfer stations in the town by the district heating pipeline. The heat plant at Akadémia St. has 4 pairs and the heat plant at Szultán St. has 2 pairs of pipelines. The length of the primary district heating network from heat plants to heat transfer stations is around 16,3km and the length of the secondary district heating network from the heat transfer stations to the flats is around 13,4km. The temperature of the primary heating fluid is according to the ambient temperature.

4.1.2 District Heating Company

Termostar Ltd. is the local heating company and it is owned by the municipality (69,5%) and the EDF DÉMÁSZ Zrt. (30,5%) since 1995. The capital is 1.114.130.000 HUF. In 2012, the company had 87 employees.

TERMOSTAR Ltd. today deals with not only district heating and hot water supply but it also generates and sells energy. It produces the necessary heat one hundred percent with the aid of hot water boilers and gas engines of its own. The total heating capacity of the gas boilers are 93,7MW and the gas engines have 6,6MW heating and 6,2MW electrical capacity. The company is supplying heat and hot water to almost 11.200 flats and has 678 non-residential consumers. The produced electricity is covering the 20% of the electrical demand of Kecskemét.

Heating and hot tap water usage is measured by the customers at each heated end-user. More than 50% of the heated flats have been recently renovated to save heating energy.

4.2 Additional consumers

Homokbánya area at South-West side of Kecskemét is a former military barrack, there are many existing buildings, major part of it is unused now. Municipality plans to build and operate a large residential rental-flat area here with commercial and educational facilities. There are ~400 flats used now in renovated buildings, and additional 60 will be renewed in the next year. According to the plans of the municipality additional 400-600 is expected in the next 5 years, and also new commercial and educational buildings are planned to build in the future. This development area is named as so-called green investment or green district where renewable energy source is expected to be used to heat the buildings.

The existing buildings are heated now by gas boilers in each buildings installed in separate heat stations. There is no heat requirement data available for this area. According to national average heat requirements, total ~3MW heat demand is estimated in the next 2 years, and additional ~2MW in later phase of the development.

There are several large communal buildings at the west side of the city downtown in Felsőszéktó district which are owned or managed by the municipality. It is the municipality's intention to provide cheap and environmental friendly heat to these buildings. The following institutes are located here:

- Thermal spa (potential consumer of the cooled geothermal fluid)
- Sport hall and stadium
- Technical college
- Hotel and conference centre
- County hospital
- Other commercial buildings, market houses

5 Geothermal Resource

5.1 Geothermal reservoir characterization

The Kecskemét area is located in the central part of the Pannonian Basin which is a young sedimentary basin formed since Middle Miocene until Quaternary.

The crystalline rocks of the area belong to the Mórágy Complex (Szederkényi, 1998). Based on the information from Haas et al. (2010) the bottom of Kada Trough consists of “9 Middle Jurassic to Lower Cretaceous pelagic limestones, cherty limestones” and “10 Lower and Middle Jurassic pelagic fine siliciclastic formations”. The ridges on the SW and NE sides of Kada Trough mainly consist of “22 Variscan granitoid rocks”. There is a second order Mesozoic tectonic line in the NW part of the defined Area of Interest running in NE-SW direction, while in the SE part there is a second order Cenozoic tectonic line running also in the same direction. There are third order Cenozoic tectonic lines between Mesozoic and Paleozoic rocks (Figure 4), which border the Kada Trough and run in NW-SE direction.

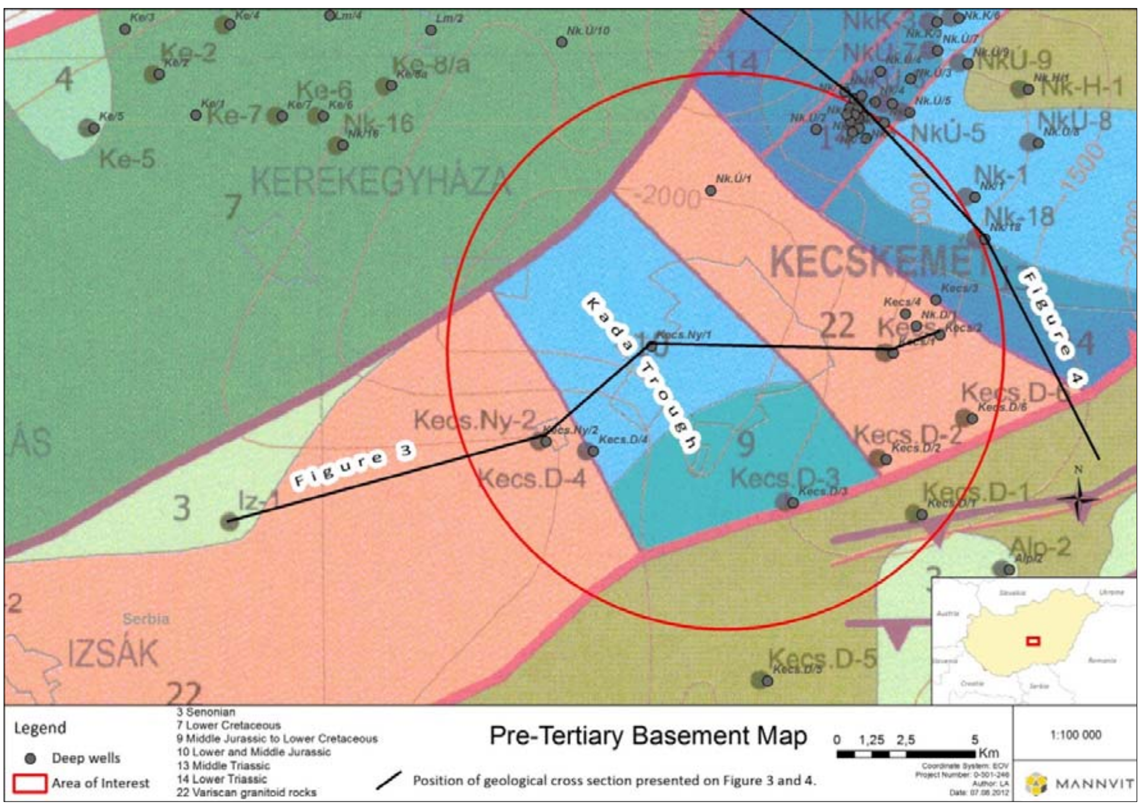


Figure 4: Geological map of the pre-Tertiary basement in the Kecskemét area (modified from Haas et al., 2010)

The former pre-Tertiary basement map of Hungary after Fülöp and Dank (1987) indicated metamorphic rocks (including granitoids) in the Kada Trough. Despite no additional drilling data between 1987 and 2010, the newly edited basement map from Haas et al. (2010) differs by the interpretation of the rock type for the basement of the Kada Trough. Unfortunately there is no drilling deep enough to penetrate the pre-Tertiary basement of the Kada Trough. Only the basement rocks on the surrounding ridges were penetrated by drilling.

Figure 5 shows a geological cross-section across Kada Trough in WSW-ENE direction, with the path line of the cross-section indicated on Figure 4. The indicated rocks of pre-Tertiary basement are gneiss on the WSW side and granite on the ENE side. Cserepes-Meszéna (1985) evaluated the crystalline basement rocks on the Danube-Tisza Interfluve and described migmatites on the west side of the Kecskemét area and granite rocks on the east side.

Fodor et al. (1999) described the normal faults with NW-SE direction which resulted from the Middle Miocene synrift extension phase, when the Pannonian basin started to open. The Kada Trough was formed during this extension phase.

Figure 6 shows a geological cross-section on the north part of Area of Interest in NW-SE direction. The pre-Tertiary rocks are dipping in SE direction, and the older crystalline rocks are over-trusted on Mesozoic rocks towards NW.

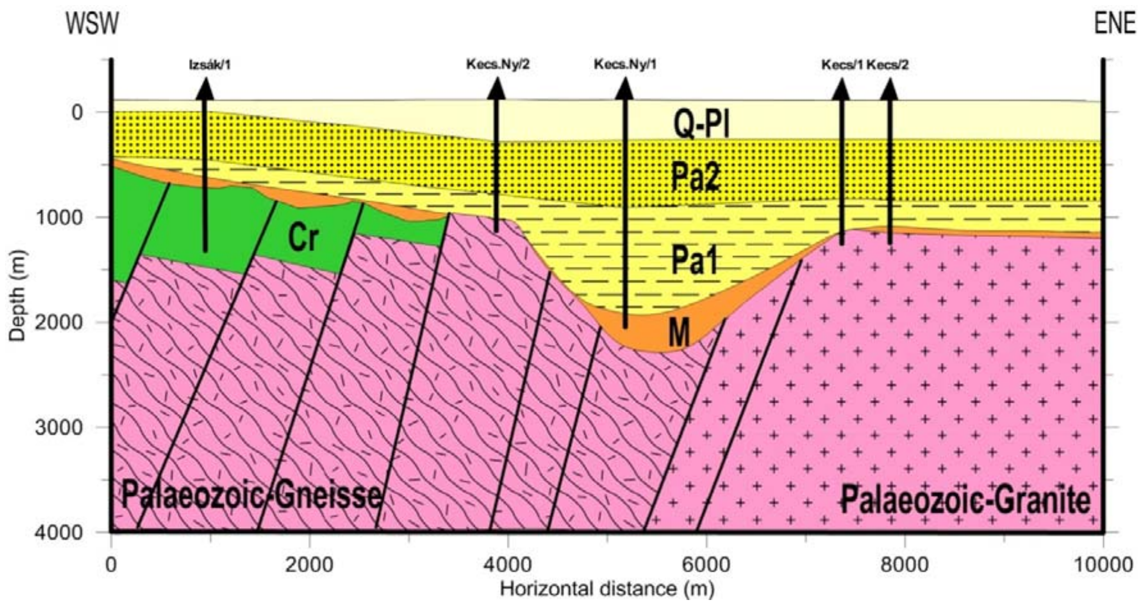


Figure 5: Geological cross section after Kőrössy (1992); Q-Pl: Quaternary-Pliocene, Pa2: Upper Pannonian, Pa1: Lower Pannonian, M: Miocene, Cr: Cretaceous

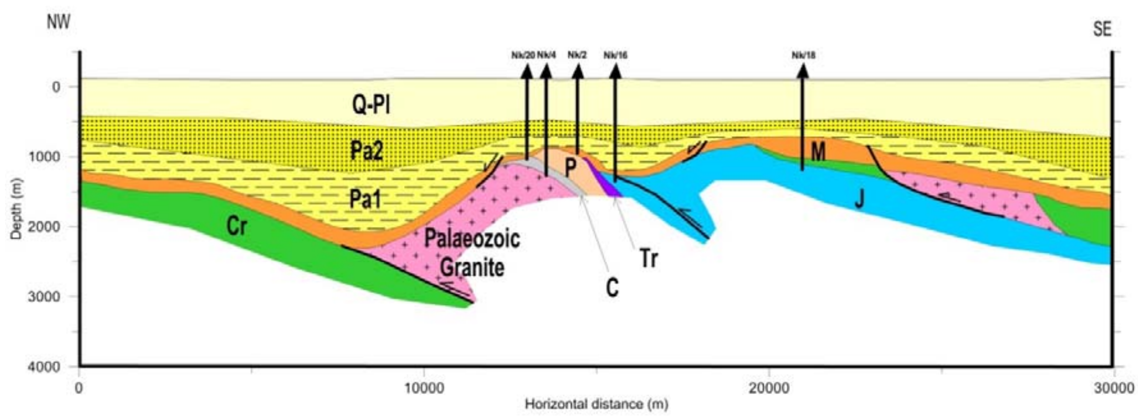


Figure 6: Geological cross-section after Gyarmati (2000); Q-Pl: Quaternary-Pliocene, Pa2: Upper Pannonian, Pa1: Lower Pannonian, M: Miocene, Cr: Cretaceous, J: Jurassic, Tr: Triassic, P: Permian, C: Carboniferous

The target reservoir is a hot, likely fractured, crystalline rock body belonging to the Mórágy Complex. The targeted rock body at Kecskemét mostly consists of granite and migmatite. The texture of the granites is variably grained and inhomogeneous. The crystalline rocks were exposed at the surface during the Miocene, so their top part is weathered.

The reservoir rock is an elongated granitic body stretching along a NE-SW direction forming a syncline approximately 200 km long and 25-30 km wide. Its boundaries are delineated by regional tectonic and lithological features. The northern and southern boundaries are drawn along nappe features and the eastern and western boundaries are drawn along 2nd order Cainozoic faults. The top of the reservoir starts at 1000 m depth below sea level and sinks deeper down below 3000 m in the Kada Trough. It is difficult to define the bottom of the reservoir because these crystalline rocks are part of the crust. It is expected that porosity and permeability are negligible below 7 km depth.

The geothermal gradient shows quite high variability between 38 and 54 °C/km values. This feature is likely due to unequal areal distribution of geothermal heat flow presumably triggered by water bearing deep fractures. There is no access to reliable pressure and yield data in good amount referred on granitic rocks, which does not allow of evaluating flow properties of the targeted reservoir.

6 Geothermal Energy Utilization

6.1 Basis of Design

6.1.1 Terminology

- Geothermal Loop (Supply and Reinjection system): Transfers the heat from the production well(s) to the geothermal heat plant and back to the reinjection well(s)
- Primary Loop (District Heating Primary Loop): Transfers the district heating water from the heat plants to the heat transfer stations
- Secondary Loop (District Heating Secondary Loop): Transfers the heat from the heat transfer stations to the end-users' radiator system
- Heat Plant (HP): Produces heat from gas source
- Geothermal Heat Plant (GHP): Provides geothermal heat from the geothermal loop to the primary loop
- Heat Transfer Stations (HTS): Provide heat from the primary loop to the secondary loops with heat exchangers

6.1.2 Basic data

Tables below shows basic input data of the conceptual system design.

Table 3: Geological Basis of Design/Well

Description	Data
Outflow temperature	100°C
Flow rate from one well	25 l/s
Depth	~ 2500m

Table 4: Electrical Basis of Design

Description	Data
Network type	TN-C-S
Supply voltage	400V
Supply frequency	50Hz
Number of main power feeders	3

Table 5: Energetical Basis of Design

District heating network	Peak	Average
Primary loop – forward temperature	115 °C	100 °C
Primary loop – return temperature	73 °C	68 °C
Heating capacity requirement – Széchenyiváros	34.8 MW	18.3 MW
Heating capacity requirement – Árpádváros	19.2 MW	10.1 MW
Yearly heat requirement – Széchenyiváros	340 000 GJ	
Yearly heat requirement – Árpádváros	200 000 GJ	

6.1.3 Geothermal Capacity

Required heating capacity depends on the ambient temperature. District heating systems shall be designed to fulfill heat demand in the coldest time. Ambient temperature distribution according to meteorological statistical data during one year is summarized in Figure 7.

Heating capacity is calculated as a percentage of the design capacity. Figure 7 presents the yearly temperature distribution.

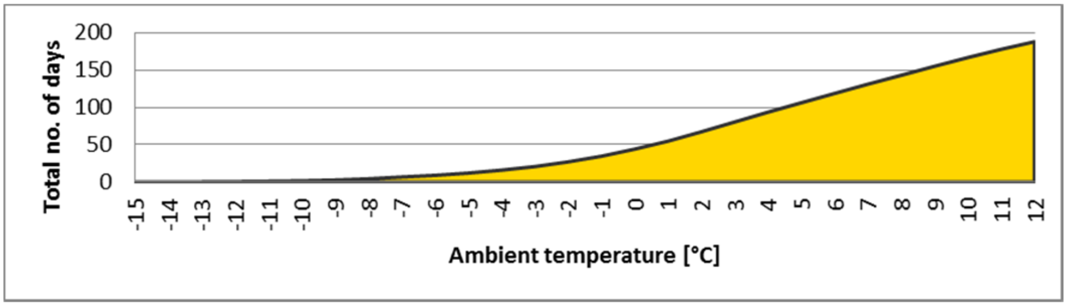


Figure 7: Temperature distribution chart

Above written chart show that the top 1/3 of the installed heating capacity is used only during a relatively short time (approximately 2 weeks) in each year. If the designed system is an addition to an existing one, which is planned to replace partly the present energy source - i.e. a geothermal system is designed to replace existing gas source - then the peak time heating is remain solved by the existing source, so the new system shall be designed only in the feasible range.

System capacity is based on the applied temperature difference between forward and return geothermal fluid, and the used yield. Basic theoretical capacities are shown in Table 6. The real geothermal capacity is lower than the theoretical maximum values, depending of the characteristic data of the connected heating system, temperature loss in pipeline, etc.

Table 6: Theoretical system capacity with the assumed production well parameters

No. of Wells	ΔT=20°C	ΔT=30°C	ΔT=40°C	ΔT=50°C	ΔT=60°C	ΔT=70°C
1	2.1 MW	3.2 MW	4.2 MW	5.3 MW	6.3 MW	7.4 MW
3	6.3 MW	9.5 MW	12.6 MW	15.8 MW	18.9 MW	22.1 MW
5	10.5 MW	15.8 MW	21.0 MW	26.3 MW	31.5 MW	36.8 MW
7	14.7 MW	22.1 MW	29.4 MW	36.8 MW	44.1 MW	51.5 MW
10	21.0 MW	31.5 MW	42.0 MW	52.5 MW	63.0 MW	73.5 MW

The produced heat amount is to be calculated based on the temperature distribution (see Figure 7) and heating requirement by the temperature. Figure 8 shows the possibilities to combine geothermal and gas source. Horizontal axis represents the installed geothermal capacity; vertical axis shows the produced yearly heat amount by the energy sources. Yellow curve shows the number of days in a year when gas source is necessary in addition to the geothermal heat as a function of the installed geothermal capacity.

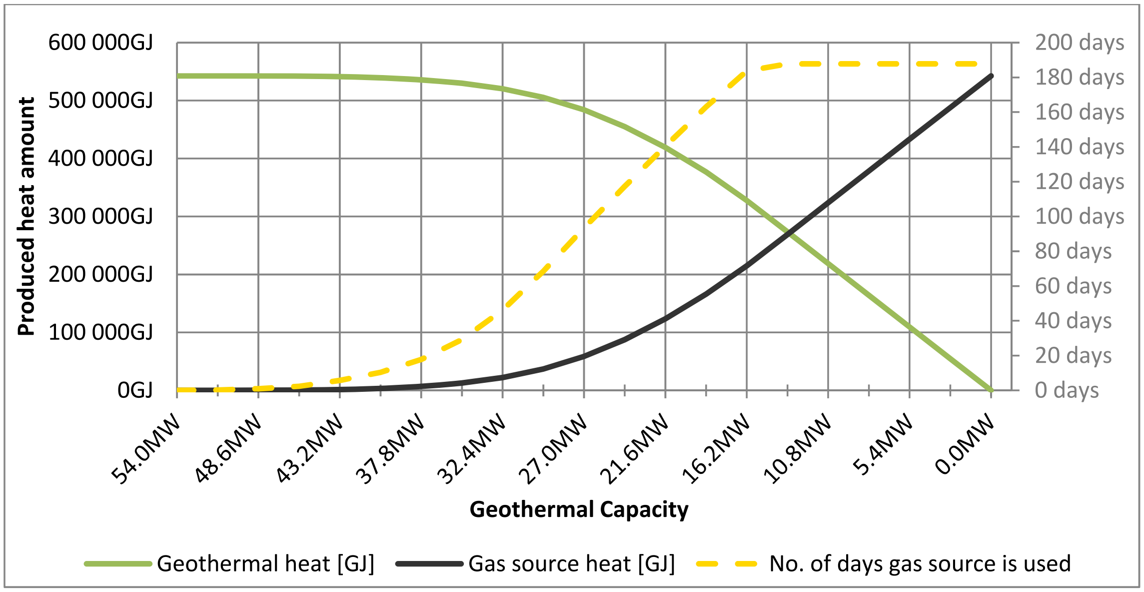


Figure 8: Marketable heat in the function of the capacity

The produced geothermal heat amount is growing linear below ~27MW geothermal capacity (~50% of the total capacity). Above ~38MW, the excess produced heat amount is not significant using geothermal resources, because the high end peak time capacity is needed only in very few days a year and because of the high operational temperature in the existing district heating system. Between 27 and 38 MW the ratio of the geothermal capacity and produced heat amount is decreasing. It can be seen from the chart that the most feasible is to design the geothermal system where the geothermal curve (green line) is increasing linear or almost linear by the enlargement of the capacity; therefore geothermal system shall be designed to fulfill 37-32 MW heat demand, if there is no extension in consumer side.

6.2 System Layout

The geothermal heat plant will be located in Homokbánya in a newly built building. In the area there is enough space to build up the geothermal heat plant and all necessary equipment. The geothermal heat plant will be extended during the project phases. The primary system will connect the geothermal heat plant and the existing heat plant of the Árpádváros system (in Szultán st.).

There are two areas containing potential additional consumers, the Homokbánya area, where there are municipality owned renewed residential buildings and continuous development is planned; and the Széktó area, where are large potential consumers and they are owned or operated by the municipality.

The production pipeline length is ~2.5 km from the drilling area to the geothermal heat plant, the reinjection pipeline length is ~5.3 km from the heat plant to the reinjection area; the two pipelines goes together in a common trench through ~2.1 km. The length of the primary connection pipeline is ~3.7 km.

Well sites are located near Kadafalva area in a geothermal active zone. The sites have been chosen taking into consideration the below written conditions.

Geological conditions

First and most important condition to locate the well sites are the results of the geological evaluation, well siting and reservoir modeling. In Kecskemét area the crystallite rock formations gives relatively narrow freedom to locate the well sites with respect to the faults and necessary distances between the production and reinjection wells. Protection areas of the existing wells shall be also considered.

Well sites are located according to the underground faults, fractures and the direction of groundwater flow. The distance of the sites has been defined to avoid cooling effect from the reinjection but ensuring the necessary reservoir pressure in the production well.

Drilling conditions

Drilling is a noisy activity with continuous operation. Furthermore, drilling has low seismic effect that can have impact to the habitants. Therefore, drilling site has been chosen by evaluating these possible negative effects during the officially required impact assessment and avoiding any conflict with the relevant rules and regulations..

Waste material of the drilling operation shall be maintained according to the relevant regulations. During well testing a relevant amount of geothermal fluid came to the surface when utilization or reinjection is not possible. This fluid shall be cooled and maintained as directed by the relevant drilling license documentation. Location of the well sites shall be chosen to evaluate the possibility to handle the waste materials and harvested geothermal fluid during well testing.

Market conditions

All sites and pipeline route shall be chosen with evaluating the present and future market possibilities. Some of the possible future heat consumers locate close to the drilling sites, therefore there is a possibility to enlarge the system by connecting them and provide cheap environmental friendly heat energy.

Location of the reinjection site has been chosen with respect of the low temperature users like agriculture, industrial technological use, newly built buildings, etc. Selling the waste heat is the best way to increase the feasibility of the geothermal system.

Cost optimization

The site locations and the pipeline route layout have been chosen to minimize execution cost. Shorter pipeline can have high positive cost effect for the project because of the following circumstances:

- Lower pipeline material and installation cost
- Lower pressure loss in the pipeline, lower capacity circulation pumps
- Lower temperature loss in the pipeline, higher energy efficiency
- Lower maintenance cost

Land availability

Well site lands shall be owned by the project owner or long term rental agreement shall be made, which can have relevant cost effect. Land owners along the pipeline shall give approval for the execution before licensing procedure starts. As municipality is involved in the project, best solution is to use municipality owned lands as much as possible.

6.3 Project Phases

The project shall be divided into phases to decrease the financial risk related to the high investment cost requirement. Development of the project starts by drilling the first production well, and in case of successful drilling, geothermal system can start operation with reduced capacity. In later phases the project will be developed further by drilling additional production and reinjection wells to fulfill higher percentage of the total heat requirement and/or connect additional consumers to the system. The recommended project phases are listed below.

Phase 1: Drilling of the first pair of wells and connecting Homokbánya area by installing a new geothermal distribution system. The following main facilities are to be installed:

- First production well (exploratory well)
- First reinjection well
- Supply and reinjection pipeline between the wells and Homokbánya area
- New geothermal heat plant
- New distribution system

Phase 2: Drilling further wells and connect to Árpádváros distribution system heat plant to pre-heat the return water of the primary loop. The following main facilities are to be installed:

- Additional production wells (1-2 pcs)
- Additional reinjection wells (1-2 pcs)
- Supply and reinjection system extension
- Heat plant connection in the primary loop side

Phase 3: Drilling further wells and increase geothermal system capacity to be able to fulfill base heat demand of the already connected Árpádváros-Széchenyiváros distribution system, and connect new consumers. The following main facilities are to be installed:

- Additional production wells (2-3 pcs)
- Additional reinjection wells (2-3 pcs)
- Heat plant extension
- Connection to additional consumers

6.3.1 Phase 1: First doublet

6.3.1.1 System layout in Phase 1

Project execution starts by drilling the first exploratory well, which in case of success will operate as the first production (or reinjection) well. Expected yield is 25 l/s with 100°C outflow temperature. After testing this well and evaluating all geological and geophysical data from the drilling a better estimation is possible for locating further wells with well-defined outflow parameters.

A reinjection well shall be drilled to fulfill the expected requirements of the authorities described in Chapter **Error! Reference source not found.** and to ensure sustainable operation.

Homokbánya area is a potential consumer of the geothermal heat as being developed as a "Green district" of Kecskemét city. There is 400 flats existing now, and another 600 is expected to build or renovated in the next years (see Chapter 4.2). The calculated heat demand is 3MW in 2015. In the first phase of the geothermal project Homokbánya area is expected to be the consumer of the heating system, with newly built distribution system.

A geothermal heat plant is necessary to transfer the heat of the harvested geothermal fluid to the heating system, where clear heating water is circulated. Geothermal heat plant shall be built in the area of Homokbánya. The circulation pumps in the geothermal heat plant could pump the water into the heat stations inside the consumer buildings.

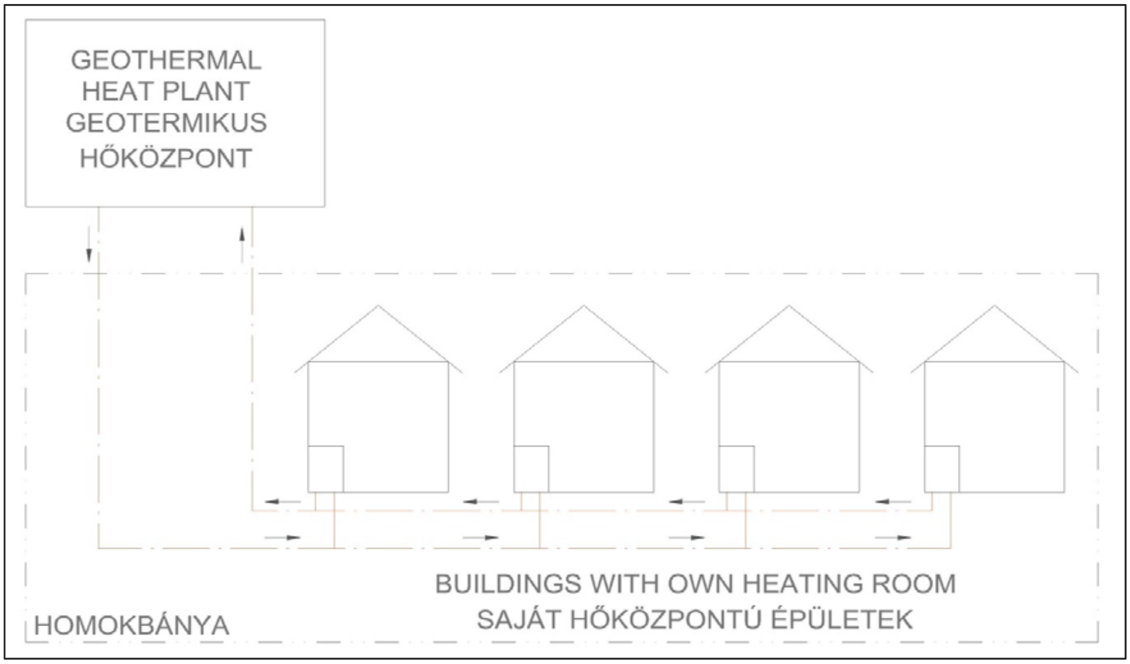


Figure 9: Connection chart of Phase 1

6.3.1.2 Capacity estimate

Harvested heat from one well can fulfill the estimated 3MW capacity requirement of Homokbánya area, therefore evaluate the utilization of further production wells are not necessary in this phase.

To determine the exact capacity of the geothermal system in function of the ambient temperature the primary loop heating parameters shall be compared to the available geothermal temperature and flow rate. The temperature of the heating systems in the area is assumed to be 70/50°C. Calculations were made based on assuming 3MW and 6MW total capacity requirement. The results of the calculation are shown in Table 7.

Table 7. Produced heat in case of connecting into primary loop

	Capacities [MW]				Produced heat [GJ]	
	Geothermal		Gas boilers		Geothermal	Gas boilers
	Peak time	Maximal	Peak time	Maximal		
3MW	3.0	3.0	-	-	28 000	-
6MW	6.0	5.0	-	-	57 000	-

With 3MW heating capacity the geothermal system can fulfill the total heat demand of the distribution system in case of both temperature ranges. If the capacity requirement of the district heating system increases lower forward and return heating temperature causes higher efficiency of the harvested geothermal energy, therefore higher yearly heat amount can be produced.

The necessary facilities need to be installed in case of executing this phase are:

- One production well
- One reinjection well
- Supply and reinjection pipeline (1xDN300+2xDN200, length: 2.5/5.3 km)
- New geothermal heat plant
- New distribution system

6.3.2 Phase 2: Connecting to Árpádváros heat plant

6.3.2.1 System layout in Phase 2

The geothermal heating system can be enlarged by drilling additional production (and reinjection) wells and connecting to the heat plant of Árpádváros. The geothermal heat plant will be extended in Homokbánya and a new primary loop will be installed between the geothermal heat plant and the existing heat plant in Árpádváros. Geothermal loop heating water heats up the return water of the primary heating loop (which provides heat to secondary loop and hot tap water loop during heating season; and to the hot tap water loop during out of heating season).

Because of the relatively high return and forward temperature of the circulated water in the primary loop, geothermal system is not able to fulfill total capacity requirement independently of the number of production wells drilled, therefore additional heat source is needed during peak time to boost up the pre-heated temperature. This additional heat source is the already existing gas boilers, but installation of new gas boilers are also possible especially if methane content of the geothermal fluid is sufficient to provide energy to them.

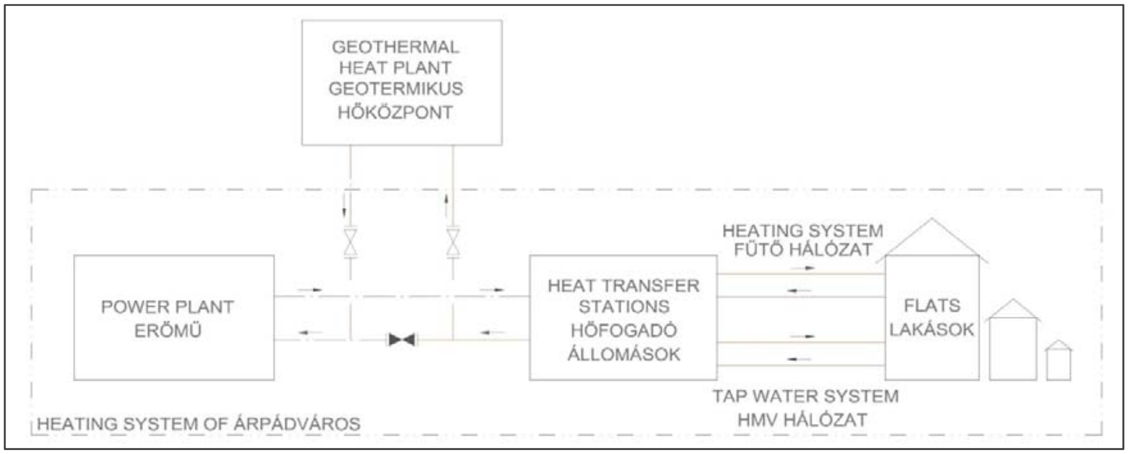


Figure 10: Connection chart of Phase 2

6.3.2.2 Capacity estimate

Available geothermal capacity depends on the number of production wells but limited because of the high heating temperature. To determine the exact capacity of the geothermal system in function of the ambient temperature the primary loop heating parameters shall be compared to the available geothermal temperature and flow rate. The results of the calculation are shown in Table 8.

Table 8. Produced heat in Árpádváros system

Total number of production wells	Capacities [MW]				Produced heat [GJ]	
	Geothermal		Gas boilers		Geothermal	Gas boilers
	Peak time	Maximal	Peak time	Maximal		
1 well (ph1)	2.5	3.0	16.5		102 000	98 000
2 wells	5.0	6.0	14.0		150 000	50 000
3 wells	7.4	8.8	11.6		173 000	27 000
4 wells	9.9	10.7	9.1		177 000	23 000

The return temperature in the geothermal loop is 70-75°C after pre-heating the Árpádváros system primary loop. This temperature allows to connect further consumers with lower heating temperature. If the end-user system of the Homokbánya area is designed with 70/50°C temperature range, it can be connected to the return pipeline of the geothermal loop and still can be fully heated by geothermal. If temperature range is higher, then small amount of gas boiler capacity (or small amount from the forward water from geothermal loop) is required to boost up the temperature during peak time.

In case of heating the Homokbánya area from the return water in the geothermal loop the capacity and yearly heat amount of Homokbánya area (written in Table 7) should be added to the values of Árpádváros system (shown in Table 8).

Total number of production wells shall be defined according to financial analysis in respect of the produced and marketable yearly heat amount and the installation cost. The distribution of the heating capacities and the produced heat amount in case of different number of production wells are shown in Figure 11.

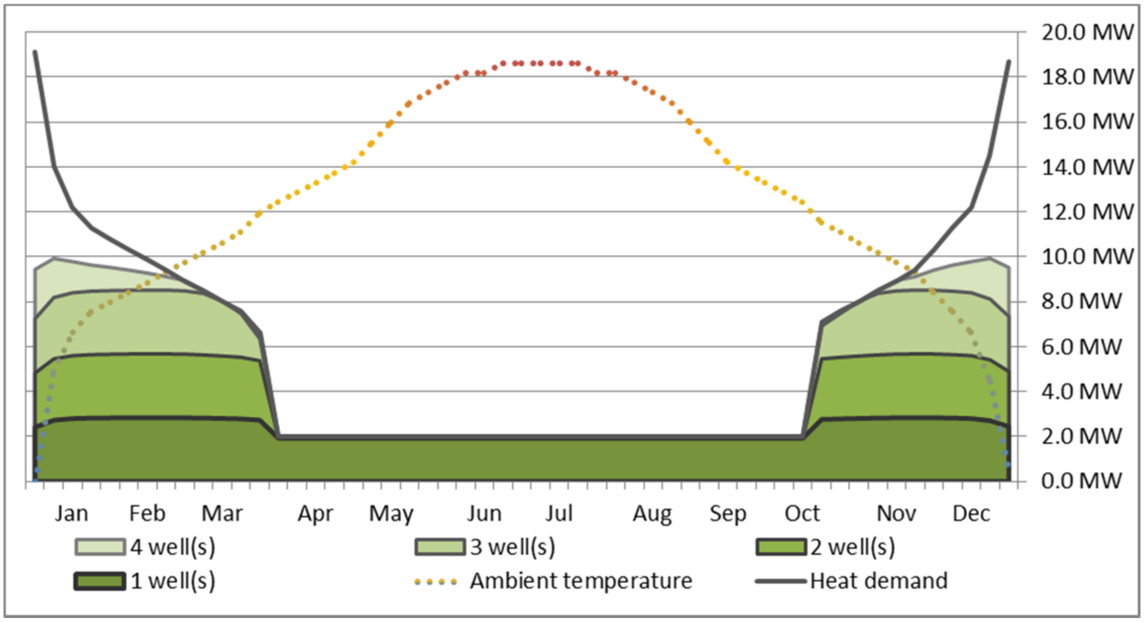


Figure 11. Yearly heating capacity distribution chart in Phase 2

Figure and table above shows that drilling the third production well cannot increase the yearly produced geothermal heat by the same amount as the second production well. The fourth production well has almost no effect to the produced heat amount because of the limited geothermal temperature and the high heating return temperature therefore this scenarios is excluded from further calculations.

The necessary facilities need to be installed in case of executing phase 2 are:

- One or two production well(s)
- One or two reinjection well(s)
- Supply and reinjection pipeline enlargement (2xDN200+1xDN300, length: 4.2 km)
- Connection to the existing heat plant

6.3.3 Phase 3: Connecting to the combined district heating system

6.3.3.1 System layout in Phase 2

The geothermal heating system can be enlarged further by drilling additional production (and reinjection) wells without installing new pipeline in geothermal loop (expect the connection of the wells into the system) and in the primary loop. Geothermal pipeline connects to the primary loop of the heating system in the existing geothermal heat plant in Homokbánya. Geothermal loop heats up the return water of the primary loop of the combined Árpádváros-Széchenyiváros system and provides sold base heat for the city district heating network.

Because of the relatively high return and forward temperature of the circulated water in the primary loop, geothermal system is not able to fulfill total capacity requirement independently of the number of production wells drilled, therefore additional heat source is needed during peak time to boost up the pre-heated temperature. This additional heat source is the already existing gas boilers both in Árpádváros and Széchenyiváros heat plants.

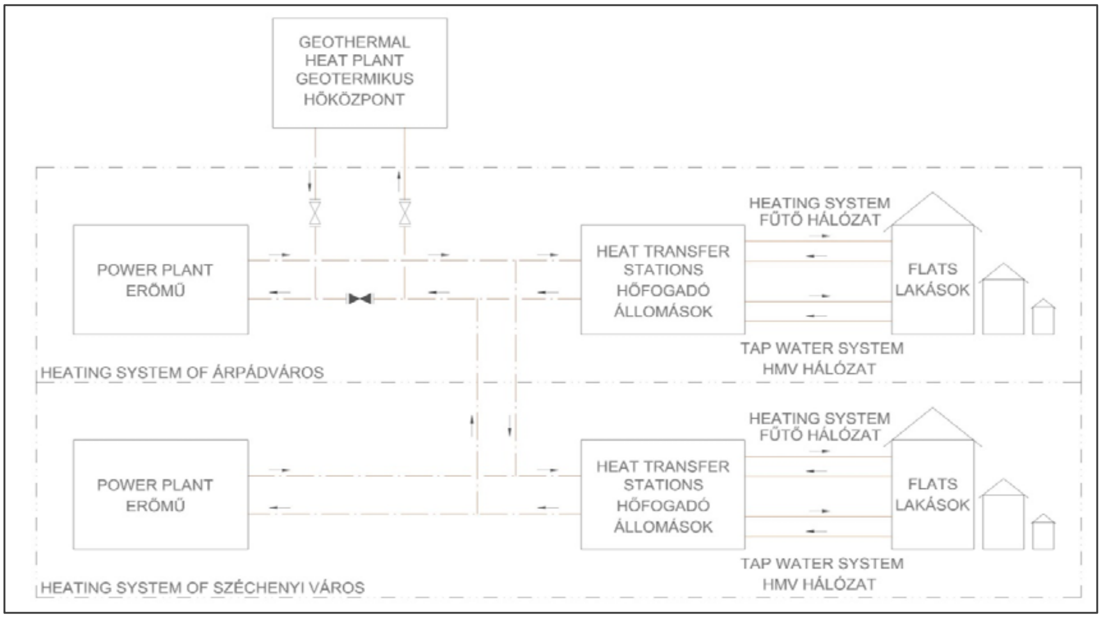


Figure 12: Connection chart of Phase 2

6.3.3.2 Capacity estimate

Available geothermal capacity depends on the number of production wells but limited because of the high heating temperature. To determine the exact capacity of the geothermal system in function of the ambient temperature the primary loop heating parameters shall be compared to the available geothermal temperature and flow rate. The results of the calculation are shown in Table 9.

Table 9. Produced heat in case of heating Árpádváros+Széchenyiváros system

Total number of production wells	Capacities [MW]				Produced heat [GJ]	
	Geothermal		Gas boilers		Geothermal	Gas boilers
	Peak time	Maximal	Peak time	Maximal		
1 well (ph1)	2.5	3.0	51.5		133 000	407 000
2 wells	4.9	6.0	49.1		247 000	293 000
3 wells	7.4	9.1	46.6		295 000	245 000
4 wells	9.9	12.1	44.1		343 000	197 000
5 wells	12.3	15.1	51.7		390 000	150 000
6 wells	14.8	18.1	39.2		428 000	112 000
7 wells	17.3	21.0	36.7		456 000	84 000
8 wells	19.7	23.7	34.3		473 000	67 000

The return temperature and the high flow rate of phase 3 allows to connect further additional consumers with lower heating temperature. Calculations were made by assuming 5MW additional consumer in Széktó area.

In case of heating Homokbánya area and additional consumers from the return water in the geothermal loop the capacity and yearly heat amount of Homokbánya area (written in Table 7) and the capacity and heat amount of additional consumers should be added to the values of Árpádváros system (shown in Table 9).

Total number of production wells shall be defined according to financial analysis in respect of the produced and marketable yearly heat amount and the installation cost. The distribution of the heating capacities and the produced heat amount in case of different number of production wells are shown in Figure 13.

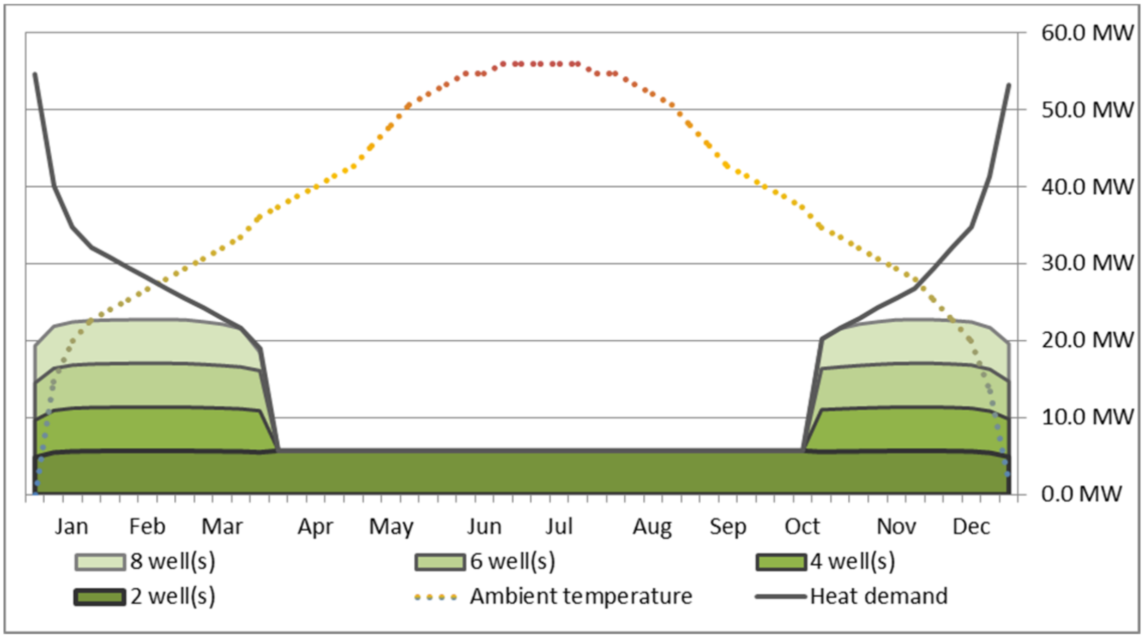


Figure 13. Yearly heating capacity distribution chart in Phase 2

Figure and table above show that marketable heat amount can be increased by drilling further wells, but the added heat amount is decreasing rapidly after the 5th production well. Further calculations are based on adding 2 or 3 production (and reinjection) wells in phase 2.

The necessary facilities need to be installed in case of executing of this version are:

- Two or three production well(s)
- Two or three reinjection well(s)
- Extension of the heat plant connection
- Connection to additional consumers

7 Facility Description

7.1 Supply and reinjection pipeline

A new supply pipeline shall be installed to provide geothermal heat to the heat plant, and then a reinjection pipeline transports the waste fluid to the reinjection site. The expected flow rate in the pipeline is 25 l/s from one production well. In case of system extension with additional production wells in 2nd phase, higher flow rate is expected. Supply and reinjection pipeline shall be designed to be able to transport also the increased amount.

Sizing of the pipeline shall be according to the necessary flow speed in the pipe. The pressure loss from friction and height difference shall be considered. The following flow speeds are calculated given in case of different available pipe diameters:

Table 10. Flow speed in case of different pipe diameters

	DN 150	DN 200	DN 250	DN 300	DN 350	DN 400
25 l/s	1.4 m/s	0.8 m/s	0.5 m/s	0.4 m/s	0.3 m/s	0.2 m/s
50 l/s	2.8 m/s	1.6 m/s	1.0 m/s	0.7 m/s	0.5 m/s	0.4 m/s
75 l/s	4.2 m/s	2.4 m/s	1.5 m/s	1.1 m/s	0.8 m/s	0.6 m/s
100 l/s	5.7 m/s	3.2 m/s	2.0 m/s	1.4 m/s	1.0 m/s	0.8 m/s
125 l/s	7.1 m/s	4.0 m/s	2.5 m/s	1.8 m/s	1.3 m/s	1.0 m/s
150 l/s	8.5 m/s	4.8 m/s	3.1 m/s	2.1 m/s	1.6 m/s	1.2 m/s

To keep the flow in turbulent zone and decrease friction loss the flow speed shall be kept between 0.8 - 2.0 m/s. With respect to a possible future extension and different from rates according to the operational conditions the following pipeline diameters are recommended:

- 2x DN200
- 1x DN300

The pipeline is made from black steel or GRE (Glass Reinforced Epoxy) material according to the chemical content of the harvested geothermal fluid. The directly buried pre-insulated bonded pipeline shall be laid underground with sufficient earth cover to protect against frost (in case of system stop) and surface loads. The trench will be backfilled with fine sand around the pipes and with excavated material on top of the sand up to the final grading. The final grading will be comparable (as close to identical as practical) to the existing surface.

Draining valves shall be installed in manholes made out of concrete or plastic in each low point of the pipeline and venting valves are necessary in the high points.

Compensators are necessary for partial absorption/distribution of expansion movements in the buried pipelines. Compensators are 4-6m long U-turns, but in case of insufficient space pre-stressed longitudinal compensators shall be installed.

Covering pipe needs to be installed in each place where pipeline crosses roads, railways, canals and unmovable utilities.

7.2 Site works

The site works include such items as preparations of the site for the works, access roads, fencing, temporary structures for the wells, supply and reinjection system etc. This area must be secure during execution of the project, for reasons such as public and employee safety, security reasons, etc. It must also be accessible for transportation of the largest components and may possibly require on-site cranes.

7.3 Production well sites

The production well extracts the geothermal fluid from the geothermal reservoir and supplies it to the geothermal heat plant.

Production well is located inside the administrative area of Kecskemét but outside from the residential areas, near agricultural lands and small cottages. Location and/or size of the production site shall allow further extensions with additional production wells.

The mechanical solution is designed to receive varying flow rate of geothermal fluid from the production well. The flow of the production well is determined by the need of the heating system. Draw-down, temperature, pressure and flow shall be monitored at the production well site.

The production well site includes the following main equipment:

- Well pump system
- Gas separator/Surge vessel
- Piping system (above ground)
- Valves
- Instruments and indicators
- Cooling unit
- Control system

7.3.1 Layout

Equipment except gas separator/surge vessel will be covered from weather by installing a shed over the production wellhead. Shed will be made out of steel frames and cladded with insulated sandwich panel. The well shed will be anchored to the drilling-rig foundation, which is made out of concrete. Gravel covered access road and a parking lot is designed to reach the well shed, and fence will be installed around the site.

7.3.2 Equipment

7.3.2.1 Well pump

The well pump will harvest and supply the geothermal fluid towards the heat plant and circulate the harvested fluid in the geothermal loop. Down hole pump will be “line-shaft” or submersible type and located inside the production well.

Control system for well pump and appurtenances shall be placed inside the wellhead shed.

The pump capacity will be adjustable with VSD (Variable Speed Drive). It will control the speed of the pump, via a reference signal from the control system, and provide protection of the motor. The motor shall be selected to be ample size with respect to the speed torque curve of the pump and only be 80 % loaded at full load of the pump.

Well pump shall be designed for continuous operation, 24 hours/day, 365 days/year at the site conditions.

7.3.2.2 Gas separator

To protect the process equipment and minimize risk of damage, separator will be needed for to remove solids from the geothermal fluid. Gas separator is required for separation of gas from geothermal fluid if its amount is above 10 l/m^3, according to the 12/1997. (VIII.29.) KHVM regulation.

Pressure shall be kept unchanged inside the gas separator tank to avoid scaling in the system, therefore pressure level shall be determined such to allow gases to settle out from the fluid but avoid unwanted scaling.

Gas separator will be placed at the production well site, outside the well shed, insulated and cladded.

7.3.2.3 Heat exchangers

If the chemical or gas content of the harvested geothermal fluid cause danger of scaling or corrosion in the teal pipe, plate heat exchangers may need to be installed in the production well shed to transfers the harvested heat into clear heating fluid. This solution allows decreasing the pressure of the circulated fluid in the long section of the geothermal pipeline and extends its lifetime.

The production well will provide variable flow of geothermal fluid, the geothermal heat exchanger will utilize only the required heat to the geothermal heating system, than the remaining amount of geothermal fluid will be reinjected into the reservoir.

7.3.3 Piping system and appurtenances

7.3.3.1 Pipes

The pipe sizing will be based on pressure drop calculations, equipment requirements and available fluid pressures.

Pipelines and wellhead shall be of non-alloy steel, insulated with rock-wool and cladded to minimalize temperature loss. Vents shall be provided on piping high points and drains on piping low points and are to include a capped or plugged valve.

7.3.3.2 Surge vessel

To avoid damages on pipe system and equipment in case of pressure shock related to “water hammer”, a surge vessel shall be connected to the pipe system. Physical placement of this vessel is planned to be outside the well shed, combined with the gas separator. Nitrogen may be used to create surge resistance, if needed. A standard Nitrogen cylinder with all of the accessories will be placed inside well shed.

7.3.3.3 Sensors

Flow measuring unit, temperature- and pressure indicators, heat meters and transmitters shall be placed close to the production wellhead, for regulating and monitoring purposes.

7.3.3.4 Valves

Isolation valves shall be placed close to the wellhead, because it may need to be isolated, for example in case of failure. Control valves are necessary to control the forward flow of the geothermal fluid. Sample valves are needed to take water sample from the harvested geothermal fluid. Air venting valves are necessary to exhaust air from the pipeline system. Draining valves are necessary to drain off the pipeline system in case of system stop.

7.4 Reinjection well site

The injection well receives the cooled down geothermal fluid from the geothermal heat plant and injects back into the reservoir.

Reinjection well is located inside the administrative area of Kecskemét but outside from the residential areas, near agricultural lands and small cottages. Size of the land shall allow later well reparations, if needed.

The keystone of reinjecting the waste water is the filtration. In most cases, the pressure increase during long term operation of a reinjection system is due to technical reasons:

- Incorrect installation of the injection horizon (incorrect running-in of the filter screen installation, screen installation in clayey interbeds, etc.).
- Insufficient preparation of the water (application of filtration techniques which were not adjusted to the reservoir conditions, entry of oxygen, selection of improper materials).

Before reinjection, the geothermal fluid will be led through a filtration system to protect the well against the clogging. The filtrated water will be pumped down to the reservoir by the surface pump system. Temperature and pressure will be monitored at the reinjection well site.

Equipment such as pump, filter, control and measuring system shall be covered from weather by installing a shed over the production wellheads. Buffer tank(s) may be needed to secure constant flow with appropriate pressure and temperature in the reinjection system.

The reinjection well site includes the following main equipment:

- Fluid filtration system
- Pressure booster pump system
- Piping system (above ground)
- Valves
- Instruments and indicators
- Control system
- Cooling unit

7.4.1 Layout

Equipment will be covered from weather by installing a shed over the reinjection wellhead. Shed will be made out of steel frames and cladded with insulated sandwich panel. The well shed will be anchored to the drilling-rig foundation, which is made out of concrete. Gravel covered access road and a parking lot will be designed to reach the well shed, and fence will be installed around the site.

7.4.2 Equipment

7.4.2.1 Reinjection pump

Reinjection pump may be necessary in case of additional pressure boosting is required for sufficient reinjection. Pump capacity shall be adjusted by frequency converter.

7.4.2.2 Water filtration

7.4.3 Fluid filtration

Filters shall be installed inside the well shed to secure the long term reinjection. Filter of "self-cleaning" or "twin" type will be installed just before the reinjection pump in the geothermal loop. Filtration fineness will be of suitable fineness for protection of the individual equipment. "Self-cleaning" type has a back flush system, where the back flushed geothermal water is lead to sedimentation pond ready for disposal or interim storage.

7.4.4 Piping system and appurtenances

Piping system, valves and sensors are necessary, as described above in chapter 7.3.3.

7.5 Geothermal Heat Plant

Geothermal heat plant is located in the area of Homokbánya which is inside the administrative area of Kecskemét but outside from the residential areas. The geothermal heat plant is receiving the geothermal fluid from the production well, where the geothermal heat will be utilized by the geothermal heat exchanger line or through direct hydraulically connection.

The geothermal heat plant includes the following main equipment:

- Heat exchangers
- Dynamic pressure maintenance
- Circulation pumps
- Piping system (above ground)
- Valves
- Filtration system
- Instruments and indicators
- Control system

7.5.1 Layout

New building will be constructed to protect the equipment and appurtenances against the weather. Building will be made out of steel frames and cladded with insulated sandwich panel. The building of the geothermal heat plant will be anchored to a concrete foundation.

Gravel covered access road and a parking lot will be designed to reach the well shed, and fence will be installed around the site.

The plant will be designed with remote system supervision, there shall be a control room but no equipment and rooms need to be installed for permanent stay of the operators.

7.5.2 Equipment

7.5.2.1 Heat exchangers

If heat exchangers would be installed into the production well shed, the heating fluid could be connected to the primary distribution loop with direct hydraulically connection, without new geothermal heat exchangers. In other case, geothermal heat exchanger line are necessary to produce heat by transferring it from the geothermal fluid into the primary distribution system.

The heat exchangers will be of countercurrent plate type. Plates of the heat exchanger will be constructed in minimum 0,5mm thickness, with the material of Titanium in the geothermal plant, but stainless steel in the rest of the facilities.

The production well will provide variable flow of geothermal fluid, the geothermal heat exchanger line will utilize only the required heat to the district heating system, than the remaining amount of geothermal fluid will be returned to the reinjection site.

7.5.2.2 Circulation pumps

7.5.3 Surface pump

Circulation pumps may be installed in the return pipeline of the supply and reinjection system after the heat exchangers due to increase the pressure to ensure proper circulation. Two parallel connected circulation pumps shall be installed for heating season and two smaller parallel connected pumps for non-heating season. Pumps capacity will be adjusted by frequency converter.

The pumps shall operate near its point of maximum efficiency and the diameter of the impeller limited to less than 90% of the maximum permissible diameter that can be used with the selected casing.

All centrifugal pumps shall be designed for continuous operation, 24 hours/day, 365 days/year at the site conditions.

7.5.4 Water filtration

7.5.4.1 Self-cleaning filter

Water filter is placed at the inlet of the geothermal fluid to the heat exchanger. One of the possible filter types is a self-cleaning filter with back flush system. Self-cleaning filter measures the pressure on both inlet and outlet side, and when pressure drop increases above a defined value the flow automatically turns back and flushes the filter. Back flushed geothermal fluid shall be lead to a cooling and sedimentary pond, after that it goes for disposal or interim storage.

7.5.4.2 Bag filter

Bag filter is another option to be installed or shall be installed in parallel with the self-cleaning filter in case of failure or maintenance. Filtration fineness shall be the same in both filters.

7.5.4.3 Strainers

Strainers shall be installed inside the heat plant before the geothermal heat exchangers in the primary distribution system to avoid damages of the heat exchanger caused by the floating particles in the heating water.

7.5.5 Dynamic pressure maintenance

The dynamic pressure maintenance includes make-up water system and membrane vessels. These are necessary if heat exchangers are installed in the production well site and clear heating fluid is circulates in the geothermal loop. Dynamic pressure maintenance needs to be installed into the primary loop in the first phase.

Make up water system is needed for supplementation of the heating water, if necessary. It includes a water treatment unit, feed pump(s) and all of the necessary equipment like valves, sensors etc. The make-up water system shall be located inside the geothermal heat plant and connected to the return side of the supply and reinjection system.

Membrane vessels are required to remain the pressure in the geothermal heating system. It will be located inside the geothermal heat plant with all of the necessary equipment, connected to the make-up water system.

7.5.6 Appurtenances

7.5.6.1 Sensors

Flow measuring unit, temperature- and pressure indicators, heat meters and transmitters shall be installed inside the geothermal heat plant, for regulating and monitoring purposes.

7.5.6.2 Valves

Isolation valves shall be placed before the main equipment to allow isolation, for example in case of failure. Sample valves are needed to take water sample from the harvested geothermal fluid. Air venting valves are necessary to exhaust air from the pipeline system. Draining valves are necessary to drain off the pipeline system in case of system stop.

Electrically powered and remote controlled valves are necessary to control the flow between the bag filter and the self-cleaning filter. Control valves also need to be installed both for geothermal heat exchangers and for the additional heat exchangers to controlling the flow in the geothermal loop and in the heating loop.

7.6 Electrical System

7.6.1 Process electricity and control

The voltage level will be 3x400, 50Hz, TN-C-S system. A feeder from the electrical utility company will be installed.

Power cabinets will be installed to feed the equipment in the sheds. The cabinets will be free floor standing. The cabinets will supply power to all process equipment and appurtenances as well as a separated service cabinet. Service cabinet will supply power to the auxiliary system i.e. lighting, cooling system etc.

A control cabinet will be installed next to the power cabinet. The cabinets will be connected together and with partially open access between the cabinets for the intention to integrate the control- and power systems. The control cabinet will include UPS backup system.

7.6.2 Control system

The control system consists of PLC, HMI's (Human Machine Interface) and communication system. The PLC manages all control and alarms for the whole system. The overall control system is monitored by a HMI, which allows the operators to view the actual operational parameters of the system and log the data.

The communication bus is Ethernet based control bus. The heat plant, production well and reinjection well are connected together with a fiber optic cable that is laid with the supply and reinjection pipeline.

7.6.2.1 PLC's

PLC is located in the heat plant and has remote IO (Input/Output) at the production well and the reinjection well. The PLC is primarily for controlling and monitoring all function.

Signal transmitters, pump control, switches such as temperature, pressure and flow transmitters are connected to the PLC via HW IO (Hard Wired Input/Output), Ethernet switch and wireless communication with the well sites. The HMI will communicate with the PLC through an L1 network.

7.6.2.2 HMI's

A local HMI touch screen panel will be at the production well site and in the heat plant. The HMI can be considered as a SCADA system. It consists of a PC computer with a Windows® operating system. The main function of it is to log historical data, monitoring and control all of the process in the facilities of the geothermal system related to the geothermal heat supply. Therefore the operators will be able to get full overview about these processes, including water harvesting, geothermal heat extraction or respond to all faults and alarms that can occur in the process.

7.6.2.3 Communication bus

The communication bus is an Ethernet based control bus. Each of the geothermal facilities will include an Ethernet switch witch manage all communications from the PLC's to the HMI's, remote IO's and all control devices, which are connected to the communication bus as well.

7.7 Operation and maintenance

The system will be operated by automatic control system. A minimum of two operators may be expected for handling of daily service and maintenance.

Maintenance of the system includes maintenance of the wells, the heat exchangers, control system etc.

The operation and maintenance cost is expected to be relatively low. It will increase with time, as the geothermal heating system gets older and more maintenance or replacement is needed.

The production rate of the geothermal heating system is an average over a period of technical service lifetime of 30 years. The production will start out at a higher level and then fall below the average at some point. Mitigating measures will be taken to counteract the fall in the system's output to some degree.

Normally there are two types of maintenance for geothermal and conventional heat plants; preventive - and corrective maintenance.

Preventive maintenance is the planned maintenance of a plant and equipment that is designed to improve the equipment life and avoid any unplanned maintenance activity. Preventive maintenance includes painting, lubrication, cleaning, adjusting and minor component replacement to extend the life of the equipment and facilities. Its purpose is to minimize breakdowns and excessive depreciation. Neither equipment nor facilities should be allowed to go to the breaking point.

Corrective maintenance is maintenance after break down of the equipment. This maintenance is often very expensive because worn equipment can damage other parts and then cause further damage.

Inspection and maintenance routines will vary with operating conditions and operator preference. In general, the machines and the other equipment in the heat plants are typical for this process needing a standard, basic maintenance. Any variation from normal operation should be investigated immediately.

8 Project execution plan

8.1 Implementation schedule

The execution of the project can be divided into 3 phases:

- Preparation
- Implementation
- Finalization

The following list summarizes the tasks performed in each execution periods:

Project preparation

- Conceptual design
    - Preliminary geological and water base evaluation
        - Preliminary geological evaluation, data collection
        - Estimation of expected well depth and outflow parameters
    - Preliminary concept design
        - Market evaluation
        - Defining the size of the project
        - Determine project concept, evaluate possible scenarios
        - Define the producible/marketable heat amount
        - Estimate investment cost
    - Comparing financial scenarios
        - Prepare preliminary business model
        - Explore financing possibilities
    - Decision about continue or stop the project (Milestone 1)
- Pre-design
    - Geological and well siting report
        - Gathering necessary (missing) data, perform the necessary measurements
        - Hydrogeological evaluation, water base modelling (flow, heat transport)
        - Well siting, estimating expected outflow parameters
    - Feasibility study
        - Gathering data necessary for pre-design
        - Define project locations (production and reinjection site, heat plant site), determine pipeline layout
        - Define main mechanical equipment parameters
        - Determine expected investment cost
    - Licensing design
        - Explore ownership status, negotiate with owners, get the necessary approvals
        - Gather necessary infrastructural and geographical data
        - Licensing design of the pipeline
        - Overview mechanical design of the system
- Business preparation

- Prepare the business model and financing plan
    - Explore financing possibilities
    - Negotiate with investors, get letter of intends
- Decision about start execution of the project (Milestone 2)
- Legal preparation of the project
    - Fund project company
    - Sign power purchase (pre-) agreement
    - Start execution licensing procedures
- Ensure necessary subsidies
    - Prepare grant application(s)
    - Start and manage grand procedure

Project implementation

- Licensing
    - Manage licensing procedures
    - Prepare the necessary modifications
- Detail design
    - Tender design
        - Design the main parts of the system, define the main parameters
        - Prepare bill of quantities
    - Construction design
        - Design all parts of the system
        - Prepare the execution schedule
- Procurement
    - Contractor tenders
        - Prepare tender documentations, evaluate bids
        - Contracting
    - Procurement of equipment
        - Gather and evaluate quotations
        - Order the materials
- Drill geothermal wells
    - Drill the production and reinjection wells
        - Drilling site preparation, drilling rig foundation
        - Drilling, well tests, evaluate results
    - Decision about continuing the execution (Milestone 3)
- Construction
    - Pipeline laying
    - Build heat plant(s)
    - Build well sheds and well sites
- Test run and commissioning
    - Make the necessary quantity tests and measurements
    - Test runs by system parts
    - Official handover process of the system

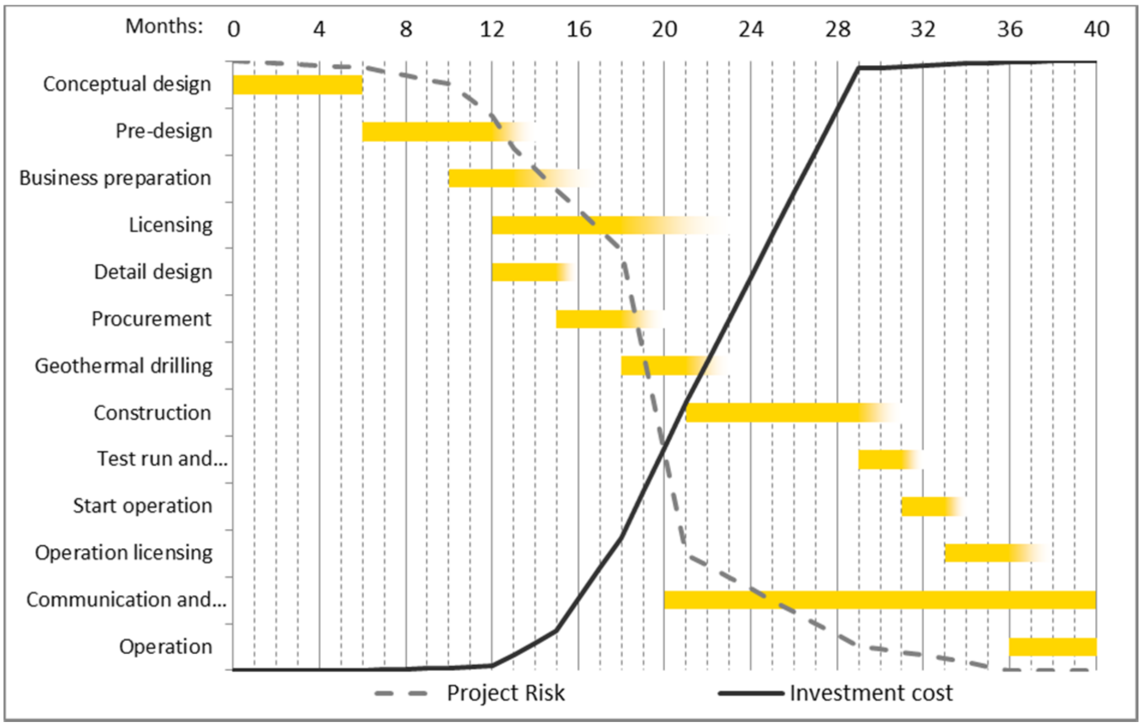
Project finalization

- Start operation
    - Long time test run
        - Continuous operation of the complete system

        - Monitoring, evaluate results
    - Train operators, prepare operation manual
    - Optimization of system parameters
- Operation licensing procedure
    - As-build design
        - Make necessary modifications of the design
        - Gather all measurement reports and construction documents
        - Gather and complete test run reports
    - Start and manage operation licensing procedures
- Communication and dissemination
    - Advertise the experiences of the project
    - Teach the achievements of the project
- Operation

The planned schedule for Phase 1 of the project with expected cost and risk mitigation are shown in Figure 14

Figure 14. Phase 1, execution schedule



8.2 Non-refundable grants

There are two funds currently or will be available for geothermal developments:

EEA/Norway Grant 2009-2014 – The overall objective of the grants includes reduction of economic and social inequalities and strengthening of bilateral relations between Hungary and the Donor States. Bilateral relations can be strengthened in the context of the various programs (including renewable energy) with the institutions and organizations of those of the Donor States that have contributed to financing the given program. The Rules on the implementation of the Grants were set out in Government Decree 326/2012 (XI. 16.). The decree contains implementing rules transposing the Regulations issued by the Donor States (Regulations on the implementation of the EEA / Norwegian Financial Mechanism 2009-2014) into the Hungarian national legislation.

The work of the Program Operators is assisted, in most programs, by donor program partner. A donor program partner is an organization or institution in the Donor States or an inter-governmental organization designated by the Donor States, fulfilling an advisory role during the preparation and the implementation of a program. For the program "Renewable Energy" (code: HU03) the Program Operator is the "National Environmental Protection and Energy Centre Non-Profit Ltd (NKEK), the Donor Program Partner is the "Icelandic National Energy Authority".

The available fund for geothermal projects is 8 million Euro. The expected number of funded projects is 3-5. The rate of support is at least 30% of the total project cost; the maximum can be up to 50% for enterprises and up to 85% for municipalities and governmental institutes.

KEHOP 2014-2020 – Region development with renewable energy will be available for development for heat production, heat efficiency increasing, combined heat- and electricity production, electricity production and district heating projects.

The available fund for this tender between 2014-2020 is not known yet, according to the previous period it is expected to be around 5000 million HUF. The rate of support is at least 10% of the total project cost; the maximum is expected to be up to 60% for enterprises and up to 80% for municipalities and governmental institutes.

9 Risk Analysis

9.1 Resource and drilling risks

The exploration risks in general deal with the uncertainty of the resource existence, the results of surface exploration, exploration drilling and the geothermal parameters that are critical in the geothermal utilization.

The results and information obtained from geophysical surveys and information from old wells in the area reduce the uncertainties and mitigate the risk factors involved in the later phases of the geothermal project development. For instance, once the existence of a commercially exploitable geothermal system has been confirmed and productive confirmation wells have been drilled in the field or constructed successfully from existing wells, better information on the system and its characteristics will become available which help identifying and mitigating risks involved in the geothermal field design.

In general it can be said about the Kecskemét and the surrounding area that very limited data are available and geologically it is a very complex area therefore the geological risk is high compared to other areas in the Pannonian-basin.

The drilling risk is related to the actual job of drilling and completing a geothermal well successfully according to the predefined designs without considering the actual outcome, i.e. the energy output from the well.

9.2 Technical and project risk

Development and construction risks of the utilisation, heat plant, are very similar to the risks associated with all other heat plant projects. When the risks of the resource and field development are not considered, the following risks remain:

- Traditional market risk
- Legal risk
- Cooperation with suppliers of equipment and services
- Environmental risk
- Risk of overstepping time schedule and budget
- Risks connected to the site such as construction risk
- Health and safety
- Geological risk for buildings
- Weather conditions
- Force majeure
- Findings of archaeological remains or endangered species that could pose a risk to the time schedule.

All equipment utilized within the conventional geothermal heat plant is technically proven, commonly available and utilized within the geothermal industry as well as other industries. Requirements of equipment regarding quality of material are affected by geothermal fluid quality, gases and scaling. However, this does not pose a risk to the technical function of the equipment nor construction and should be included in initial plans to affect neither time schedule nor budget of the plant equipment.

Legal and regulatory risks are generally present throughout the lifetime of a normal geothermal project. As geothermal projects are often executed and financed by international players, country and political risks are also part of the risk profile. Frequent government changes may cause changes in policies and the legal and regulatory framework may force constraints to the geothermal project, which may impact the project in long delays or costly adaptations. In certain geothermal markets, the legal, environmental and institutional factors may rank high in the terms of their impact upon the successful development of geothermal projects. For example, there might be a lack of well-established legal structure capable to deal with geothermal projects, contracts may not be enforced and property rights are not respected.

The main barriers and inconsistencies of the legal framework, concerning geothermal development noted within the analysis, are:

- Land ownership related legal issues may cause a serious risk to the geothermal project development except when the investor is a public utility, i.e. when the Law on expropriation may be applied.
- The lack of legal clause on reinjection of the geothermal fluid.
- The obstacles met by a private person (like a farmer or house owner) to utilize geothermal resource for heating unless being registered as a business entity.
- Applicability and justifiability of the clause regarding mining royalty for geothermal fluid for all applications disregarding size and utilization.
- The process (location and construction permit) is directly affected by municipalities spatial planning and this poses a risk to the timeline where a spatial plan has not been adopted.
- Inconsistency was found between different legal procedures concerning required technical documentation.
- Deadlines by which the relevant ministry is obliged to answer to all requests for issuance of certain documents (approval for geological explorations, approval for exploitation of mineral resource, approval for mining works execution, approval for trial operation) are not defined within the Law on geological exploration and the Mining Law.

9.3 Geothermal source related risks

Geothermal resources are known as high risk projects. Even though the risks of geothermal resources can never be eliminated there are several steps that can be taken to minimize the risk impact and strategies to deal with the situations if they occur.

The exploration risk in general deals with the uncertainty of the resource existence, the results of surface exploration, exploration drilling and the geothermal parameters that are critical in the geothermal utilization. These geothermal parameters are:

- temperature
- permeability
- resource size
- acidity
- seismicity
- initial gas content

The results and information obtained from the geophysical surveys and information from old wells in the area reduce the uncertainties and mitigate the risk factors involved in the later phases of the geothermal project development. For instance, once the existence of a commercially exploitable geothermal system has been confirmed and productive confirmation wells have been drilled in the field or constructed successfully from existing wells, better information on the system and its characteristics will become available that help identifying and mitigating risks involved in the geothermal field design.

Risks can be lowered by an insurance program for the geological exploration risks. The insurance premium is based on the desired level of insurance, which means the higher the desired level (volume and temperature of the drilling), the higher the risk and therefore the insurance premium.i

The drilling risk is related to the actual job of drilling and completing a geothermal well successfully according to the predefined designs without considering the actual outcome, i.e. the energy output from the well.

9.4 Development and operational risks

Development and construction risks of the geothermal utilization, heat stations, are very similar to the risks associated with all other heat plant projects. When the risk of the resource and field development is not considered, the following risks remain:

- Traditional market risk
- Legal risk
- Cooperation with suppliers of equipment and services
- Environmental risk
- Risk of overstepping time schedule and budget
- Risks connected to the site such as construction risk
- Health and safety
- Geological risk for buildings
- Weather conditions
- Force majeure

To decrease these risks, all equipment utilized within the conventional geothermal heat plant is technically proven, commonly available and utilized within the geothermal industry as well as other industries. Demands to equipment regarding quality of material are affected by geothermal fluid quality, gases and scaling.

Only state-of-art component is allowed to use in the plant, and all current standards and directives have to be observed.

Findings of archaeological remains or endangered species that could pose a risk to the time schedule.

9.5 Political risks

Legal and regulatory risks are generally present throughout the lifetime of a normal geothermal project. As geothermal projects are often executed and financed by international players, country and political risks are also part of the risk profile. Frequent government changes may cause changes in policies and the legal and regulatory framework may force constraints to the geothermal project, which may impact the project in long delays or costly adaptations. In certain geothermal markets, the legal, environmental and institutional factors may rank high in the terms of their impact upon the successful development of geothermal projects. For example, there might be a lack of well-established legal structure capable to deal with geothermal projects, contracts may not be enforced and property rights are not respected.

The main barriers and inconsistencies of the legal framework, concerning geothermal development noted within the analysis, are:

- Land ownership related legal issues may cause a serious risk to the geothermal project development except when the investor is a public utility, i.e. when the Law on expropriation may be applied.
- The lack of legal clause on reinjection of the geothermal fluid.
- The obstacles met by a private person (like a farmer or house owner) to utilize geothermal resource for heating unless being registered as a business entity.
- Applicability and justifiability of the clause regarding mining royalty for geothermal fluid for all applications disregarding size and utilization.
- The process (location and construction permit) is directly affected by municipalities spatial planning and this poses a risk to the timeline where a spatial plan has not been adopted.
- Inconsistency was found between different legal procedures concerning required technical documentation.

Deadlines by which the relevant ministry is obliged to answer to all requests for issuance of certain documents (approval for geological explorations, approval for exploitation of mineral resource, approval for mining works execution, approval for trial operation) are not defined within the Law on geological exploration and the Mining Law.

9.6 Natural hazards

Natural hazards are geological hazards, climatic and atmospheric hazards, wildfire hazards and disease.

Geological hazards can be avalanches, earthquakes, lahars, sinkholes and volcanic eruption. Since the geological resource is a low enthalpy resource the risk of earthquakes is moderate naturally. However with reinjection of the geothermal fluid a certain risk for induced seismicity has been established. It is not known to have happened where re-injection in to sandstone aquifers is on-going.

Climatic and atmospheric hazards can be blizzard, drought, hailstorm, heat wave, cyclonic storms, ice storms, tornado, geomagnetic storm etc. Wildfire and disease could pose a risk to the project time schedule if they would occur.

In Kecskemét the known natural hazards are mainly landslides, floods, extreme temperatures, seismic hazards, torrential floods, excessive erosion, droughts and forest fires.

Risks from natural hazards are not considered to be serious threats to the project.

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