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Detailed Design Specifications including Economic and Financial Analysis for Geothermal Heating Systems in Bulgaria

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ABSTRACT

Eight site designs were ordered by the Ministry of Economy and Energy of the Republic of Bulgaria for investment projects for the construction and rehabilitation of geothermal plants at different sites in Bulgaria. The contractor for all designs is a Consortium consisting of Geothermie Neubrandenburg GmbH /Neubrandenburg, Germany, and the project partners AQUATER-Groundwater Geothermics and Geoenvironment Consulting /Sofia, Bulgaria, and Lahmeyer International GmbH/ Frankfurt a. M., Germany.



Figure 1: Consortium between GTN, Aquater, and Lahmeyer International

The National Action Plan on Climate Change, adopted in 2000 and the Environment Review of the World Bank, completed and approved by the Government of Bulgaria, include provisions to increase the share of renewable energy resources in the total energy production of the country.

The Government of Bulgaria has secured a Grant from the Japanese Trust Fund for Climate Change Initiatives, managed by the IBRD, towards the cost of studies Sustainable Use of Geothermal Resources in Bulgaria.

The project comprised for each of the eight geothermal systems the following:

- Detailed technical specifications and computation of quantities for all supplies, assemblies, commissioning,
- Bills of quantity
- Economic and financial analyses, according to internationally acceptable methodologies
- Estimation of the amount of Greenhouse Gases (GHG) emission reduction in accordance with a methodology acceptable under the Kyoto Protocol
- Baseline study to support GHG reduction
- Development of an appropriate financial scheme, including a scheme involving the purchase of GHG emission reductions as provided for under the Kyoto Protocol and/or the EU carbon emission trading system
- Proposal of a set of monitoring indicators to keep track of the project performance against the targets of GHG emission reduction.
- Pilot investigation of the potential use of Ground Source Heat Pumps (GSHP) in Bulgaria.

1. INTRODUCTION

The use of geothermal resources has a long tradition at all of the eight sites under consideration. The geothermal sites are located in Sapareva Banja, Velingrad Kamenitza, Sandanski, Zlatograd, Pavel Banja, Momin Prohod, Banja Karlovo and Kjustendil.

Already in the 1950s and 1960s, wells were drilled at the sites with depths between 100m and more than 1000m. Some of the springs are artesian and thus, self-flowing. Temperatures between 50°C and 100°C were found with flow rates up to 33l/s.

The thermal water is used for different purposes like balneology and heating of polyclinics, schools, kindergartens as well as municipal buildings, amongst others. At most of the sites the consumers can cover their heating capacities completely with the existing geothermal energy. In some cases, however, additional gas or oil fired burners are necessary for peak loads.

With regard to the financial and economic viability of the projects some of the geothermal sites are profitable with high Internal Rate of Return (IRR) and short Equity Payback Period whereas others have shown less positive results from economic or financial point of view.

In the following chapters the technical and economic/-financial results of one the project sites are described exemplarily in more detail, followed by a description of the investigation results of the potential use of Ground Source Heat Pumps in Bulgaria.

2. GEOTHERMAL HEATING SYSTEM

2.1 Main Data and Technical Results at Sapareva Bania

2.1.1 Geothermal System

The use of geothermal resources has a tradition at Sapareva Banja. Already in 1956 and 1957, four wells were drilled in the western part of the town. More wells were drilled later.

Today, the well C-1HG „Gejzera“ is used for both, the production of mineral water and heating. The well is artesian and has a flow rate of approximately 15l/s at present delivering water with a temperature of 96°C.

- Geothermal reservoir: gneisses and granites, overlain by conglomerates, sandstones and gravel
- Depth 458 m
- Pressure of the well head 29 m
- Initial flow rate 23 l/s
- Initial temperature 98 °C

- Mineralization 680 mg/l



Figure 2: Existing Well House 1 HG „Gejzera“

2.1.2 Consumer System

Predominantly public buildings are supplied with geothermal heat. Partly, this is done directly, i.e., thermal water is supplied to the consumers to be used primarily as bathing water having passed a heat exchanger. Due to the limited resource, but also because of the technical condition of the systems, the capacity of the existing plant is actually almost exhausted, so that more potential consumers cannot be supplied.

Heat demand figures of the public buildings		
Gymnasium "Aleko Konstantinov"	260	kW
Cultural Centre "Prosveten Luch"	550	kW
Municipality	135	kW
Kindergarten	550	kW
Primary school "Christo Botev	295	kW
Policlinic	150	kW
Public bathing facility	100	kW
Municipal Centre	55	kW

Heat demand figures of the future potential consumers		
Department Store (GUM)	400	kW
Sanatorium (former SBR)	750	kW
Hotel Germania	450	kW
Hotel Euro- Vital	410	kW
Hotel CKS	500	kW
New hotel	272	kW
Public health station	108	kW
Printing shop	250	kW
Post Office	45	kW

Table 1: Heat Demand Figures

During project implementation above consumers were additionally identified. Jointly with the consumer stock, they form the basis for the dimensioning of the heat production plant and the heat distribution network.

2.1.3 Technical Measures

Project aim was to develop geothermal capacity reserves by using new and efficient heat exchangers and pumps, thermal insulation materials, resistive materials and equipment, and applying modern control systems for heat production and heat uses. For that a new geothermal station needs to be constructed and the district heat supply system has to be renewed

Derived from the scope of services contracted with the Ministry of Economy and Energy of the Republic of Bulgaria, the following planning measures were implemented coming up to the requirements of a “Technical Design”:

- Partial rehabilitation of the built volumes of the well cellar
- Rehabilitation and reconstruction of the surface piping system at the well 1 HG incl. measuring installation and relevant electrical installations
- Construction of a geothermal station in the immediate vicinity of the well with the relevant technical installations
- Thermal water pipeline connecting the well cellar with the new geothermal station
- Renewal of the district heat supply system within the stock considering a higher capacity for the potential later connection of buildings in the town area
- Construction or rehabilitation of house service sub-stations in buildings geothermally supplied already
- Renewal of the mineral water supply to the public bath incl. pressure increase installation in the geothermal station, new installation of the pipeline supplying the bath and consideration of capacity reserves for more future mineral water users
- Renewal of the cooled thermal water outlet pipeline

The entire pipe system flown through by thermal water is made of fibre-glass reinforced plastic material. In a group of high-grade steel plate-type heat exchangers, the thermal water gets into contact with the heating loop in the geothermal station. It will be cooled from the original temperature of 98°C down to 44°C. The thermal water flow rate that is taken from the production well via a control valve, results from the actual load on the consumer side. The design of the district heating system is based on the following parameters:

- feeding flow temperature 90°C, flexible mode of operation depending on the outdoor temperature (minimum 65°C due to the warm water production)
- required return flow temperature 42°C

Totally, 3,400m of pre-insulated plastic-sheathed pipes are buried for that in Phase 1, i.e., the connection to the public buildings.

Indirect house service sub-stations are installed in the consumer facilities. Here, plate-type heat exchangers separate hydraulically district heat (primarily) and house installation and drinking water supply (secondarily). The temperature difference of the heat exchangers for heating and SHW preparation has to be executed with 2K.

The supply pipeline to the public bathing facility will be buried jointly with the district heat supply pipeline in the road.

Thermal water which is not pumped to the consumers as mineral water is disposed of into a draining canal.

2.2 Economic and Financial Results of Sapareva Bania

2.2.1 Economic Analysis

Introduction

Economic analysis has been carried out to evaluate the viability of the project from the perspective of the entire country and measures the effects of the project on the

economy as a whole; whereas, financial analysis focuses on the project entity. The decisive difference between economic and financial analysis is the way in which inputs and outputs are valued, for example due to tariffs, export taxes and subsidies, excise and sales taxes, production subsidies, etc.

Methodology

The economic analysis has been conducted by an appraisal of the cash flows pertaining to the project. Due to the fact that the same amount of a credit or debit can have a very different value depending on when the transaction takes place, a dynamic calculation approach has been applied. Hence, the Dynamic Unit Cost criterion (DUC) has been chosen as decision criterion, i.e. the option with the lowest DUC is deemed to be the economically most attractive.

In consequence of the aspects described above, the calculation has been made on the basis of the following parameters.

- Investment cost for the different components;
- Operation and maintenance costs;
- Fuel costs (if applicable);
- Verified Emission Reductions (VER)

Reference System

It has been assumed, that a reference system compared to the planned geothermal heating system shall generate the same technical benefits in terms of quantity and quality.

After thorough evaluation of the local circumstances and in cooperation with the project partners a gas-fired heat supply system has been identified as reference system for Sapareva Bania.

The methodology of the applied economic evaluation model is as follows:

- Define the basic parameters (base year of prices, investment period, operational period, discount rate)
- Specify energy demand of geothermal customers
- Define supply options with equal technical primary benefits for geothermal and reference system to cover the respective geothermal energy demand during the operational period
- Define investment and operation costs for the supply options
- Calculate the cash flows of the investment and operation costs
- Calculate the net present value of the investment and operation costs (fuel and O&M costs) of the heat supply systems under consideration
- Calculate the present value of costs and energy production
- Calculate the DUC for geothermal and reference system.

The robustness of the results was assessed within the scope sensitivity analysis.

Basic Assumptions		
Commercial Operation Date (COD)	2008	
Period under Consideration	20	Years
Basic Project Cost	> 2,000,000	BGNst/kWh
Total Heating Capacity	2,140	kW
Average Saleable Energy	> 3,000,000	kWh/a
Average O&M Cost	48,800	BGN/a
Exchange Rate	1.95	BGN/EUR
Discount Rate	10	%
Specific gas price (world market)	10.8	BGNst/kWh

Table 2: Basic Assumptions of the Economic Analysis

Results

Results		
Dynamic Unit Cost – DUC for the geo-thermal system	9.5	BGNst/kWh
DUC gas-fired system	12.1	BGNst/kWh

Table 3: Summary of the Economic Results

The results let the following conclusions be drawn:

- The geothermal heating project in Sapareva Bania shows a lower DUC than the gas-fired reference heating system;
- The project is economically viable.

The critical discount rate for reaching the DUC of the reference system would be 14.5%.

Sensitivity Analysis

Regarding their influence on the project's DUC the input parameters can be ranked as follows (most influential first):

1. Investment cost - District Heat Piping;
2. Investment cost - Geothermal Heating station;
3. O&M cost.

Conclusions

The geothermal heating project in Sapareva Bania shows the lowest DUC of regarded alternatives generating the same technical benefits in terms of quantity and quality. The project is deemed to be economically viable.

2.2.2 Financial Analysis

Introduction

Financial analysis looks at the project from the perspective of the implementing agency, identifies the project's net cash flows and assesses the project's ability to meet its financial obligations. It was assumed that a project company be established to implement, administer and operate the project in all legal and commercial aspects.

Methodology

Based on the relevant technical and economic inputs, the cash likely to be generated by the project and the cash likely to be needed to sustain the project are estimated for every period during the expected life of the project.

The cash flows comprise following items:

- Investment cost for the different components, including taxes and duties, contingency allowances,
- Operation and maintenance costs,
- Heat sales revenues (based on a reference tariff for a

gas-/oil fired heating system).

- Verified Emission Reductions (VER)

The financial feasibility of the project was evaluated based on the following indicators:

- internal rate of return (IRR),
- return on equity (ROE),
- debt service coverage ration (DSCR),
- payback period.

The robustness of the results was assessed within the scope sensitivity and scenario analysis.

Basic Assumptions (Base Case)		
Construction Period	7	months
Commercial Operation Date (COD)	01.10.2008	
Period under Consideration	20	Years
Basic Project Cost	> 2,000,000	BGN
Total Heating Capacity	approx. 2,000	kW
Average Saleable Energy	> 3,000,000	kWh/a
Average O&M Cost	45,000	BGN/a
Exchange Rate	1.95	BGN/EUR
Discount Rate	10	%
Debt/Equity Ratio	75/25	
Soft loan	3.75	%
Depreciation	Straight-line	
Corporate Income Tax	15	%
Concession Fee	0	BGN/kWh
Assumed Geothermal Heat Sales Tariff (Reference Tariff)	12.1	BGNst/kWh

Table 4: Basic Assumptions of the Financial Analysis

A particular sales tariff for geothermal energy per kWh is currently not in force. However, a (concession) fee for the use of mineral water per m³ has been in force for years.

In terms of modeling of geothermal heat sales revenues, it is understood that customers shall pay only a simple tariff in form of an energy charge per kWh consumed. This tariff shall be slightly smaller or at maximum be equal to the DUC of an economically competitive reference heating system. In cooperation with the project participants the reference system has been defined to be a gas-fired one. The Reference Tariff for the financial analysis of the geothermal system and has been calculated to be 12.1 BGNst/kWh.

Results

Results (Base Case - incl. concession fee)		
Internal Rate of Return - IRR (post-tax)	7	%
Return on Equity – ROE	8	%
Equity Payback Period	15	Years
Operating Ratio	0.6	
Minimum DSCR	0.9	x
Average DSCR	1.0	x
Dynamic Unit Cost (for the geothermal system at 10% discount rate)	< 13.5	BGNst/kWh

Table 5: Summary of the Financial Results

The results regarding the base case including the payment of the legally binding concession fee to the Bulgarian state can be summarized as follows:

The internal rate of return (IRR) is positive, which indicates that the project generates a positive net cash flow during its operational period. However, the rates of 7% (post-tax) and 8% (pre-tax) are below the discount rate of 10%. If the discount rate was interpreted as minimum rate of return, the project's IRR would be below that rate.

The return on equity (ROE) is 8%. Whether this rate is adequate depends on the investor's objective and its pre-determined cut-off rate. In this case no cut-off rate has been determined, but according to the consultants' experience the ROE minimum rate is usually 10% to 15%, depending profoundly on the project's risk profile.

The equity payback period is 15 years, which is five years prior to the end of the operational period.

The results of this base case including concession fee are analyzed further within the scope of sensitivity and scenario analyses.

Sensitivity Analysis

Regarding their importance the parameters of the sensitivity analysis can be ranked as follows (most influential first):

1. Sales tariff;
2. Annual energy sold;
3. Investment cost - District Heat Piping
4. Investment cost - Geothermal Heating station;
5. O&M cost; and
6. Interest rate.

Scenario Analysis

As indicated above, a concession fee for the use of mineral water has to be paid by the operator of a geothermal heating system to the Bulgarian state by law. In the case of Sapareva Bania this fee is about 0.032 BGN/kWh.

Reportedly, the calculation methodology of the concession fee leading to this significant cost component seemed to be under review by Bulgarian government during project implementation.

Conclusions

Due to the absence of a geothermal heat sales tariff in Bulgaria, the DUC of a competing gas-fired heating system delivering the same quality and quantity of heat supply, has been applied in the financial analysis in order to model the geothermal project's revenue stream. The project's CAPEX consist of investment costs for the geothermal heating station and the district heat piping. The project's OPEX consist of O&M costs as well as personal costs for the maintenance of the geothermal heating station.

The results of the base case calculation show that the project generates a positive net cash flow. However, key indicators, such as ROE, payback period or debt service coverage ratios indicate a relative poor project performance under the given circumstances.

Considering a required minimum DSCR by financing institutions of approximately 1.2x, the project will most likely not overcome the financing hurdle. Hence, the project in the base case scenario (including concession fee) will not be financially viable.

Sensitivity analysis showed that the project's most important input parameters are:

- The geothermal heat sales tariff, followed by
- the annual energy sold, and
- the investment costs for the district heat piping and the geothermal heating station.

Since the applied heat sales tariff is equal to the dynamic unit cost of the most competitive heating system offering the same quantity and quality of service as the geothermal system, it is unlikely to improve the project's financial performance by a potential tariff increase without inducing a shift towards the competing gas-fired system.

Furthermore, the annual geothermal energy sold has been technically optimized to meet the demand of its customers, which suggests, that a major increase in energy sales is not very likely without further investments.

Finally, the investment costs have been based on the consultants' detailed engineering and experience in similar projects, which leaves only little room for significant changes.

A scenario analysis compared the base case scenario *including* the concession fee with the scenario 1 *excluding* the concession fee. Three additional scenarios have been analyzed in order to determine critical performance values. The results clearly revealed the distinct impact of the concession fee on the project's performance.

Scenario analyses showed that, if there was an option to exclude the concession fee, this would lead the geothermal project towards financial viability (IRR 12%, ROE 20%, equity payback period of 7 years).

With regard to the Greenhouse Gas (GHG) emissions it can be stated that the total GHG emission reduction potential amounts to approximately 800 t CO2/a, which can be neglected for the economic and financial analysis.

3. GROUND SOURCE HEAT PUMPS

Heat pumps including Ground Sources Heat Pumps (GSHP) offer the possibility to utilize low-temperature ambient heat for the heating of buildings or sanitary hot water preparation. The temperature level of the heat source is transformed onto the demand level of the heat sink (the heating system). For that, of course, work needs to be done, i.e., primary energy must be used. However, its quantity forms a small part only of what is needed in the respective conventional boiler units.

The specific energy use decreases when using heat pumps, thus, also reducing the emissions into the environment and the costs tied to consumption. On the other side, modern heat pump installations require, of course, higher investment in the energy production itself, but also in the consumer systems.

The above interrelationships were investigated exemplarily within the framework of a Pilot Investigation into the Possibilities for the Application of a Ground Source Heat Pump (GSHP) Technique in Bulgaria.

For this investigation, a proper building was selected at a site with typical Bulgarian climate and geological conditions (stratification, heat conductivities etc.). The investigation included the following analyses:

- dimensioning of the heat pump installation incl. heat source
- estimate of the required investment and determination of the heating costs
- comparison to the actual heating costs of a conventionally supplied building and those to be expected in the future.

3.1 Geothermal Application

3.1.1 The Heated and Cooled Building

The analysis is based on a typical single-family Bulgarian house with the following characteristics:

- First Floor Allocation-entrance hall, staircase, bathroom, closet, technical room, living room with canteen and kitchen.
- Second Floor Allocation-corridor, bedrooms-3, bathrooms-2 and balconies–2
- Built area 100 m^2
- Total built area 220 m^2

The following heat and cold demand was determined based on the building standards applicable in Bulgaria and on the meteorological conditions in the Sofia area:

- Heating load (maximum per hour):
  - Heating capacity 18 kW
  - Domestic hot water capacity 9 kW
  - Total: 27 kW
- Energy load for heating:
  - Heating energy 29.25 MWh/a
  - Domestic hot water energy 5.95 MWh/a
  - Total 35.20 MWh/a
- Cooling capacity 12 kW
- Cooling energy 10.10 MWh/a

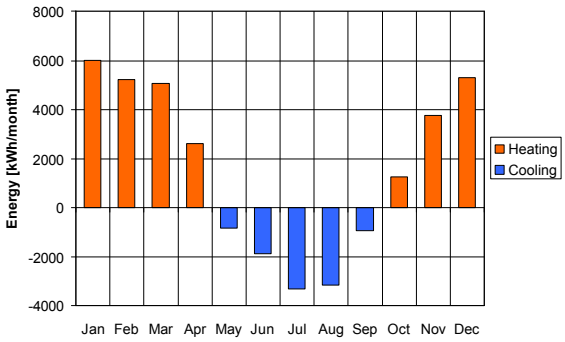


Figure 3: Energy Balance of the "Typical Bulgarian House"

Using a heat pump, essential shares of the heating load of the building (15kW) and the complete cooling load are transferred via fan coils to the living and sleeping rooms. Only bathrooms and corridors will be equipped with floor heating installations.

- Heating network parameters of the fan-coil- and floor heating 35°C/28°C
- Cooling network parameters of the fan-coil cooling 18°C/21°C

In the conventional comparative systems, also the consumer installations are dimensioned conventionally, i.e., heating network temperatures 90°C/70°C and split units for cooling.

3.1.2 Investigated Types of Ground Source Heat Pumps

Two solutions form the basic types of the shallow geothermal systems – open (in Germany 12% of the overall

number of heat pumps) and closed ones (64% of all installations).

- Variant A:

Open loop system – This variant is characterized by the fact that the heat carrier water flows freely in the underground and acts as both, a heat source/sink and a medium to exchange heat with the solid earth. Main technical parts of these systems are groundwater wells to extract or inject water from/to water bearing layers (aquifers).

- Variant B:

Closed loop system – heat extraction by "borehole heat exchanger" (BHE) - For the transportation of heat from the subsoil, an artificial intermediate loop is used with a heat carrying medium circulating in it. This loop is installed in the sub-soil as a heat exchanger. The heat transport in the subsoil to this heat exchanger is done basically through heat conduction.

3.1.3 Geology and Hydrogeology of the GSHP Well

The two selected sites north of Sofia are typical for large regions of the Bulgarian territory with regards to their climatic, geological and geothermal conditions.

- Variant A:
  - Depth of the well: 80 m
  - Geological section:
    - 0–10 m soil, artificial embankments, deposits
    - 10–40 m sands (aquifer)
    - 40–50 m clays (aquiclude)
    - 50–70 m sands (main aquifer)
    - 70–80 m clays (aquiclude)
  - Flow rate: 1.5-2 l/s
  - Temperature at the well mouth: 12.5 °C

- Variant B:
  - Depth of the well: 100 m
  - Geological section:
    - 0–100 m alternation of clays and sandy clays
  - No aquifer layers, the section is "dry" in practice

3.1.4 Shaping and Behaviour of the Production Units

- Variant A: Water-Water Heat Pump

It is assumed that the water quality will allow groundwater flowing directly through the heat pump and the heat exchanger for direct cooling.

Heating operation - 35 °C / 7 °C

- Heating capacity 19.5 kW
- Power demand 3.7 kW
- COP 5.3

Hot water production - 55 °C / 7 °C

- Heating capacity 18 kW
- Power demand 5.1 kW
- COP 3.5

The produced groundwater is cooled from 12.5°C down to 7°C in the evaporator of the heat pump. An amount of approx. 2.5m³ of groundwater has to be circulated per hour in the heat source loop. Accordingly, two wells dimensioned for this flow rate will be drilled down to a depth of 80m, cased and equipped with an underground screen in the aquifer. One of these wells serves for production. The submersible pump will be installed there. The other well is for injection. For the later estimate of the investment, an internal well distance of 50m is assumed.

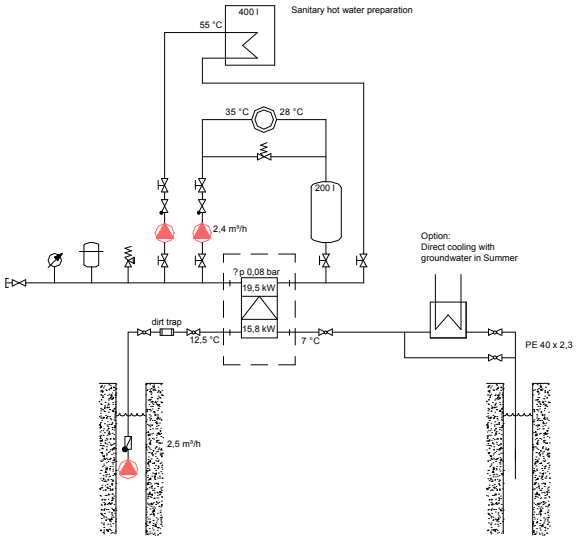


Figure 4: Principle Scheme: Heat Pump with Groundwater Loop

Energy input:

- Energy carrier power
- Heat pump drive 7,270 kWh/a
- Groundwater circulation 1,050 kWh
- Consumer installations 1,700 kWh/a

- Variant B: Brine-Water Heat Pump

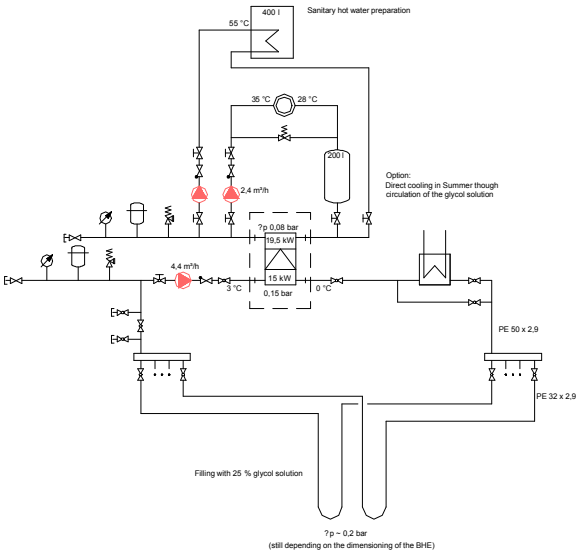


Figure 5: Principle Scheme: Heat Pump with Borehole Heat Exchangers

The energetic parameters of the installed heat pump are as follows:

Heating operation - 35 °C / 0 °C

- Heating capacity 19.5 kW

- Power demand 4.5 kW
- COP 4.3

Hot water production - 55 °C / 0 °C

- Heating capacity 18 kW
- Power demand 6.7 kW
- COP 2.7

For the calculation of the shaping of the BHE field, the program "Earth Energy Designer Version 2" (Eskilson, G.; Hellström, G., Claesson, J.; Blomberg, T.; Sanner; B., 2000) was applied. The result was as follows:

- number of boreholes 5
- depth of the boreholes 75 m
- arrangement 3 x 2
- internal distance of the boreholes 5 m

Energy input:

- Energy carrier power
- Heat pump drive 9.000 kWh/a
- Brine circulation 1,150 kWh
- Consumer installations 1.700 kWh/a

- Conventional Heating and Cooling System

For the comparison with the heat pump installations, 25kW boiler units are drawn up. They serve for heating and sanitary hot water (SHW) preparation in winter. SHW preparation is done in summer by means of an electrically driven heating cartridge which is arranged in the boiler.

The living and sleeping rooms are cooled in summer by means of decentralized split systems (wall-mounted).

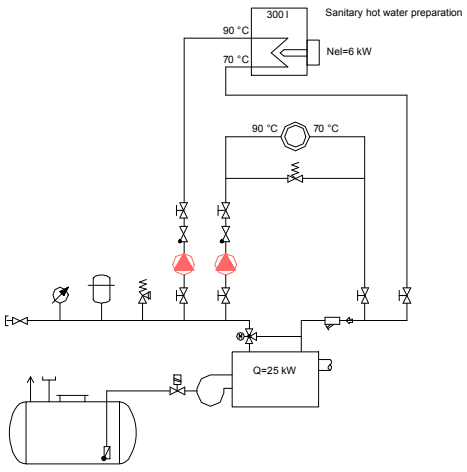


Figure 6: Principle Scheme: Conventional Heat Supply

Energy input:

- Energy carrier fuel oil, briquettes, and gas
- Boiler-based heat production for heating and SHW preparation in winter 32,350 kWh/a
- Energy carrier for summer operation power
- Heating cartridge-based SHW preparation 2,850 kWh/a
- Cooling 3,515 kWh/a

3.2 Financial Analysis of the GSHP Systems

The two configurations of Ground Source Heat Pumps for a typical Bulgarian house were analyzed regarding their financial characteristics. As, besides heating, cooling was regarded as an inherent service option of the GSHP, the financial analysis addressed heating as well as cooling. To verify the possible benefits of this innovative technology, both GSHP variants were compared with conventional heating and cooling systems (radiator-heating with oil-, gas- and briquette-fired boilers and electrical compression cooling systems).

The assumptions and input data of the analysis are summarized and the results presented. To test the stability of the results against different input assumptions, a sensitivity analysis was also performed with regard to main parameters. Based on the analyses, conclusions were derived concerning the financial attractiveness of GSHP in Bulgaria.

3.2.1 Assumptions and Input Data

The evaluation was made on the basis of the present value of the total project costs. These include:

a) Investment costs for the different components,
b) Fixed operation & maintenance costs, and
c) Variable operation & maintenance costs (e.g. for electricity, fuels).

The option with the lowest present value of total project costs was deemed the financially most attractive.

The following numbers shows the basic assumptions of the financial analysis. For the base-case, a discount rate of 10% and a period under consideration of 20 years were chosen. The discount rate, the period under consideration, and the increase of electricity tariff and specific costs of the fossil fuels are subject to sensitivity testing in order to analyze the stability of results.

Basic Assumptions		
Discount Rate	10	%
Period under Consideration	20	Years
Electricity Tariff	0.15	BGN/kWh
Electricity Tariff Increase	0	%/year
Specific Costs of Fuel Oil Combustion	0.18	BGN/kWh
Specific Costs of Gas Combustion	0.08	BGN/kWh
Specific Costs of Briquette Combustion	0.04	BGN/kWh
Increase of Specific Costs of Fuel Combustion	0	%/year
Exchange Rate	1.95	BGN/EUR

Table 6: Basic Assumptions of the Financial Analysis

The next figure is clearly indicating that among the three conventional systems the investment costs and especially the variable costs for the radiator-heating with a briquette-fired boiler are lower than those of both, the oil and gas fired system. This is mainly due to the higher cost for the heating central, the necessary additional investment for the oil and gas supply and in particular the higher fuel cost of gas and heating oil.

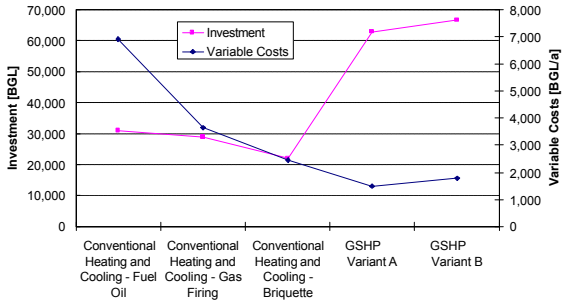


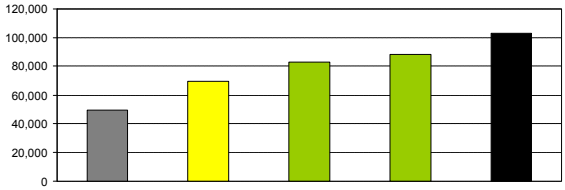
Figure 7: Summary of the Cost Input Data

The variable costs of the conventional systems mainly consist of the costs for fossil fuel (oil, gas, and briquette) to generate heat, for electricity during summer operation for water heating, and the electricity costs during summer operation to provide cooling power with the compressions cooling system. The variable costs of the GSHP variants are electricity costs for the operation of the heat pump, the circulation of the ground water, and the operation of the fan coils fort cooling.

More than two third of the investment cost of the GSHP variants result from the costs for the heat pumps and the drilling of the boreholes.

3.2.2 Results of the Base Case

The results of the financial analysis for the base case are summarized in the figure below. Under the given assumptions, the five different options can be ranked as follows:



	Convent. Briquette	Convent. Gas	GSHP A	GSHP B	Convent. Fuel Oil
Pres. Value [BGL]	49,700	69,600	83,100	88,300	103,000

Figure 8: Present Value of Total Project Costs of the Five Options in the Base Case

The conventional radiator-heating with a briquette-fired boiler and split compression cooling facilities has the lowest present value of total project costs. From the financial point of view it can be considered as the most attractive option. The gas-fired heating with a conventional cooling system reveals the second lowest present value of total project costs. It is about 40% higher than the present value of total project costs of the briquette-fired system. The GSHP A (open circulation cycle) has the third lowest present value of total project costs. It exceeds the present value of total project costs of the gas-fired system by about 20%. The GSHP B (closed circulation cycle) follows the GHSP A with an about 5% higher present value of total project costs. All GSHP specific components have higher investment costs in option B compared to option A. The same holds for the variable costs while the repairs and maintenance costs of GSHP B are lower than those of GSHP A.

The radiator-heating with fuel oil boiler and split compression cooling facilities has the highest present value of total project costs, being more than 15 % above the value of GSHP B. Oil firing is therefore the least attractive alternative under the given circumstances.

3.2.3 Sensitivity of Results

These results have not only been obtained for the base case but also for the variation of important input parameters such as discount rate, period under consideration, and electricity as well as fuel price increases. It should be mentioned, that changes in the assumed investment costs e.g. due to grants, directly effect the ranking of the technological options. A reduction of the overall investment costs of the GSHP A of more than 20 % would yield this option a better financial ranking than the gas-fired conventional heating in the base case.

4. CONCLUSION

4.1 Geothermal System Sapareva Bania

The Financial Analysis of the geothermal heating project in Sapareva Bania indicates that the project's financial performance in the base case scenario (including concession fee) is rather poor and that financial viability is unlikely. Particularly, expected minimum ROE of about 15% and the minimum DSCR of 1.2x have not been reached.

Due to the absence of a geothermal heat sales tariff in Bulgaria, the dynamic unit cost of a competing gas-fired heating system delivering the same quality and quantity of heat supply, has been applied in the financial analysis in order to model the geothermal project's revenue stream. The most influential single input parameter, the assumed geothermal heat sales tariff, mainly depends on the development of the fuel price of the reference system. A rising gas price could induce a higher geothermal heat sales price, without additional costs for the geothermal system, leading to a better financial project performance.

Scenario analyses revealed that a complete exclusion of the concession fee or a reduction of this fee by at least -84% would lead to financial viability with an IRR post-tax above 11%, a ROE above 17%, a payback period between 7 to 8 years and a minimum DSCR of at least 1.2x.

4.2 Ground Source Heat Pumps

The presented technology ranking for a "Typical Bulgarian House" solely reflects financial criteria. For investment and support decisions other criteria like environmental attractiveness, fuel access (not all households have gas access), and ease of use (the briquette-fired system requires permanent manual firing while the gas, oil, and heat pump systems are automatically controlled) should be considered as well.

Gas heating is the main competitor of the GSHP Variant A. The sensitivity analysis has shown that for a gas price increase of more than 6.6% and an electricity cost increase of more than approximately 3.3 % the GSHP A gets the financially more attractive option. More relevant than this high fuel price scenario might be the fact that not all households have access to gas. Where no gas is available in a foreseeable period of time, the GSHP A is the financially most attractive choice.

Furthermore, it should be mentioned that an exhaustive introduction of GSHPs in Bulgarian houses will assist in reducing emissions as well as in decreasing the dependence on fuel imports