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# GEOTHERMAL DISTRICT HEATING IN A PART OF ELBASAN CITY, ALBANIA

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**ABSTRACT**

District heating is widely accepted as a method for providing a safe, efficient and financially beneficial solution of house heating to the consumer. In this study, experience with district heating systems in Europe has been investigated and evaluated, focusing on the Icelandic systems using geothermal energy. The main purpose was to evaluate the feasibility of geothermal district heating with the aim to reduce heat and water losses, to improve thermal efficiencies, and to reduce the high cost of pipe installation and maintenance. Technical details of district heating systems were investigated, including a central heating plant for conversion to cogeneration facilities, with sliding temperature-variable flow of medium-/low-temperature hot water as a heating source.

## 1. INTRODUCTION

Albania is located in the western part of the Balkan Peninsula. It borders former Yugoslavia (Serbia and Montenegro) and Kosovo in the north and the east, FYR of Macedonia in the east, and Greece in the south. It has access to the Adriatic and Ionian Seas in the west. From the Strait of Otranto, Albania the distance to Italy is less than 100 km. The country covers a total of 28,000 km$^2$ and its population is 3.6 million.

Geothermal energy, as a clean and renewable form of energy, has been used more and more widely in the world during the second half of the 20$^{th}$ century for electricity generation, district heating, balneology, fish farming, agriculture, aquaculture, etc. It makes substantial contributions to the energy supply even when the resource temperature is not high enough for electricity generation. Low-temperature geothermal resources are found in most countries of the world.

In Albania there are three potential geothermal zones, see Figure 1:

- Kruja zone;
- Ardenica zone; and
- Peshkopia zone

The Kruja geothermal zone has large geothermal resources. It stretches for 180 km and extends from the Adriatic Sea in the north to southeast Albania and to the Konitza area in Greece (Frashëri et al.,

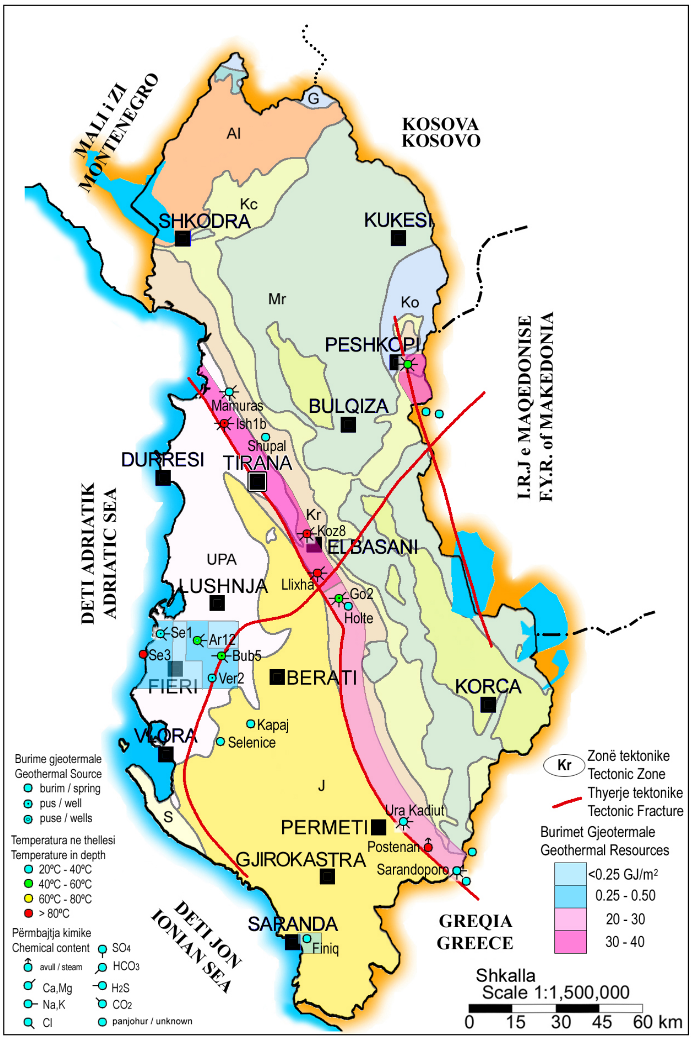


FIGURE 1: Geothermal map of Albania

2004). The geothermal aquifer is associated with a karstified neritic carbonate formation with numerous fissures and micro fissures. Thermal springs of the Llixha Elbasan spa are located about 12 km south of Elbasan city (Frashëri et al., 2004).

Three boreholes have been drilled that produce hot and mineralized water: Ishmi-1/b (Ishm-1/b), Kozan-8 (Ko-8) and Galigati-2 (Ga-2) (Frashëri et al., 2004). Well Kozan-8 is located about 35 km southeast of Tirana. It is only 8 km northwest of Elbasan, in a beautiful valley with the village Kushës, famous for its relish. Well Kozan-8 yields a high surface temperature, 65.5°C. Water emerges from the bottom aquifers in a carbonate formation at a depth of 1816-1837 m, where the water temperature is 80°C. The pressure is 188.5 bars in the limestone aquifer and 11.8 bars at the wellhead. Mineralization of the water is 4.6 g/l. The flow rate is stable, at 10.3 l/s. To date, five wells have been drilled in this structure to search for oil and gas. Of these, only geothermal wells Kozan-8 and Kozan-2 have perforated carbonated stratum.

Wells Kozan-2 and Kozan-3 are located about 2 km north of Kozan-8 and drilled in 1969 and 1971, respectively. The wells have a similar calcareous stratigraphy as Kozan-8 but extend deeper. Kozan-2 is well preserved, with a small water leak with sulphuric smell. It is necessary to fix the wellhead in order to use the well and obtain the thermal water. After drilling, Kozan-3 was left with the curing solution and is filled with clay, and the wellhead is open. Before use, the well needs to be cleaned and the wellhead equipment regulated. Production from wells Kozan-2 and 3 would at least double the geothermal production capacity from the Kozan area.

## 2. THE PROJECT SETTINGS

### 2.1 The Elbasan area

The study focuses on a small residential area in Elbasan city with a total indoor area of 119,000 m², where a district heating system is planned, including heating hot water for both space heating and hot tap water in one heat central using geothermal water as the main heat source. A gas-fired boiler is also to be used during peak heat load periods with the purpose to extend the utilization of the low-temperature geothermal energy in winter. The pressurized steel boiler is to be installed in a new building near the heating area and should be at least 100 m² equipped with all necessary equipment, including safety.

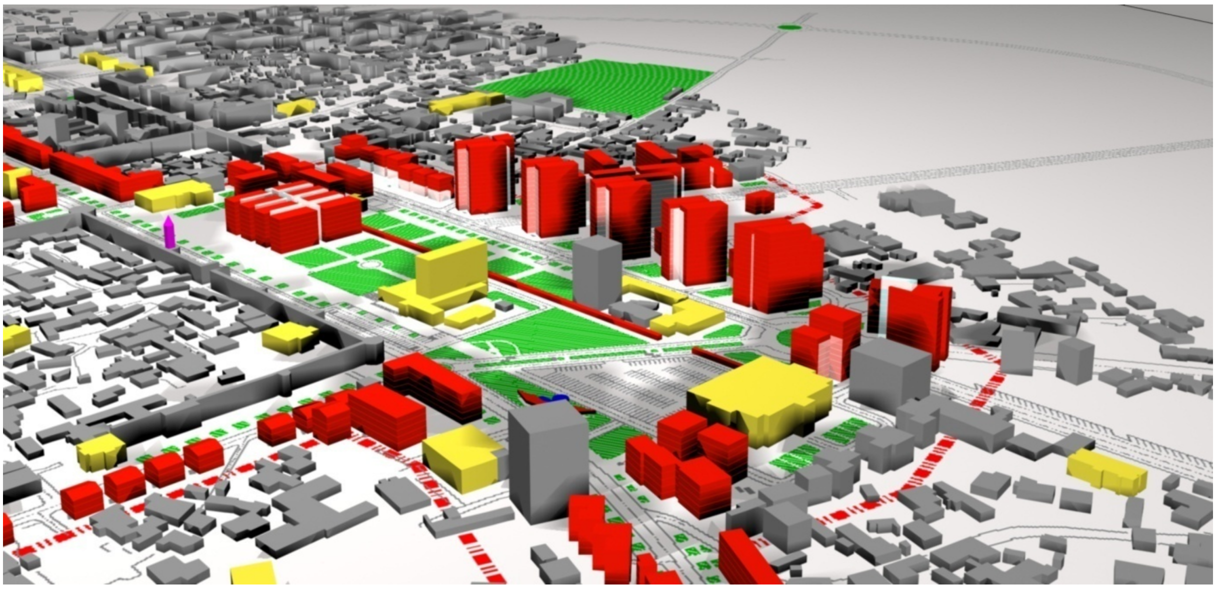

FIGURE 2: Residential area in Elbasan city (Elbasan urban study)

Most of the buildings range from 5 to 15 floors (Figure 2), divided into 4 to 7 main pressure zones for both space heating and hot tap water systems. There is a large single pipeline system from the heat central to the buildings. Connections in the buildings are simple and each individual building has a simplified control for temperature. The base energy for the district heating system is provided by the geothermal fluid, but additional energy is required to meet peak load demands. This is provided by a gas boiler located at the entrance to Elbasan city (southwest of the city). The gas boiler is used to raise the temperature of the geothermal water and the capacity for the supply area. The gas boiler station provides hot water at 80-100°C and the district heating system operates under design temperatures of 90/30-40°C. The system is composed of three parts which are: the schematic design of the wells, the machinery room and the mechanical design scheme of the buildings, and equipped with all necessary safety equipment.

## 2.2 The geothermal wells

There are several wells in the Kruja geothermal area, but only three of them concern this project: Kozan-8, which is being evaluated for optimal production capacity of thermal water, and Kozan-2 and 3 which currently are not in use. Figure 3 shows the depths and casing diameters of the wells. Evaluation of optimal production capacity is important and necessary, not least for the fact that 18 years have passed since well Kozan-8 was drilled. Its discharge was measured to be 10.3 l/s. A study of the three near wells shows that if wells Kozan-2 and 3 were to be stimulated by pumps and cleaned, a flow rate of 30 l/s might be obtained with a temperature of 65.5°C. The possible geothermal capacity of the three wells could be rated as 2.77 MWth, with reference to the space heating system.

For many years the water from Kozan-8 has been used for balneology and curative houses by the people in the region. Chemical analysis of the water is shown in Table 1. From the information in Table 1 and expert reports, it can be seen that a major risk of corrosion or formation of scaling is not associated with transport of the water through a pipe line system. Also, further cooling of the geothermal fluid to 40, 20 and 0°C does not seem to have more deposition potential.

TABLE 1: The chemical composition of the water in Kozan-8, in g/l

| | **pH** | **Mineral.** | **$Ca^{2+}$** | **$Mg^{2+}$** | **$Na^+K^+$** | **$NH_4^+$** | **$Cl^-$** | **$F^-$** | **$Br^-$** | **$J^-$** | **$SO_4^{2-}$** | **$HCO_3^-$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kozan-8 | 7-7.5 | 4.6 | 0.64 | 0.144 | 0.7285 | 0.0475 | 1.426 | 0.0067 | 0 | 0.00162 | 1.512 | 0.244 |

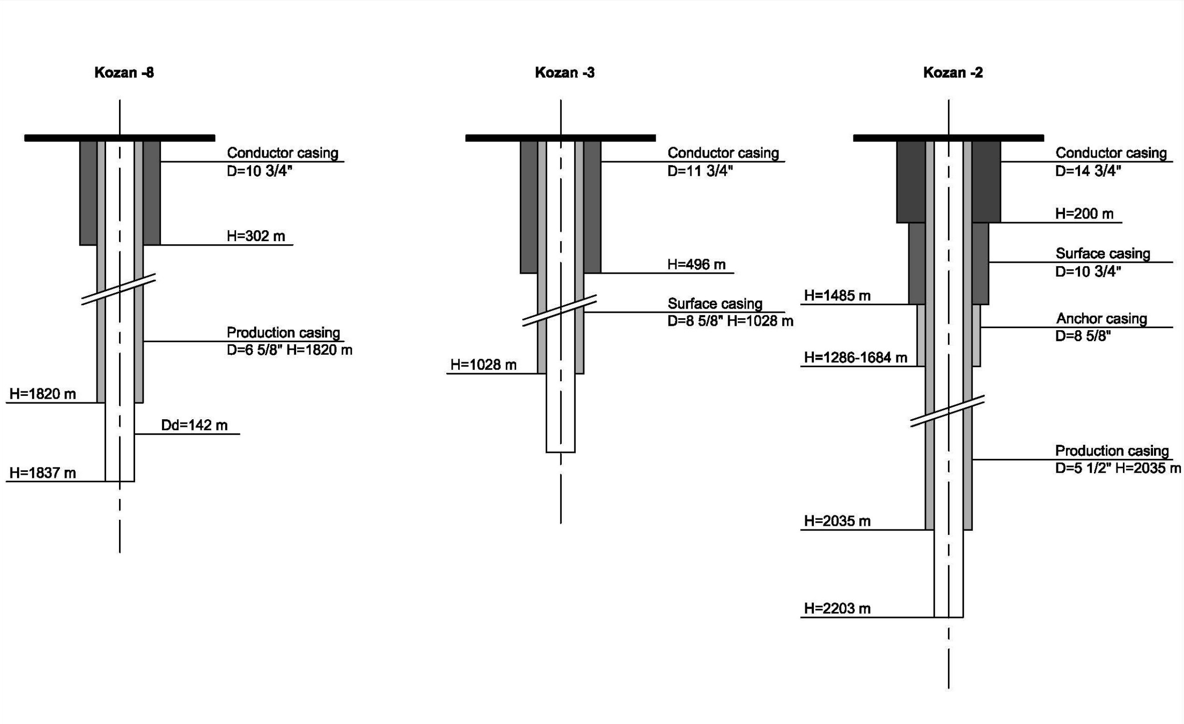


FIGURE 3: Designs of the three wells, Kozan-8, 3 and 2

### 2.3 Weather analysis

The heat load of space heating systems is closely related to the outdoor climate. The main factors influencing the load are air temperature, wind speed and solar radiation. Minor influences include steep cold wave precipitation, etc. Here the dynamic characteristics of the weather on the heating demand are examined.

The three main factors of the climate data were analysed, including observations on the highest, average and lowest air temperatures, wind speed and sunshine radiation, made on a daily basis. The weather data are taken from a ten year period. Figure 4 shows a diagram with average outdoor air temperature over time.

A minimum outdoor temperature of –2°C was chosen as the heating design temperature for Elbasan. It is the limit under which the actual outdoor temperature should not be expected to fall for more than 1% of the hours of the year. The total number of days when buildings need to be heated is 120, distributed within 6 months of the year when heating is required, based on a maximum temperature of 15°C.

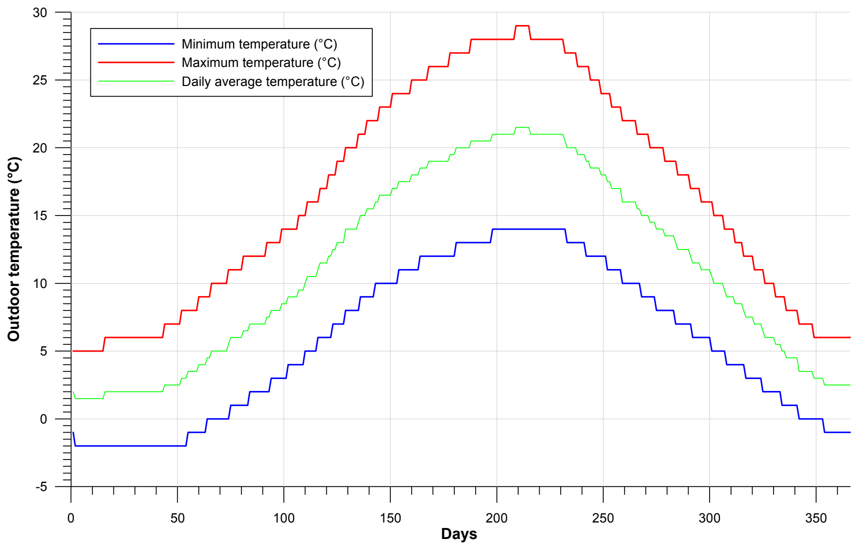


FIGURE 4: Daily average, maximum and minimum outdoor air temperatures in Elbasan City

# 3. PROJECT CONDITIONS AND HEAT LOSS RELATIONSHIPS

## 3.1 General

This city centre is composed of areas in which exercised activities differ, which share a common goal in terms of security of a normal living comfort for residents and employees. These requirements are set forth in proportion to the living standards and their impact on cost centres:

*Applicable Albanian laws and norms - Applicable European norms*

| | | |
|---|---|---|
| DIN EN ISO 1632 | 2000 | Acoustics - Measurement of sound pressure levels from service equipment in buildings - Engineering method. |
| DIN EN 12170 | 2002 | Heating systems in buildings - Procedure for preparation of documents for operation, maintenance and use. |
| DIN EN 12171 | 2002 | Heating systems in buildings - Procedure for the preparation of document for operation, maintenance and use. |
| DIN EN 12828 | 2003 | Heating systems in building. |
| DIN EN 14336 | 2002 | Heating systems in buildings, installation and technical approval. |

## 3.2 Architectural characteristic

The residential and commercial centre consists of buildings with medium to heavy construction materials which are, therefore, classified as buildings with high thermal inertia. The walls make up most of the area in contact with the surrounding environment and from that standpoint, the buildings are not very exposed to radiation and do have thermal protection. Facilities and building structures are different according to purpose, their operation and dimensions. In the project their configuration is composed of four different areas from the standpoint of construction, functionality and equipment installed.

## 3.3 Project conditions

All buildings are designed to ensure the well-being of demanding people and employers, usually in direct proportion to the quality of life and the cost of the centre. Environment and the structure of offices and houses differ in their dimensions, and location. The conditions for thermo-hygrometric comfort (physiological well being) that must be maintained indoors are based on the following data:

| | | |
|---|---|---|
| *Locality* | Elbasan | |
| *Latitude* | 41°07” | |
| *Winter* | | |
| External air temperature | -2ºC | U.R = 85% |
| Ambient temperature | 20 ºC | U.R = 50% |
| *Summer* | | |
| External air temperature | 36ºC | U.R = 40% |
| Ambient temperature | 26ºC | U.R = 50% |
| *Elevation* (above sea level) | 100 m | |

## 3.4 Building heat loss

The heat loss is a function of the outdoor weather conditions and the indoor temperature. The heat is lost by heat transfer through the building surfaces, and by the exchange of air between the heated space and the building’s surroundings. The heat loss is mainly a function of the outdoor air temperature. It is also influenced by wind velocity; increased wind velocity leads to increased air exchange and more effective cooling of the building. On the other hand, heat is supplied to the building through solar radiation especially through the windows. The radiant heat loss from the building to the sky is influenced by cloud cover. The overall heat loss from a building can be calculated as (The Engineering ToolBox, 2005):

$$Q = Q_t + Q_v + Q_i \tag{1}$$

where $Q$ = Overall heat loss (W);
$Q_t$ = Heat loss due to transmission through walls, windows, doors, floors (W)
$Q_v$ = Heat loss caused by ventilation (W);
$Q_i$ = Heat loss caused by infiltration (W);

### 3.5 Heat loss through walls, windows, doors, ceilings, floors, etc.

By taking the outdoor temperature as a primary influencing factor for the weather, the heat loss through walls, windows, doors, ceilings, floors etc. can be calculated (The Engineering ToolBox, 2005):

$$Q_{loss} = AU(T_i - T_o) \tag{2}$$

where $Q_{loss}$ = Heat loss (W);
$U$ = Heat transfer coefficient (W/(m$^2$ °C));
$A$ = Area of exposed surface (m$^2$);
$T_i$ = Indoor projecting temperature (°C);
$T_o$ = Outdoor projecting temperature (°C).

Heat loss through roofs should include an additional 15% loss because of radiation to space, thus Equation 2 can be modified to:

$$Q_{loss} = 1.15\, AU(T_i - T_o) \tag{2a}$$

For walls and floors against earth, Formula 2 should be modified with the earth temperature:

$$Q_{loss} = 1.15\, AU(T_i - T_e) \tag{2a}$$

where $T_e$ = Earth temperature (°C).

*Overall heat transmission coefficient, U*
The overall heat transmission coefficient - *U* (K) - can be calculated as:

$$U = \frac{1}{\left(\frac{1}{f_1} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} + \cdots + \frac{1}{f_0}\right)} \tag{3}$$

where $f_i$ = Surface conductance for inside wall (W/m$^2$K);
$x$ = Thickness of material (m);
$k$ = Thermal conductivity material (W/mK);
$f_o$ = Surface conductance for outside wall (W/m$^2$K).

The conductance, *C,* of building elements can be expressed as:

$$C = \frac{k}{x} \tag{4}$$

where $C$ = Conductance or heat flow through unit area in unit time (W/m$^2$K).

The thermal resistivity, *R,* of the building element can be expressed as:

$$R = \frac{x}{k} = \frac{1}{C} \tag{5}$$

where $R$ = Thermal resistivity ($m^2K/W$).

Using Equations 4 and 5, Equation 3 may be modified to:

$$\frac{1}{U} = R_i + R_1 + R_2 + R_3 + \cdots + R_o \tag{6}$$

For walls and floors against earth, Equation 6 should be modified to:

$$\frac{1}{U} = R_e + SR_o \tag{6a}$$

### 3.6 Heat loss caused by ventilation

The heat loss due to ventilation without heat recovery can be expressed as (The Engineering ToolBox, 2005):

$$Q_v = c_p\rho\, q_v(T_i - T_o) \tag{7}$$

where $Q_v$ = Ventilation heat loss (W);
$c_p$ = Specific heat capacity of air (J/kg °C);
$\rho$ = Density of air ($kg/m^3$);
$q_v$ = Air volume flow ($m^3/s$);
$T_i$ = Inside air temperature (°C);
$T_o$ = Outside air temperature (°C).

The heat loss due to ventilation with heat recovery can be expressed as:

$$Q_v = \left(1 - \frac{\beta}{100}\right) c_p\rho\, q_v(T_i - T_o) \tag{8}$$

where $\beta$ = Heat recovery efficiency (%).

A heat recovery efficiency of approximately 50% is common for a normal cross flow heat exchanger. For a rotating heat exchanger the efficiency might exceed 80%.

### 3.7 Heat loss caused by infiltration

Due to leakages in the building construction, opening and closing of windows, etc., there is a shift in the air in the building. As a rule of thumb the number of air shifts is often set to 0.5 to 1 per hour. The value is hard to predict and depends on several variables - wind speed, difference between outside and inside temperatures, the quality of the building construction, etc. The heat loss caused by infiltration can be calculated as (The Engineering ToolBox, 2005):

$$Q_i = c_p\rho\, n\, V\, (T_i - T_o) \tag{9}$$

where $Q_i$ = Heat loss infiltration (W);
$c_p$ = Specific heat capacity of air (J/kg °C);
$\rho$ = Density of air ($kg/m^3$);
$n$ = Number of air shifts, or the amount air being replaced in the room per second,

as a rule of thumb it is 0.5 per hr. = 1.4 $10^{-4}$ per s;

$V$ = Volume of room ($m^3$);

$T_i$ = Inside air temperature (°C);

$T_o$ = Outside air temperature (°C).

## 4. SPACE HEATING AND DOMESTIC HOT WATER DEMAND

### 4.1 Space heating demand

The total surface of the new heating area is scheduled to be 119,000 $m^2$ and the total heating capacity is 5,954 MWth (see Appendix I). The calculations are based on the weather conditions and European norms for the buildings. The calculations are for the entire area that will be heated through the geothermal district heating system including the stainless steel boiler.

The new residential area, which will be built in the centre of the city, is divided into 27 blocks where the total area is 119,000 $m^2$. Figure 5 is a demonstrative graph, showing the heating demand of the heating system and tap water. The system consists of two important components:

a) The geothermal production system with water from three wells; and
b) The peak load boiler.

The real effects of the system are shown very clearly on the graph, where the geothermal potential is set up with a capacity of 2.77 MWth and utilisation hours of maximum power of 3474 hr. Table 2 gives the total thermal power taken from the geothermal water and boiler water specified as well and annual demands.

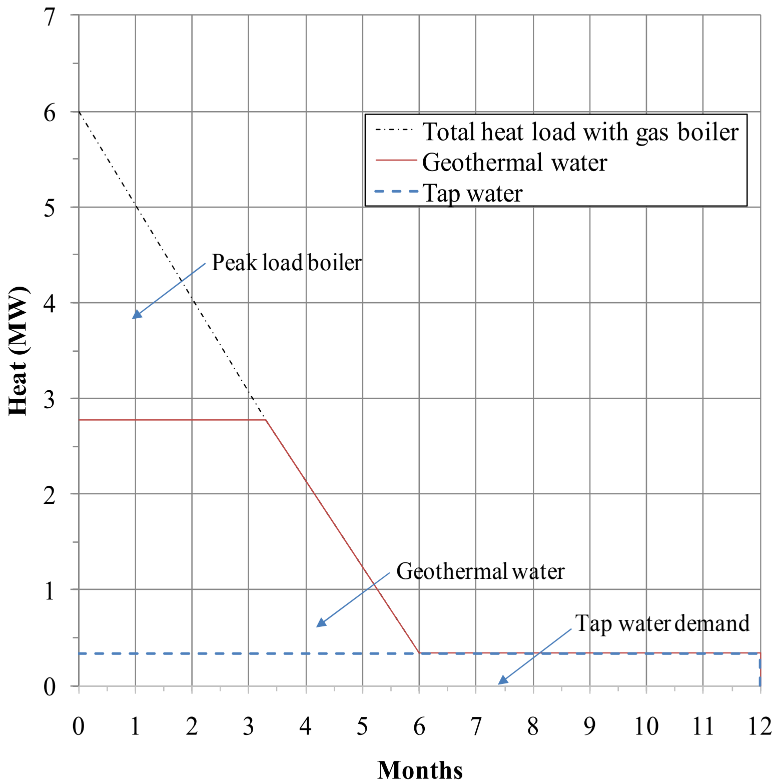


FIGURE 5: Heat demand for district heating and tap water (simplified duration graph)

TABLE 2: Total power and annual energy for space heating

| System | Maximum power util. (hr) | Power demand ($MW_{th}$) | Power demand (%) | Annual energy utilization ($MW_{th}$hr/year) | Share of annual energy (%) |
|---|---|---|---|---|---|
| Geothermal water | 3,474 | 2.770 | 46.18 | 9,622.98 | 69.41 |
| Stainless steel boiler | 1,314 | 3.228 | 53.82 | 4,241.59 | 30.59 |
| **Total** | | **5.998** | | **13,864.57** | |

**4.2 Domestic hot water demand**

The following publications are a part of the specification used here. The publications are referred to in the text by the basic designation only.

*Applicable Albanian laws and norms - European Norms and Standards:*

| | | |
|---|---|---|
| DIN EN 1717 | 2000 | Protection against pollution of potable water installations and general requirements of devices to prevent pollution by backflow. Technical rule of the DVGW. |
| DIN EN 806 | 2001 | Specifications for installations inside buildings conveying water for human consumption - Part 1: General |
| DIN EN 805 | 2000 | Water supply - Requirements for systems and components outside buildings. |
| DIN EN 545 | | Ductile iron pipes, fittings, accessories and their joints for water pipelines. Requirements and test methods |
| DIN EN 12201 | | Plastics piping systems for water supply - Polyethylene (PE). |

Referring to the norms above and also the standard UNI and ISO requirements for an apartment, the average flow rate of tap water for 1200 apartments gives a total of 1.6 l/s and the maximum simultaneous flow rate is expected to be about 8.2 l/s. The total heat capacity is:

$$V = \frac{Q}{\rho c_p \Delta t} \tag{10}$$

where $V$ = Flow rate (l/s);
$Q$ = Heat capacity of the water (W);
$\rho$ = Density of the water (kg/m$^3$);
$cp$ = Specific heat capacity of water (J/kg °C);
$\Delta t$ = Temperature difference between supply and return water (°C).

Based on Equation 10, when 10°C water from network l is heated to 60°C, the total heating capacity needed for the tab water is about 0.336 MWth (see Figure 5). Table 3 shows the total power and annual energy need for both the system space heating and domestic water demand. It shows that of the total annual energy used, the share from the geothermal water is 74% and that of the boiler 26%.

TABLE 3: Total power and annual energy for space heating and domestic water demand

| **System** | **Utilisation of max. power (hr)** | **Power demand (MWth)** | **Share of power demand (%)** | **Annual energy (MWthhr/year)** | **Share of annual energy (%)** |
|---|---|---|---|---|---|
| Geothermal (space heating + domestic water) | 3474 / 8760 | 2.770 | 46 | 11,444 | 74 |
| Stainless steel boiler | 1314 | 3.228 | 54 | 3,930 | 26 |
| **Total** | | **5.998** | | **15,374** | |

The domestic water in the system is additional and it is in the hands of the company to offer clients more service at a profitable rate.

## 5. GEOTHERMAL DISTRICT HEATING DESIGN

### 5.1 Background

District heating system design consists of two parts: design of the heating system and design of the piping networks. The system is a combination of geothermal water supply and a stainless steel boiler, used in a centralized heat centre with a large and complex piping network, where the use of the stainless steel boiler extends the use of the available geothermal energy. At the same time because of its low investment cost and high operational cost, a natural gas boiler system is used to supply the peak heat load.

The study is based on the design of a decentralized district heating system (see Appendix II). This can reduce the investment in a large piping network and make it simpler. In addition, a natural gas boiler heating peak load system is compared with a heat pump system for each building, both economically and environmentally. Appendix II shows the principal scheme for the building supply system, the machinery room and the wells with the necessarily equipment. This includes:

- Zone (1) is the principal scheme of one building with two sections which show the floor heating system and the domestic hot water system. The scheme is combined with a water exchanger (boiler) with two serpentines, one for geothermal water and another for solar panels in case the district heating company wants to elevate the efficiency of the system.
- Zone (2) is the section of the heat central containing a stainless steel boiler, thermo-regulator and other necessary things.
- Zone (3) is the geothermal field with the wells and flow rate, temperature and control system.

The selection of a piping system is an important aspect of system design in any energy consuming system. Selection issues such as material, configuration, diameter, insulation etc, have their own impact on the overall energy consumption of the system. Piping is one of a few systems where over sizing will generally save energy, unlike for a motor or a pump.

### 5.2 Heat exchanger for geothermal water

Heat transfer units used in geothermal water are based on some common principles:

- Cross flow exchangers;
- Fluid – fluid exchange with different temperature and enthalpy;
- Rotating heat exchangers.

Cross flow and rotating heat exchangers are illustrated in Figure 6.

*Heat transfer in the heat exchangers*

*Cross flow heat exchangers.* In a cross flow heat exchanger, heat is transferred directly from the outlet water to the makeup water through the separating walls of the heat exchanger.

*Fluid-fluid exchange.* With a fluid-fluid heat recovery unit, heat is transferred in a heat exchanger from the outlet water to an inlet circulating fluid.

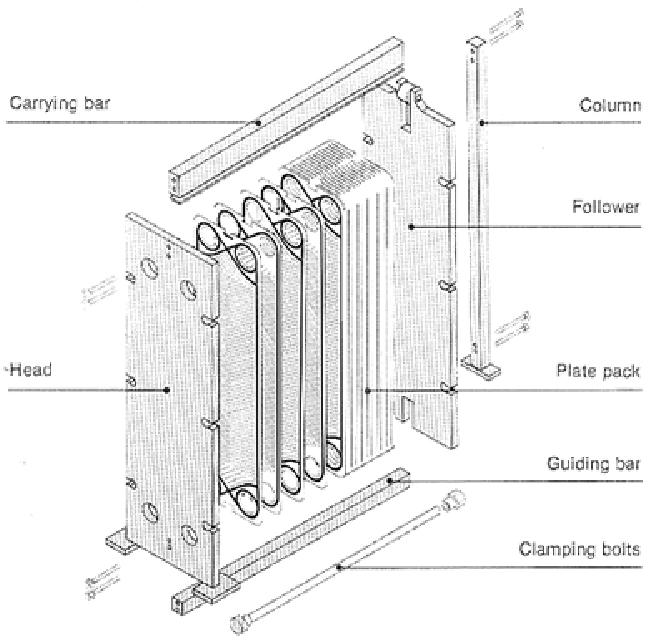

FIGURE 6: Heat exchanger (Sondex Australia, 2009)

*Rotating heat exchangers.* In a rotating heat exchanger the outlet geothermal water heats the exchanger when the inlet water passes through the exchanger. The energy is transferred to the inlet water as the outlet geothermal water passes through the exchanger.

The related equations (Gengel and Turner, 2001) are:

$$Q = m_h c_p (T_{h1} - T_{h2}) \tag{11}$$

$$Q = m_c c_p (T_{c1} - T_{c2}) \tag{11a}$$

$$Q = UA\Delta T_m \tag{11b}$$

where $m_c$ = Mass flow rates of water required for circulation in the system (kg/s);
$m_h$ = Mass flow rates of geothermal water as a heat source (kg/s);
$C_p$ = Specific heat capacity of water (J/ (kg °C));
$T_{c1}$ = Temperature of inlet cold water before heating by heat exchanger (°C);
$T_{c2}$ = Temperature of outlet heated cold water by heat exchanger (°C);
$T_{h1}$ = Temperature of inlet geothermal water at heat exchanger (°C);
$T_{h2}$ = Temperature of outlet geothermal water at heat exchanger (°C);
$Q$ = Heat transfer capacity of the heat exchanger (W);
$U$ = Overall heat transfer coefficient (W/m2°C);
$A$ = Surface area of the heat exchanger (m2);
$\Delta T_m$ = Logarithmic difference temperature (°C).

The use of heat exchangers has three purposes:

a) A few consumers refuse to have direct connection to the geothermal water in their house.
b) In the machinery room, a direct connection scheme (see Appendix II) is not allowed by the manufacturer, to avoid corrosion and scaling; hence the use of heat exchangers is required.
c) Finally, the use of heat exchangers is linked to the high concentration of chemicals; hence the district heating system cannot use the water directly from the wells, as well as the distribution network.

### 5.3 Hot water pressurized boiler

The design system is based on geothermal water and with a hot water pressurized boiler to increase the capacity of the system (sees Figure 7). The hot water pressurized boiler selected for this study is a mono-bloc in steel, with three effective flue passes, flame passing, and wet end plate. It is utilized for the combustion of liquid and gaseous fuels. It has the following design values:

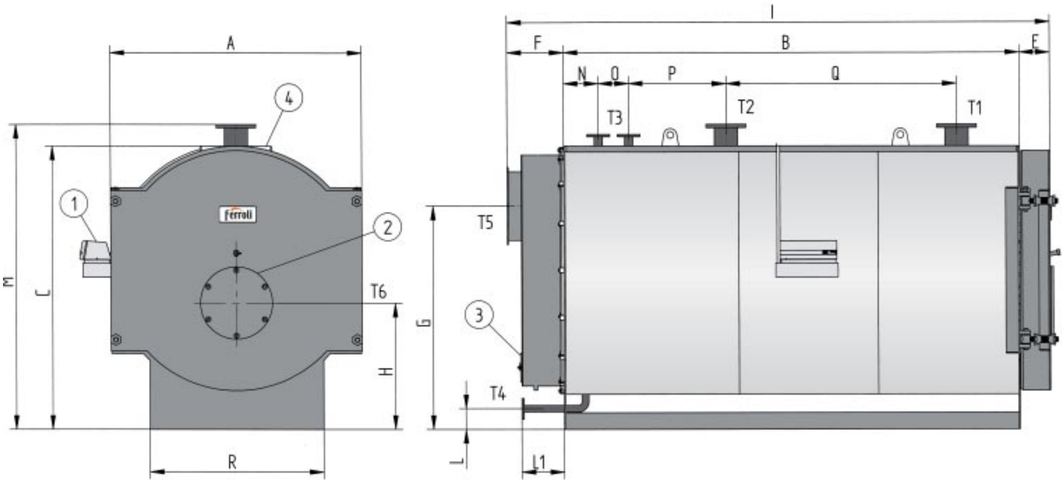


FIGURE 7: The pressurized hot water boiler (Ferroli, 2009)

- Heat output 3,400 kW;
- Standard design pressure 6 and 10 bar standard design pressure (higher design pressure can be supplied on request);
- Design temperature is 110°C or 120°C max design temperature;
- CE certification in accordance to the Pressure Vessel Directive (97/23 EEC) (PED);
- There are three effective flue passes: the first inside the furnace, the second and third in the tubes, with generous combustion chamber dimensions and exchange surfaces for a high heating efficiency (efficiency 93%) and NOx low pollution emissions;
- Insulation through mineral wool mattress of high density protected by a stainless steel (AISI 430) sheet for very low losses.

### 5.4 Radiator

The district heating water return temperature from a building is determined by the performance of the building's radiator system. The radiator is a water/air heat exchanger transferring heat from the district heating water to the indoor air. The input signals to the radiator model are:

- Indoor temperature;
- Water flow;
- Building supply temperature.

The water flow and the indoor temperature depend on the heat transfers which are the losses from the walls, windows, doors, losses from ventilation and infiltration.

In the analysis presented below, a functional relationship between the return water temperature and the independent and control factors is obtained. First, the heat transfer from a radiator to its surroundings has to be studied. The logarithmic mean temperature difference for a radiator is defined as (Valdimarsson, 1993):

$$\Delta T_m = \frac{(T_S - T_i) - (T_r - T_i)}{ln\ (\frac{T_S - T_i}{T_r - T_i})} \tag{12}$$

where $\Delta T_m$ = Logarithmic difference temperature (°C);
$T_s$ = Supply temperature (°C);
$T_i$ = Indoor temperature (°C);
$T_r$ = Return temperature (°C).

Relative heat duty of a radiator can be written as:

$$\frac{Q}{Q_O} = \left(\frac{\Delta T_m}{\Delta T_{mo}}\right)^n \tag{12a}$$

where $Q$ = Heat duty (W);
$Q_o$ = Heat duty at reference condition (W);
$\Delta T_m$ = Logarithmic difference temperature (°C);
$\Delta T_{mo}$ = Logarithmic difference temperature at reference condition (°C);
$n$ = Parameter equals 1.3

This project is based on high differences of temperature, $\Delta T_m$, for the radiator used. The most current type of heating systems is based on radiant panels (floor heating). One important thing to take into consideration is that our system has two modes of operation during the heating period:

a) During the coldest period, the radiators should work with 90°C supply temperature, 40°C return temperature and constant flow; this is when both geothermal water and a gas boiler are used.

b) During the rest of the heating period, when outdoor temperature is above 5°C, the radiator should work with 63°C supply temperature, 38°C return temperature and constant flow; here only geothermal water is used.

The question is how to determine the radiator area when the second system works with 45% less capacity? Dimensions of the radiators will be based on the biggest radiator area which, in this case, is the radiator based on the second case.

### 5.5 Floor heating system – radiant panels

Radiant heating is a technology for heating indoor and outdoor areas. Radiant heating consists of "radiant energy" being emitted from a heat source. It heats a building through radiant heat, rather than through other conventional methods including convection heating.

Under-floor and wall heating systems often are referred to as low-temperature heating systems. Because their heating surface is much larger than for other systems, a much lower temperature is needed to achieve the same level of heat transfer. The maximum temperature of the heating surface can vary from 29 to 35°C depending on the room type. Hence, the supply and return temperatures should be in the range 35-45°C and 30-40°C, respectively. Radiant overhead panels are mostly used in production and warehousing facilities or sports centres; they hang a few metres above the floor and, hence, their surface temperature is much higher.

The under floor heating circuits can be laid in a double meander pattern, which gives an even spread of heat by alternating the supply and return pipes. In the district heating system with radiant panels discussed here, the pipe sizes will assumed to be 16×1.5 mm and 20×1.9 mm. The installation method follows that of using rails and the pipes are supplied in rolls. The floor heating system is designed to be as shown in Figure 8. Calculation of the floor temperature refers to the literature for floor heating systems with the equation below, where a floor temperature of 24°C is calculated for a comfortable room temperature of 20°C (see ASHRAE, 2000):

$$T_f = T_a - \frac{\rho_w}{\rho_a}.(T_s - T_r) \tag{13}$$

where $T_f$ = Temperature of the floor (°C);
$T_a$ = Temperature of the air (°C);
$T_s$ = Temperature of the supply water (°C);
$T_r$ = Temperature of the return water (°C);
$\rho_w$ = Density of the water (kg/m3);
$\rho_a$ = Density of the air (kg/m3).

### 5.6 Downhole pumps

Downhole pumps have been installed in many low-enthalpy geothermal systems to increase energy production and avoid boiling (and mineral scaling) in the wellbore. Two types of downhole pumps are used in geothermal wells, line shaft pumps and electrical submersible pumps. The line shaft pumps are powered by a long shaft driven by a motor installed at the wellhead, while the electrical submersible pumps use a combination of an electric motor and a pump set inside the well. Wells in this study use electrical submersible pumps (Aksoy, 2007):

$$h_{pump} = \frac{p_{fr} + p_{RNPSH} + p_{fp} + \Delta p_d + p_{wf}}{\rho_b g} + h_i \tag{14}$$

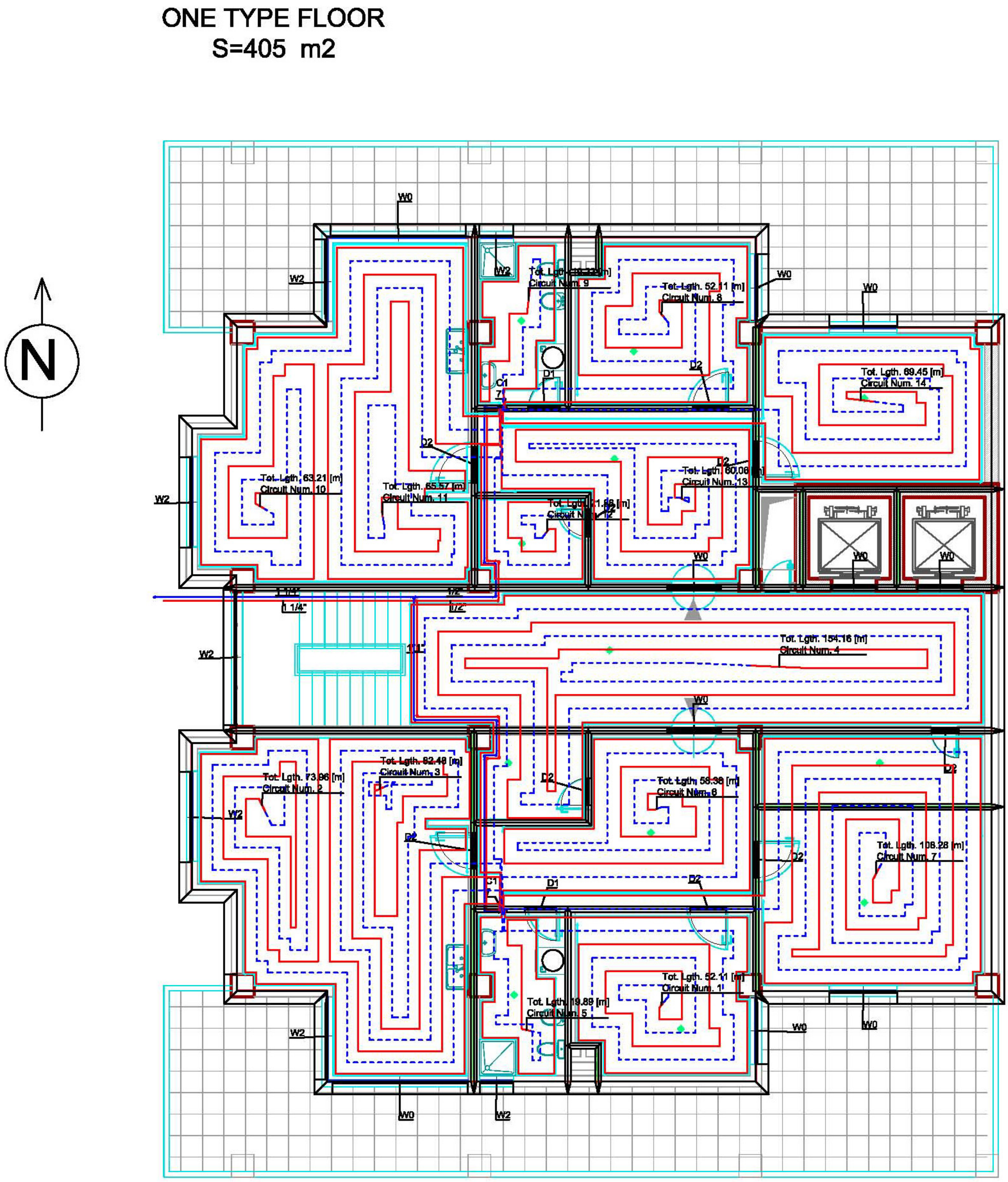


FIGURE 8: The distribution plan for the floor heating system

where $h_{pump}$ = Pump depths (m);
$h_i$ = Average production zone depths (m);
$p_{fr}$ = Pressure loss corresponding to the minimum flow rate from the average feed zone to the pump inlet (Pa or m c.w.);
$p_{RNPSH}$ = Pressure of Net Positive Head Suction of the pump (Pa or m c.w.);
$p_{fp}$ = Boiling pressures (Pa or m c.w.);
$\Delta p_d$ = Reservoir pressure drawdown (Pa or m c.w.);
$p_{wf}$ = Bottom hole flowing pressure (Pa or m c.w.);
$\rho$ = Density of the water (kg/m$^3$);
$g$ = Gravity (m/s$^2$).

*Hydraulic pump power*

The ideal hydraulic power to drive a pump depends on the mass flow rate, the liquid density and the differential height - either it is the static lift from one height to another; or the friction head loss component of the system, calculated by:

$$P = q\,\rho\,g\,\frac{h}{3.6 \times 10^6} \tag{15}$$

where $P_h$ = Power (kW);
$q$ = Flow capacity ($m^3/h$);
$\rho$ = Density of fluid ($kg/m^3$);
$g$ = Gravity (9.81 $m/s^2$);
$h$ = Differential head (m).

*Shaft pump power*

The shaft power - the power required to be transferred from the motor to the shaft of the pump - depends on the efficiency of the pump and can be calculated by:

$$P_s = \frac{P_h}{\eta} \tag{15a}$$

where $P_s$ = Shaft power (kW);
$\eta$ = Pump efficiency.

Using this equation together with the total friction loss in the pipe (for a pipe distance of 10-11 km), the characteristics of each pump, for all three wells, are shown in Table 4.

TABLE 4: Pump characteristics for the Kozan wells

| Pump data | Kozan-2 | Kozan-3 | Kozan-8 |
|---|---|---|---|
| Pump flow rate (l/s) | 9.0 | 8.0 | 12.3 |
| Pump pressure (m c.w) | 120 | 70 | 120 |
| Hydraulic power (kW) | 10.30 | 5.34 | 14.07 |
| Shaft power (kW) | 17.16 | 8.90 | 23.40 |

## 5.7 Pressure loss in pipes

Whenever fluid flows in a pipe there will be some loss of pressure due to several factors:

a) *Friction:* This is affected by the roughness of the inside surface of the pipe, the pipe diameter, and the physical properties of the fluid.
b) *Changes* in size and shape or direction of flow.
c) *Obstructions:* For normal, cylindrical straight pipes the major cause of pressure loss will be friction. Pressure loss in a fitting or valve is greater than in a straight pipe. When fluid flows in a straight pipe the flow pattern will be the same throughout the pipe.

In a valve or fitting, changes in the flow pattern due to factors (b) and (c) will cause extra pressure drops. Pressure drops can be measured in a number of ways. The SI unit of pressure is the Pascal. However, pressure is often measured in bar. This is illustrated by the Darcy equation:

$$hf = \frac{fLu^2}{2gd} \tag{16}$$

where $L$ = Length (m);
$u$ = Flow velocity (m/s);

$g$ = Gravitational constant (9.81 m/s²);
$d$ = Pipe inside diameter (m);
$h_f$ = Head loss to friction (m);
$f$ = Friction factor (dimensionless).

Before the pipe losses can be established, the friction factor must be calculated. The friction factor will be dependent on the pipe size, inner roughness of the pipe, flow velocity and fluid viscosity. The flow condition, whether 'turbulent' or not, will determine the method used to calculate the friction factor (see Valdimarsson (1993):

$$f = \frac{64}{Re} = \frac{64v}{Vd} = \frac{16v\rho d\pi}{m} \tag{17}$$

where $Re$ = Reynolds number;
$V$ = Volume ($m^3$);
$d$ = Pipe inside diameter (m);
$v$ = Velocity (m/s);
$\rho$ = Density ($kg/m^3$);
$m$ = Mass (kg/s);
$\pi$ = Pi number (3.14).

The modified Colebrook equation relates the friction factor *f* to the pipe's inner surface roughness *k*, the pipe's inner diameter *d* and the Reynolds number Re:

$$f = \frac{1{,}325}{(\ln\left(\frac{k}{3{,}7d} + 5{,}74Re^{0{,}9}\right))^2} \tag{17a}$$

**5.8 Supply pipeline optimisation diameter**

Pipeline supply is an important element of district heating design. This network is composed of a set of elements, e.g. pipes, pumps or compressors, valves, etc., interconnected in order to transport a fluid from the supply sites to demand locations.

Water distribution in a city is an important example of a service provided by a pipe network. The design of the network is a complex engineering task. Due to a high number of alternatives, the traditional procedure, a trial-and-error based scheme, is usually not efficient. The least cost design of a distribution network consists of the selection of the network elements associated to minimum costs such that each consumer is supplied according to hydraulic head constraints. Many works approach the least cost design as a pipe sizing problem, describing the pipelines in different ways, such as:

(i) Pipe diameters as continuous variables;
(ii) Pipe diameters as discrete parameters and pipelines can present sections with different diameters (split-pipe), where the optimization variables are the lengths of these sections;
(iii) Pipe diameters as discrete variables with split-pipes not allowed (Costa et al., 2000).

One of the most important factors in a pipeline system is the distance of the wells to the area of district heating, as well as the topography (road profile) of the zone. The profile for the project discussed here is shown in Figure 9. The topographical profile shows that the total distance from Kozan to Elbasan is around 10.5 km with the highest point 205 m above sea level. Hence, a pipeline with a 200 mm nominal diameter can be used.

The pipeline calculations were made by EES - Engineering Equation Solver (F-Chart Software, 2009) and the results are shown in Table 5 as well as in the graph in Figure 10:

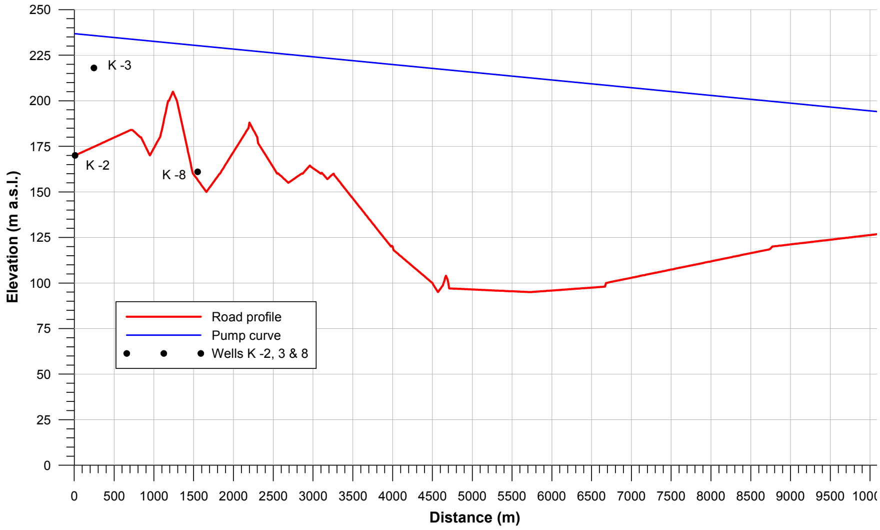


FIGURE 9: Topographical profile for the wells and supply pipeline, and the pump curve

TABLE 5: Pipeline supply optimisation diameters

| Nominal diameter DN (m) | Outside diameter DN (m) | Pipe cost (€/m) | Capital cost[1] Cc=Lp×Pc (€) | Annual cost[2] Ce=(ek/1000)×Oh×P (€) | Estimated long term cost[3] Ct=Ce×(1-1/(1+I)$^{Lt}$)/I (€) | Total cost[4] Ctot=Cc+Ct (€) |
|---|---|---|---|---|---|---|
| 0.08 | 0.0889 | 66.2 | 695,100 | 811,089 | $9.45\times10^6$ | $1.01 \times10^7$ |
| 0.10 | 0.1143 | 83.8 | 879,900 | 248,132 | $2.89\times10^6$ | $3.77\times10^6$ |
| 0.13 | 0.1397 | 96.5 | $1.01\times10^6$ | 76,083 | 886,639 | $1.90\times10^6$ |
| 0.15 | 0.1683 | 112.7 | $1.18\times10^6$ | 29,007 | 338,036 | $1.52\times10^6$ |
| 0.20 | 0.2191 | 135.9 | $1.43\times10^6$ | 6,352 | 74,021 | $1.50\times10^6$ |
| 0.25 | 0.2730 | 224.7 | $2.36\times10^6$ | 1,960 | 22,838 | $2.38\times10^6$ |
| 0.30 | 0.3239 | 269.8 | $2.83\times10^6$ | 750.8 | 8,749 | $2.84\times10^6$ |

[1]*Capital cost* (Cc=Lp×Pc) is the cost of the total distance with the total cost of installation of the supply pipeline system.
[2]*Annual cost* (Ce=(ek/1000)×Oh×P ) is the cost product of the electricity price, operation hours and pump consumption.
[3]*Estimated cost* (Ct=Ce×(1-1/(1+I)$^{Lt}$)/I) in long terms is the total cost of index rate 7% and the duration time of 25 years.
[4]*Total cost* (Ctot=Cc+Ct) is the sum of capital cost plus estimated cost in the long term.

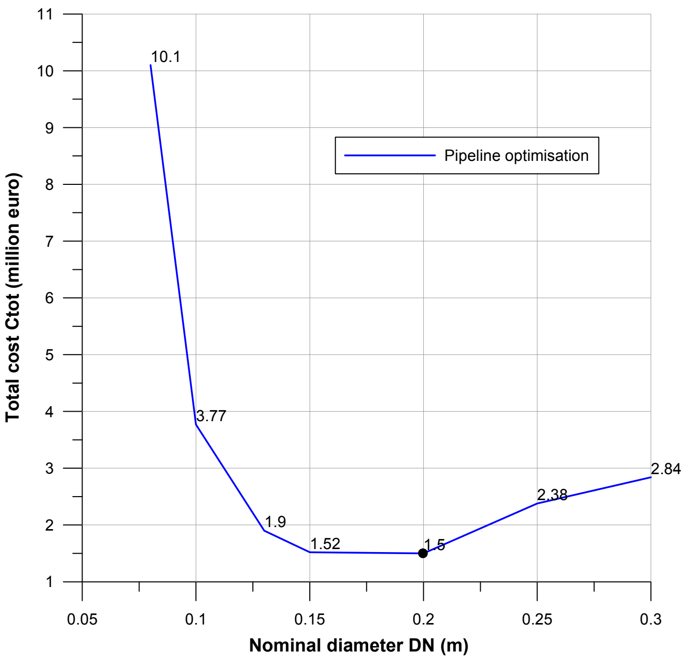


FIGURE 10: Pipeline supply optimisation diameter

## 5.9 Thermal insulation

There are many reasons for insulating a pipeline, the most important being the increased energy cost of not insulating the pipe. Adequate thermal insulation is essential for preventing heat losses from hot surfaces of piping systems. Inadequate thickness of insulation or deterioration of existing insulation can have a significant impact on the energy consumption. The selection of insulating material is also important to achieve low thermal conductivity and low thermal inertia. Development of superior insulating materials and their availability at reasonable prices have made retrofitting or re-insulation a very attractive energy saving option.

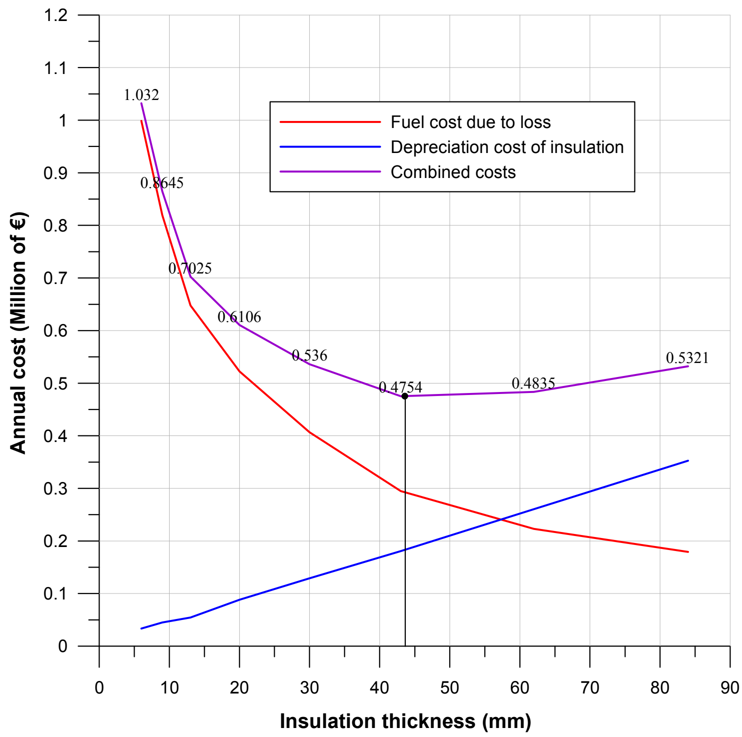


FIGURE 11: Curve showing the economic insulation thickness

The simplest method of analysing whether you should use 1", 2" or 3" insulation is by comparing the cost of energy losses with the cost of insulating the pipe. The insulating thickness for which the total cost is at a minimum is termed the economic thickness, see Figure 11. The curve representing the total cost initially goes down, but after reaching the economic thickness corresponding to the minimum cost it starts to go up again.

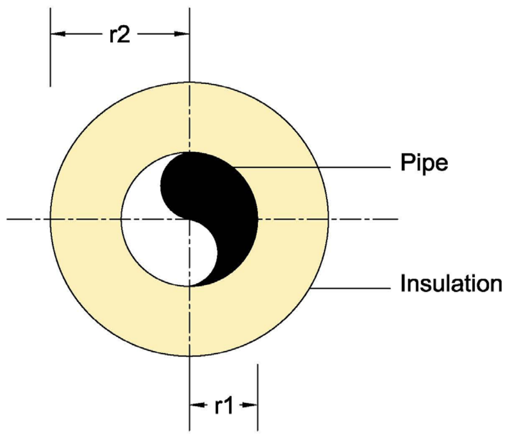


FIGURE 12: A cross-section of an insulated pipe

*Calculation of insulation thickness*

The most basic model for calculating insulation of a pipe is shown in Figure 12. The parameter $r_1$ is the outside radius of the pipe, while $r_2$ is the radius of the pipe + insulation. The optimisation method for determining the dimensions of a pipeline is similar to the one for choosing the optimal insulation thickness as described in the previous section.

Table 6 shows the optimisation calculations for insulation thickness. It includes the following parameters:

- The heat loss for the entire distance of 10.5 km;
- The temperature loss;
- Capital cost for different insulation thicknesses;
- Present value of future fuel cost to compensate for the heat loss;
- Sum of capital cost and present value for future fuel cost.

From Table 6, for a pipeline 10.5 km long, it can be seen that the optimum values are

- Insulation thickness 43 mm ( the manufacture standard);
- Heat loss in the pipe 26.3 W/m.

The total loss in a 10.5 km pipeline is 276.15 kW and the temperature is reduced by 2.3 °C, from 65.5 to 63.2°C.

TABLE 6: Results of insulation thickness optimisation

| **Thickness (mm)** | **Thickness price (€/m)** | **Total distance (m)** | **Heat loss (W/m)** | **Total heatloss (kW)** | **Temperat. loss ΔT=Q/ρ*cp*m (°C)** | **Total price of insulation (€ /ml)** | **Fuel consumption (kg/h)** | **Total fuel consumption (kg/y)** | **Total price of fuel (€/y)** | **Simple payback using i=7%, y=25** | **Present value of fuel cost (€ /25 y)** | **Total cost (€ / 25 y)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 3.2 | 10500 | 89.1 | 935.55 | 7.8 | 33600 | 20.9 | 90214 | 85703 | 12 | 998748 | 1032348 |
| 9 | 4.3 | 10500 | 73.1 | 767.55 | 6.4 | 45150 | 17.1 | 74014 | 70313 | 12 | 819399 | 864549 |
| 13 | 5.2 | 10500 | 57.8 | 606.90 | 5.1 | 54600 | 13.5 | 58523 | 55596 | 12 | 647897 | 702497 |
| 20 | 8.4 | 10500 | 46.6 | 489.30 | 4.1 | 88200 | 10.9 | 47183 | 44823 | 12 | 522353 | 610553 |
| 30 | 12.3 | 10500 | 36.3 | 381.15 | 3.2 | 129150 | 8.5 | 36754 | 34916 | 12 | 406897 | 536047 |
| **43** | **17.2** | **10500** | **26.3** | **276.15** | **2.3** | **180600** | **6.2** | **26629** | **25297** | **12** | **294804** | **475404** |
| 62 | 24.8 | 10500 | 19.9 | 208.95 | 1.8 | 260400 | 4.7 | 20149 | 19141 | 12 | 223065 | 483465 |
| 84 | 33.6 | 10500 | 16.0 | 168.00 | 1.4 | 352800 | 3.8 | 16200 | 15390 | 12 | 179349 | 532149 |

## 5.10 Valve

Valves isolate, switch and control fluid flow in a piping system. Valves can be operated manually with levers and gear operators or remotely with electric, pneumatic, electro pneumatic and electro-hydraulic powered actuators. Manually operated valves are typically used where operation is infrequent and/or a power source is not available. Powered actuators allow valves to be operated automatically by a control system and remotely with push button stations. Valve automation brings significant advantages to a plant in the areas of process quality, efficiency, safety, and productivity. Types of valves and their features can be summarised by the following:

- Gate valve - Control valve
- On / off valve - Globe valve
- Ball valve etc.

## 5.11 Pipe-laying

Soil-works have to be carried out in accordance with the general valid guidelines and standards for civil engineering. Also, the additional and different local government regulations have to be considered. Detailed information concerning civil engineering is mentioned in a manufacture design manual by Smith and Van Laan (1987) in a chapter on assembling instructions (pages M 2.0-2.5).

Assemblage progress will essentially depend on trench construction according to DIN, as well as on the quality of all executed works and, therefore, on the expected lifetime of a steel pipeline. The designed pipeline is 10.5 km and all pipes should be buried in a trench in the earth, where the trench follows the standard shown in Figure 13. The depth of soil (T) in the pipe-trench is calculated from the covering height ($Ü_H$), pipe diameter (Da) and height of the pipe support, respectively, in the sand-bed. Minimum covering height of steel pipes is 0.40 m. Frost-depth in Middle Europe is 0.80 m. The standard trench depth and width for the distance of 10.5 km and a pipe of DN200 mm should be within the following values:

- Covering height $Ü_H$ (m) = 0.40 m
- Soil depth T (m) = 0.805 me
- Minimum width M (mm) = 100 mm
- Soil width B (m) = 0.505 m

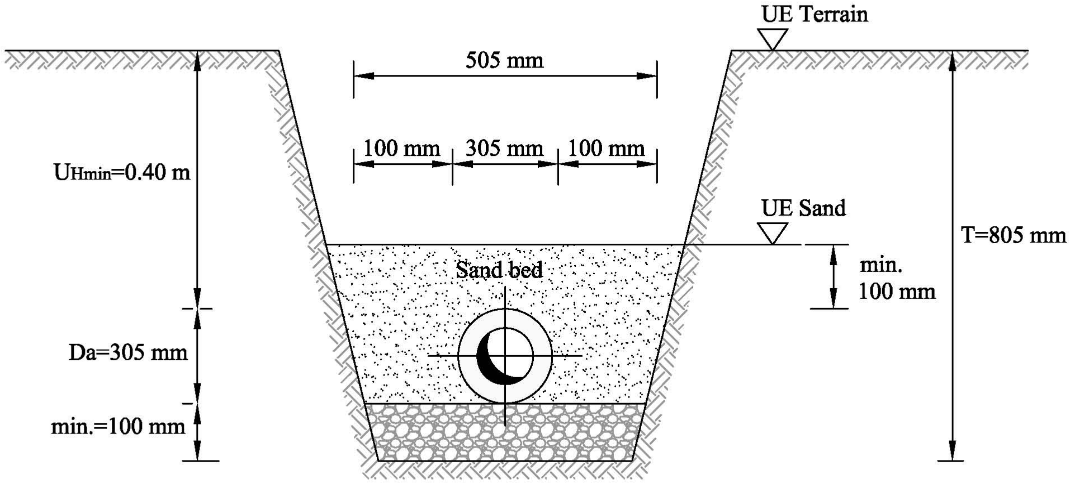


FIGURE 13: Depth and width of a trench for a main pipeline

## 8. ECONOMIC ANALYSIS

### 8.1 Investment cost

When a new system is to be installed, the first thing to be determined is the investment cost for the system and comparison of the system with other systems. In this study, focus was on three different systems:

- Geothermal system with an addition of a pressurised steel boiler;
- Pressurised steel boiler;
- Use of heat pump - split type, in individual installations.

Table 7 shows the investment costs for the three systems:

TABLE 7: Total investment costs for three different heating systems

| No. | Description | Geothermal + pressurised steel boiler | Pressurised steel boiler | Heat pump - split system |
|---|---|---|---|---|
| 1 | Wells, pipeline supply & all nec. safety equipm. | 1,576,046 € | 0 € | 0 € |
| 2 | Machinery room (heating centre), gas boiler | 90,500 € | 90,500 € | 0 € |
| 3 | Distribution system (single pipe) | 856,000 € | 0 € | 0 € |
| 4 | Distribution system (double pipe) | 0 € | 1,284,000 € | 0 € |
| 5 | Inside installation system | 5,998,200 € | 5,998,200 € | 1,260,000 € |
| **Total cost** | | **8,520,746 €** | **7,372,700 €** | **1,260,000 €** |
| **Total cost of the company without inside investm.** | | **2.522.546 €** | **1,374,500 €** | |
| **Total individual cost for heat pump - split type** | | | | **1,260,000 €** |

### 8.2 Operational cost

The second important thing when making an economical analysis is determining the operational cost which is based on four factors:

- Fuel, when a gas boiler is used, with or without the geothermal system;
- Electricity;
- Operational office and workers, experts, etc; this factor comprises 10% of the total income;
- Maintenance of the system, which should be 2% of total investment cost.

### 8.3 Economic analysis

Finally, the various alternatives are compared from the point of view of costs, based on heating the offices, and apartment buildings by geothermal water, with fuel or with air conditioners (split type) in each room. The results are summarised in Figure 14. Some details are though necessary:

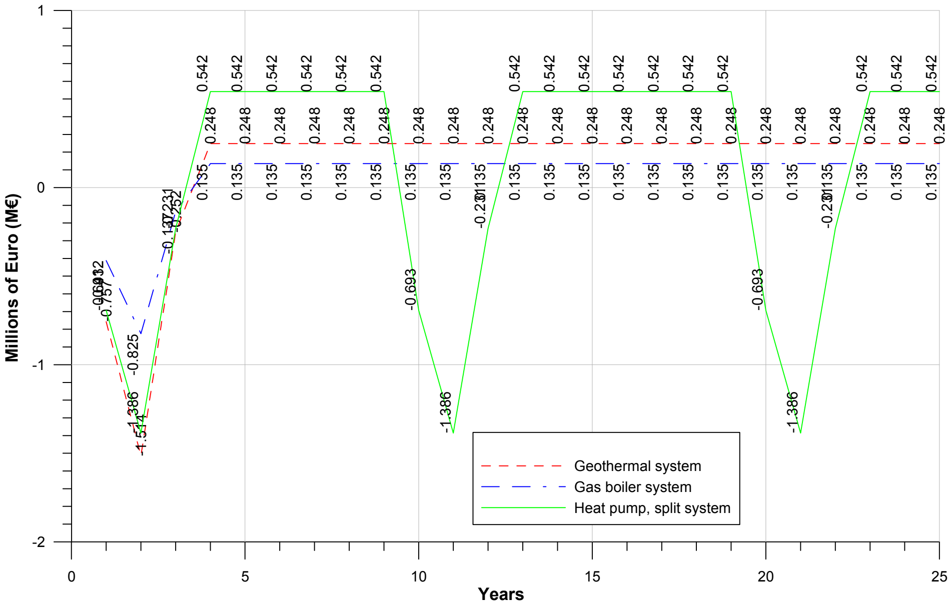


FIGURE 14: Cash flow analysis, comparing of the three alternative systems

- Investment costs of the heating appliances were estimated starting from the nominal capacity of the heating appliances.
- Ordinary maintenance and personnel costs have to be considered in calculating the cost of the useful thermal energy unit in district heating.
- Fuel cost is one of the most important items and might be volatile, particularly due to changes in the stock exchange prices on the international stock market.
- One additional item which should be taken into consideration is the price of electricity used for heating houses.

From Figure 14 it can be concluded that although the geothermal system, which has a back up from a pressurized steel boiler, had a higher initial investment cost it is, in general, more profitable and more affordable over time.

One other aspect of the economical analyses is how much would the consumer pay in each of the three cases? To answer this question, one must take into consideration two factors: the first is cash flow and the second is the net positive value, referring to the cash flow and the interest rate, 7%.

- For the first system, geothermal plus boiler water, the min. payment per consumer is 380 €/year;
- For the second system, only heating water from a boiler, payment per consumer is 406 €/year;
- For the third system, terminal split type heat pump, payment per consumer is 1,327 €/year.

Values are estimated taking into account the investment cost, operational cost and interest rate of 7%.

## 9. CONCLUSIONS

District heating systems are energy efficient, environmentally sound, easy to operate and maintain, reliable, comfortable and convenient, have lower life-cycle costs and offers design flexibility:

- *Energy efficiency.* When hot water arrives at a customer's building, it is ready for use. This means 100% efficiency "at the door," compared with 80% or lower efficiency when burning natural gas or fuel oil in a building.

- *Environmentally sound.* District heating energy enables building owners and managers to conserve energy, improve operating efficiency and protect the environment. With district heating energy, building managers no longer need to burn fuels or store or use refrigerants on site, so the site is safer and more environmentally sound - and does not need unsightly smokestacks. Instead, fuel and refrigerants are used at district energy plants. These systems employ stringent emission controls - more so than individual buildings - and this provides air-quality benefits.

- *Easy to operate and maintain*. District heating energy is worry-free heating delivered directly to a customer's building - ready to use. Customers do not need boilers, so there is less maintenance, monitoring and equipment permitting. And that allows occupants, rather than energy operations, to be the focus. District heating energy customers also eliminate the need for fuel deliveries, handling and storage so there are fewer safety and liability concerns for employees and building occupants.

- *Reliable.* Building owners and managers can count on district heating energy systems since energy professionals operate around-the-clock and have backup systems readily available. Most district heating energy systems operate at a reliability of "five nines" (99.999%).

- *Comfortable and convenient.* District heating energy service allows building operators to manage and control their own indoor environments. Building occupants can be both comfortable and satisfied, no matter what the outdoor temperature. District heating energy is available whenever a building needs heating. So, even if there are unusually warm days in January, a building can receive hot water for floor heating or radiator system, without starting up its own steel boiler. In addition, district heating energy reduces vibrations and noise problems that could annoy building occupants and frees up building space so more room is available to meet increasing tenant storage needs.

- *Lower life-cycle costs.* Since buildings using district heating energy service don't need boilers, building owners and managers reduce their upfront capital requirements and their ongoing, operating, maintenance and labour costs considerably. That means less financial risk and a far better return on investment - plus the elimination of principal and interest payments, property taxes associated with new boiler installations, costly insurance and annual maintenance contracts, and costs associated with operating boilers. In addition, district heating energy systems have the flexibility to use a variety of fuel sources in larger, more economical volumes - from oil to natural gas to coal to biomass - reducing the impact of supply and price variations.

- *Design flexibility.* Not using smoke stack boilers means greater building design flexibility. Architects can easily design or renovate buildings to be more versatile and aesthetically pleasing for both potential occupants and the community.

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## APPENDIX I: Heat loss in the buildings (software calculations)

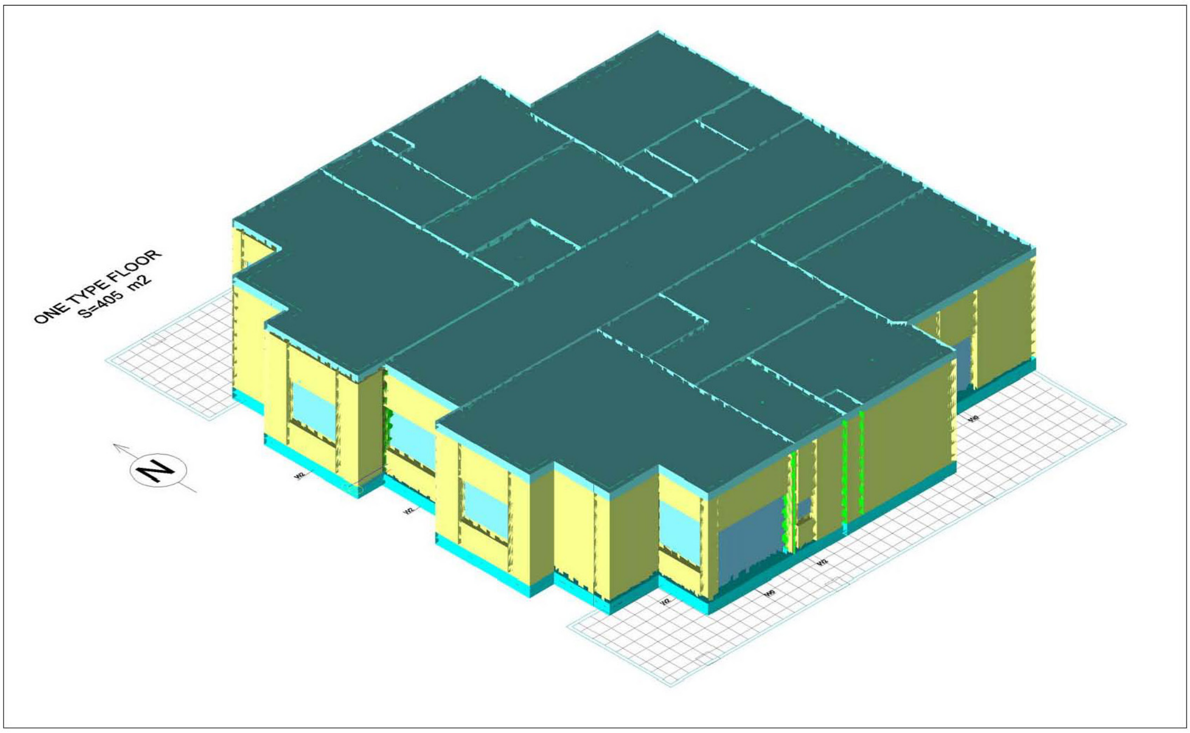


FIGURE 1: 3D modelling of a typical building floor

TABLE 1: U-Value calculations of the structure

| **Internal walls:** **Material description** | **D** | **s** | **λ** | **r** | **dT** | **Tf** | **Ps** | **μ** | **Rv** | **dP** | **DS** | **Pv** | **CT** | **CTS** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior air | 0 | | | | | 22 | 2,643 | | | | | 1,322 | | |
| Interior thermal resistance | | | | 0.12 | | 22 | 2,643 | | | | | 1,322 | | |
| Gypsum (sheetrock) 1/2 in | 1285 | 1 | 0.2 | 0.08 | | 22 | 2,643 | 10,000 | 693 | | 17 | 1,322 | 1.3 | |
| R-19 Rock Wool (loose fill) | 70 | 10 | 0 | 3.7 | | 22 | 2,643 | 1 | 0.7 | | 7 | 1,322 | 0.8 | |
| Gypsum (sheetrock) 1/2 in | 1285 | 1 | 0.2 | 0.08 | | 22 | 2,643 | 10,000 | 693 | | 17 | 1,322 | 1.3 | |
| Exterior thermal resistance | 0 | | | 0.12 | | 22 | 2,643 | | | | | 1,322 | | |
| **Total theoretical thermal resistance:** | | | | 4.1 | **Mass** | | | | | | 40.4 | **Boiler unit** | | 0 |
| **Theoretical transmissivity** | | | | **(W/m2°C)** | **0.24** | | | | | | | | | |
| **Safety increment (0%)** | | | | **(W/m2°C)** | **0.24** | | | | | | | | | |
| **Rounding off:** | | | | | | | | | | | | | | |
| **Adopted transmittance:** | | | | **(W/m2°C)** | **0.24** | | | | | | | | | |

| **Building element definition** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_{int}$ (°C) = 20 | | | | $T_{ext}$ (°C) = -1 | | | R.H.(int) (%) = 50 | | | R.H.(int) (%) = 85 | | Wind (m/s) = 4 | | |
| **Outdoor walls:** **Material description** | **D** | **s** | **λ** | **r** | **dT** | **Tf** | **Ps** | **μ** | **Rv** | **dP** | **DS** | **Pv** | **CT** | **CTS** |
| Exterior air | 0 | | | | | 20 | 2,338 | | | | | 1,169 | | |
| Interior thermal resistance | | | | 0.12 | 1 | 19 | 2,156 | | | | | 1,169 | | |
| Cement mortar | 2000 | 2.5 | 1.4 | 0.02 | 0 | 19 | 2,129 | 30 | 4 | 90 | 50 | 1,079 | 0.8 | 40.5 |
| Polyurethane expan.in place | 35 | 3 | 0 | 0.86 | 9 | 9.3 | 1,171 | 40 | 6.4 | 144 | 1 | 935 | 1.3 | 1.02 |
| Expanded PVC 40 | 40 | 1 | 0 | 0.24 | 3 | 6.7 | 981 | 200 | 11 | 240 | | 694 | 1.3 | 0.36 |
| Indoor wall brick 800 | 800 | 20 | 0.3 | 0.67 | 7 | -0.4 | 591 | 6 | 6.4 | 144 | 160 | 550 | 0.8 | 69.16 |
| Cement mortar | 2000 | 2 | 1.4 | 0.01 | 0 | -0.5 | 586 | 30 | 3.2 | 72 | 40 | 478 | 0.8 | 17.17 |
| Exterior thermal resistance | 0 | | | 0.04 | 1 | -1 | 562 | | | | | 478 | | |
| **Total theoretical thermal resistance::** | | | | 1.97 | **Mass** | | | | | | 251.5 | **Boiler unit** | | 128.2 |
| **Theoretical transmissivity** | | | | **(W/m2°C)** | **0.51** | | | | | | | | | |
| **Safety increment (0%)** | | | | **(W/m2°C)** | **0.51** | | | | | | | | | |
| **Rounding off:** | | | | | | | | | | | | | | |
| **Adopted transmittance:** | | | | **(W/m2°C)** | **0.51** | | | | | | | | | |

| Building element definition | | | | |
|---|---|---|---|---|
| $T_{int}$ (°C) = 22 | $T_{ext}$ (°C) = -1 | R.H.(int) (%) = 50 | R.H.(int) (%) = 78 | Wind (m/s) = 0 |

| Gound floors: Material description | D | s | λ | r | dT | Tf | Ps | μ | Rv | dP | DS | Pv | CT | CTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior Air | 0 | | | | | 22 | 2,643 | | | | | 1,322 | | |
| Interior thermal resistance | | | | 0.17 | 2 | 20 | 2,338 | | | | | 1,322 | | |
| Gravel 8 in | 1522 | 5 | 0.4 | 0.13 | 1.6 | 18 | 2,116 | 5 | 1.3 | 27 | 76 | 1,295 | 0.8 | 58.94 |
| Sand 6 in | 1700 | 5 | 0.8 | 0.07 | 0.8 | 18 | 2,012 | 15 | 4 | 80 | 85 | 1,215 | 0.8 | 64.63 |
| Vermiculite in granules | 120 | 3 | 0.1 | 0.37 | 4.3 | 13 | 1,527 | 3 | 0.5 | 10 | 4 | 1,205 | 0.8 | 2.45 |
| Concrete | 400 | 20 | 0.2 | 1.05 | 12 | 0.9 | 651 | 1 | 1.1 | 21 | 80 | 1,184 | 1 | 43.32 |
| Paper and cardboard | 1000 | 0 | 0.2 | 0.02 | 0.2 | 0.7 | 642 | 5 | 0.1 | 2 | 3 | 1,182 | 1.3 | 2.09 |
| Ordinary concrete | 2200 | 6 | 1.3 | 0.05 | 0.6 | 0.1 | 614 | 70 | 22 | 448 | 132 | 734 | 0.9 | 60.95 |
| Sand&grav.ex.per.concrete | 1600 | 2 | 0.8 | 0.03 | 0.3 | -0.2 | 600 | 20 | 2.1 | 43 | 32 | 691 | 0.9 | 14.6 |
| Ceramic tiles | 2300 | 1 | 1 | 0.01 | 0.1 | -0.3 | 596 | 200 | 11 | 213 | 23 | 478 | 0.8 | 9.96 |
| Exterior thermal resistance | 0 | | | 0.06 | 0.7 | -1 | 562 | | | | | 478 | | |
| **Total theoretical thermal resistance:** | | | | 1.95 | **Mass** | | | | | | 435 | **Boiler unit** | | 256.95 |

| | | |
|---|---|---|
| **Theoretical transmissivity** | **(W/m2°C)** | **0.51** |
| **Safety increment (0%)** | **(W/m2°C)** | **0.51** |
| **Rounding off:** | | |
| **Adopted transmittance:** | **(W/m2°C)** | **0.51** |

| Building element definition | | | | |
|---|---|---|---|---|
| $T_{int}$ (°C) = 22 | $T_{ext}$ (°C) = -1 | R.H. (int) (%) = 50 | R.H.(int) (%) = 85 | Wind (m/s) = 4 |

| Roof: Material description | D | s | λ | r | dT | Tf | Ps | μ | Rv | dP | DS | Pv | CT | CTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior Air | 0 | | | | | 22 | 2,643 | | | | | 1,322 | | |
| Interior thermal resistance | | | | 0.11 | 0.9 | 21 | 2,502 | | | | | 1,322 | | |
| Ordinary concrete | 2200 | 5 | 1.3 | 0.04 | 0.3 | 21 | 2,456 | 70 | 19 | 263 | 110 | 1,059 | 0.9 | 94.22 |
| Expanded PVC 30 | 30 | 1 | 0 | 0.13 | 1.1 | 20 | 2,295 | 200 | 5.3 | 75 | | 983 | 1.3 | 0.19 |
| Polyurethane exp. in factory | 40 | 5 | 0 | 2.08 | 17 | 2.3 | 721 | 80 | 21 | 300 | 2 | 683 | 1.3 | 1.48 |
| Floor block 2.1.03i/2 220 | 504 | 22 | | 0.33 | 2.8 | -0.5 | 586 | 9 | 11 | 149 | 111 | 534 | 0.9 | 52.13 |
| Cement mortar | 2000 | 3 | 1.4 | 0.02 | 0.1 | -0.6 | 581 | 30 | 4 | 56 | 50 | 478 | 0.8 | 21.33 |
| Exterior thermal resistance | 0 | | | 0.04 | 0.4 | -1 | 562 | | | | | 478 | | |
| **Total theoretical thermal resistance::** | | | | 2.75 | **Mass** | | | | | | 273 | **Boiler unit** | | 169.35 |

| | | |
|---|---|---|
| **Theoretical transmissivity** | **(W/m2°C)** | **0.36** |
| **Safety increment (0%)** | **(W/m2°C)** | **0.36** |
| **Rounding off:** | | |
| **Adopted transmittance:** | **(W/m2°C)** | **0.36** |

| Indoor ceilings-floor: Material description | D | s | λ | r | dT | Tf | Ps | μ | Rv | dP | DS | Pv | CT | CTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exterior air | 0 | | | | | 22 | 2,643 | | | | | 1,322 | | |
| Interior thermal resistance | | | | 0.11 | | 22 | 2,643 | | | | | 1,322 | | |
| Ceramic tiles | 2300 | 1 | 1 | 0.01 | | 22 | 2,643 | 200 | 10.7 | | 23 | 1,322 | 0.8 | |
| Sand&grav.ex.per.concrete | 1600 | 2 | 0.8 | 0.03 | | 22 | 2,643 | 20 | 2.1 | | 32 | 1,322 | 0.9 | |
| Expanded PVC 30 | 30 | 0.8 | 0 | 0.21 | | 22 | 2,643 | 200 | 8.5 | | | 1,322 | 1.3 | |
| Ordinary concrete | 2200 | 6 | 1.3 | 0.05 | | 22 | 2,643 | 70 | 22.4 | | 132 | 1,322 | 0.9 | |
| Basement walls perlite conc. | 250 | 20 | 0.2 | 1.33 | | 22 | 2,643 | 3 | 3.2 | | 50 | 1,322 | 0.8 | |
| Exterior thermal resistance | 0 | | | 0.11 | | 22 | 2,643 | | | | | 1,322 | | |
| **Total theoretical thermal resistance::** | | | | 1.84 | **Mass** | | | | | | 237.2 | **Boiler unit** | | 0 |

| | | |
|---|---|---|
| **Theoretical transmissivity** | **(W/m2°C)** | **0.55** |
| **Safety increment (0%)** | **(W/m2°C)** | **0.55** |
| **Rounding off:** | | |
| **Adopted transmittance:** | **(W/m2°C)** | **0.55** |

TABLE 2: Heat loss for one typical floor, where the maximum heat lost per $m^2$ is (50 $W/m^2$)

| Room # | Code | Description | Temperature (°C) | Volume (m3) | Heat loss (W) |
|---|---|---|---|---|---|
| 1 | 1 | Bath | 20.00 | 26.20 | 517 |
| 2 | 10 | Store | 20.00 | 16.43 | 226 |
| 3 | 11 | Store | 20.00 | 29.02 | 472 |
| 4 | 12 | Store | 20.00 | 16.58 | 228 |
| 5 | 17 | Main room | 20.00 | 141.88 | 3,612 |
| 6 | 18 | Main room | 20.00 | 141.33 | 3,492 |
| 7 | 2 | Bath | 20.00 | 26.53 | 497 |
| 8 | 3 | Bed | 20.00 | 52.66 | 1,19 |
| 9 | 4 | Bed | 20.00 | 65.51 | 1,563 |
| 10 | 5 | Bed | 20.00 | 74.71 | 1,59 |
| 11 | 6 | Bed | 20.00 | 53.11 | 1,169 |
| 12 | 7 | Corridor | 20.00 | 184.10 | 3,348 |
| 13 | 8 | Hall | 20.00 | 65.82 | 905 |
| 14 | 9 | Hall | 20.00 | 66.09 | 927 |
| | | | **Total:** | **959.97** | **19,737** |

TABLE 3: Total heat loss of entire apartment area

| Building (No.) | Surface ($m^2$) | Heat loss / $m^2$ ($W/m^2$) | Heat loss / building ($kW/m^2$) |
|---|---|---|---|
| 1 | 616 | 50 | 31.0 |
| 2 | 2660 | 50 | 133.0 |
| 3 | 5000 | 50 | 250.0 |
| 4 | 2400 | 50 | 120.0 |
| 5 | 10000 | 50 | 500.0 |
| 6 | 8375 | 50 | 419.0 |
| 7 | 6600 | 50 | 330.0 |
| 8 | 1650 | 50 | 83.0 |
| 9 | 7500 | 50 | 375.0 |
| 10 | 11720 | 50 | 586.0 |
| 11 | 1600 | 50 | 80.0 |
| 12 | 800 | 50 | 40.0 |
| 13 | 1210 | 50 | 61.0 |
| 14 | 4160 | 50 | 208.0 |
| 15 | 1210 | 50 | 61.0 |
| 16 | 3440 | 50 | 172.0 |
| 17 | 1210 | 50 | 61.0 |
| 18 | 2704 | 50 | 135.0 |
| 19 | 8310 | 50 | 416.0 |
| 20 | 3100 | 50 | 155.0 |
| 21 | 6000 | 50 | 300.0 |
| 22 | 1620 | 50 | 81.0 |
| 23 | 725 | 50 | 36.0 |
| 24 | 2500 | 50 | 125.0 |
| 25 | 1620 | 50 | 81.0 |
| 26 | 1620 | 50 | 81.0 |
| 27 | 20736 | 50 | 1,037.0 |
| **Total** | **119,086 $m^2$** | | **5,954 kWth** |

**APPENDIX II: The pipeline distribution system outside and inside the buildings**

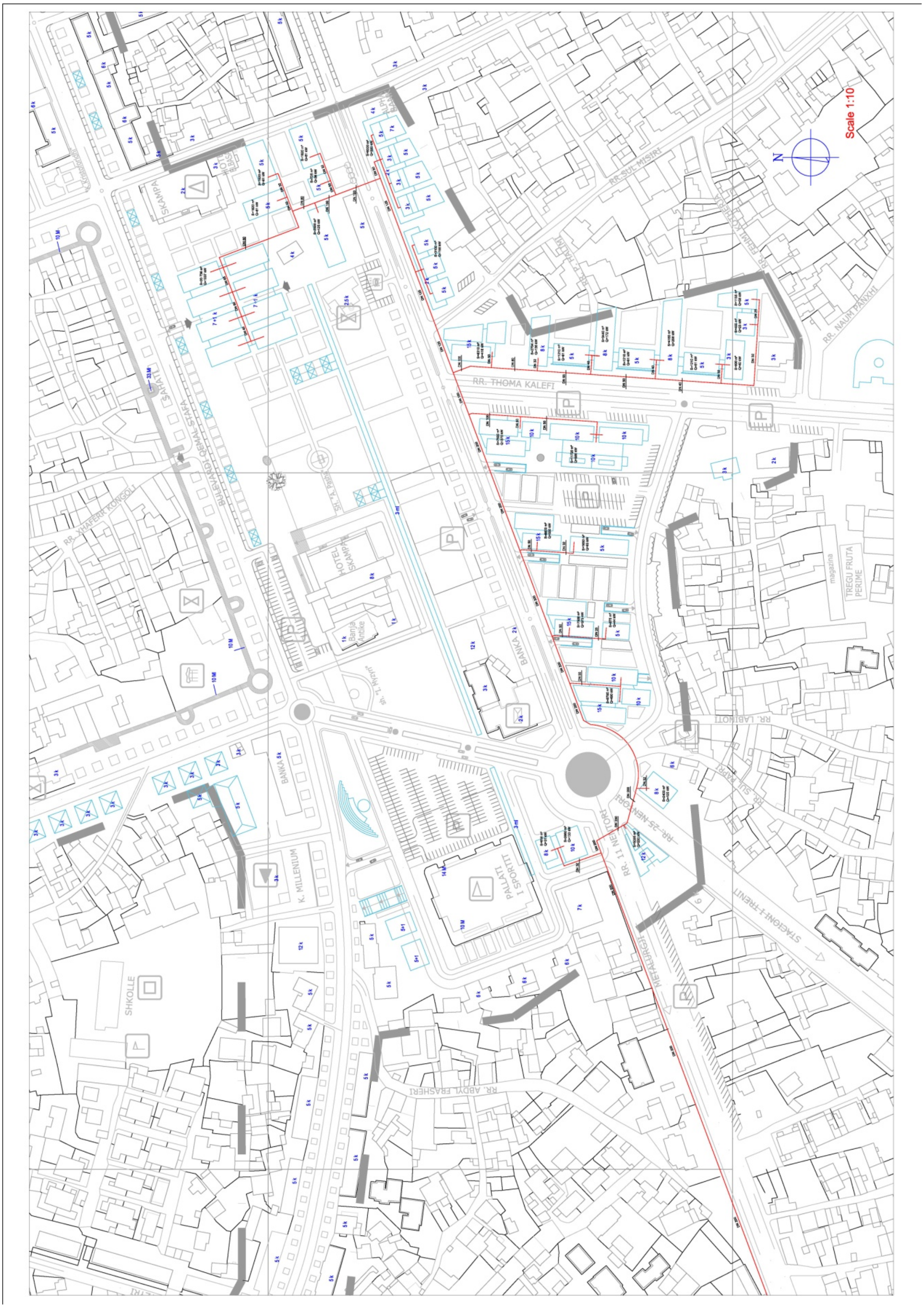


FIGURE 1: The distribution system for the pipelines outside the buildings

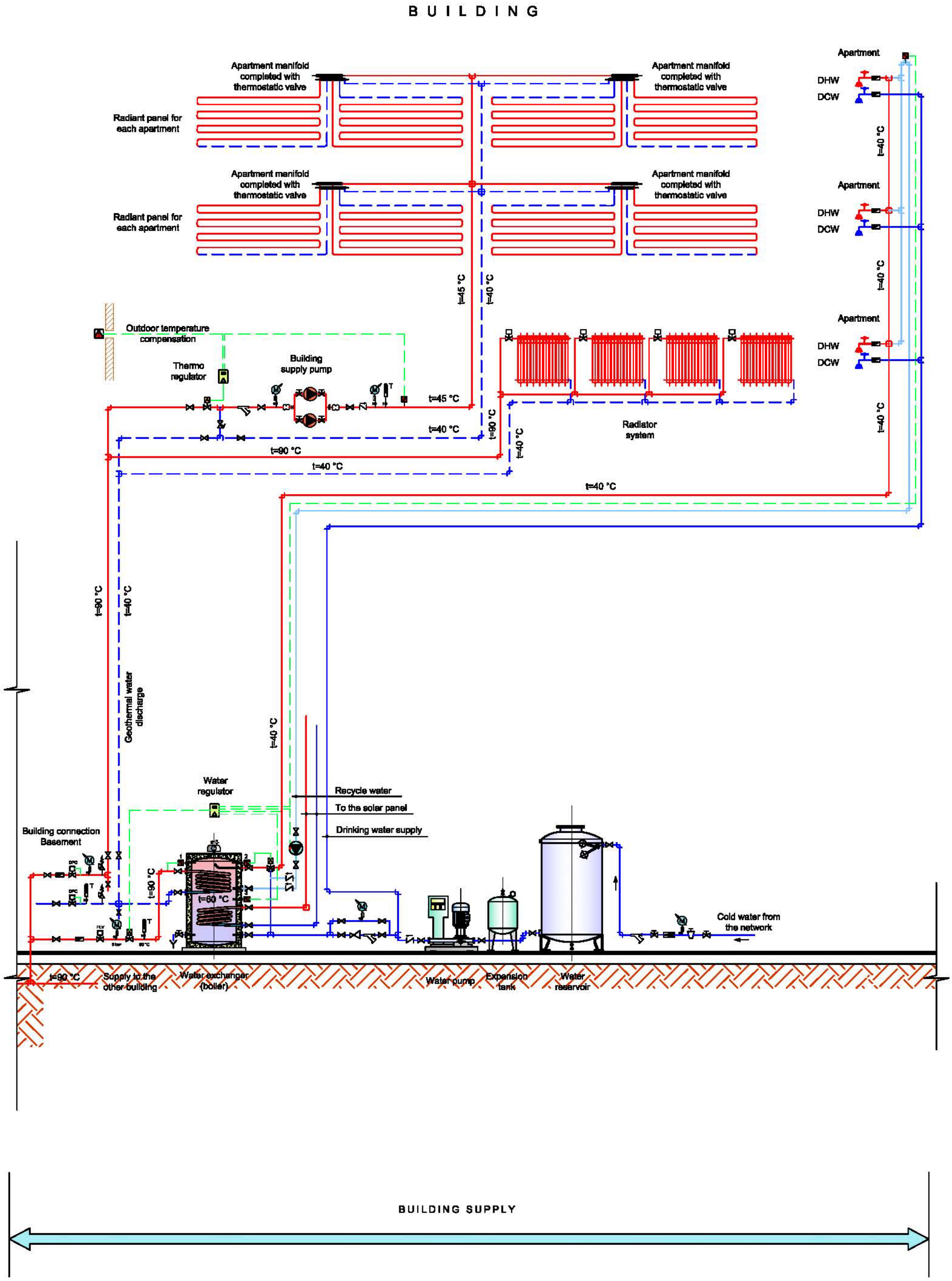


FIGURE 2: Principal scheme for a building, supply and return pipelines

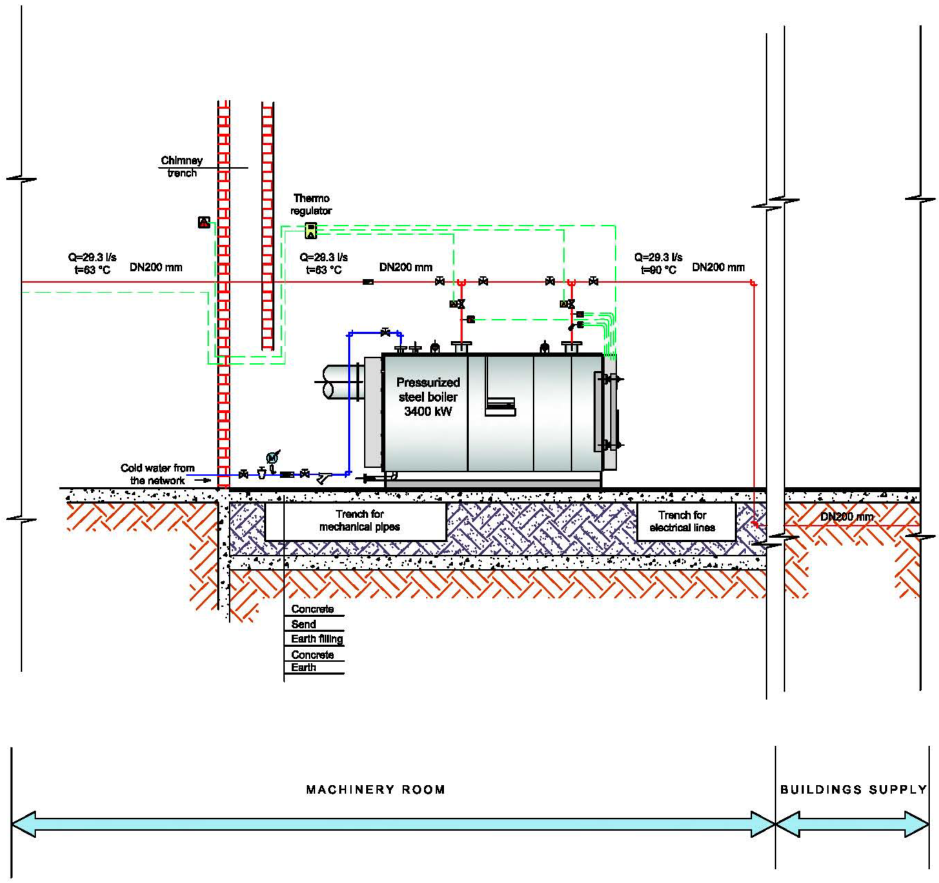


FIGURE 3: Principal scheme – the machinery room

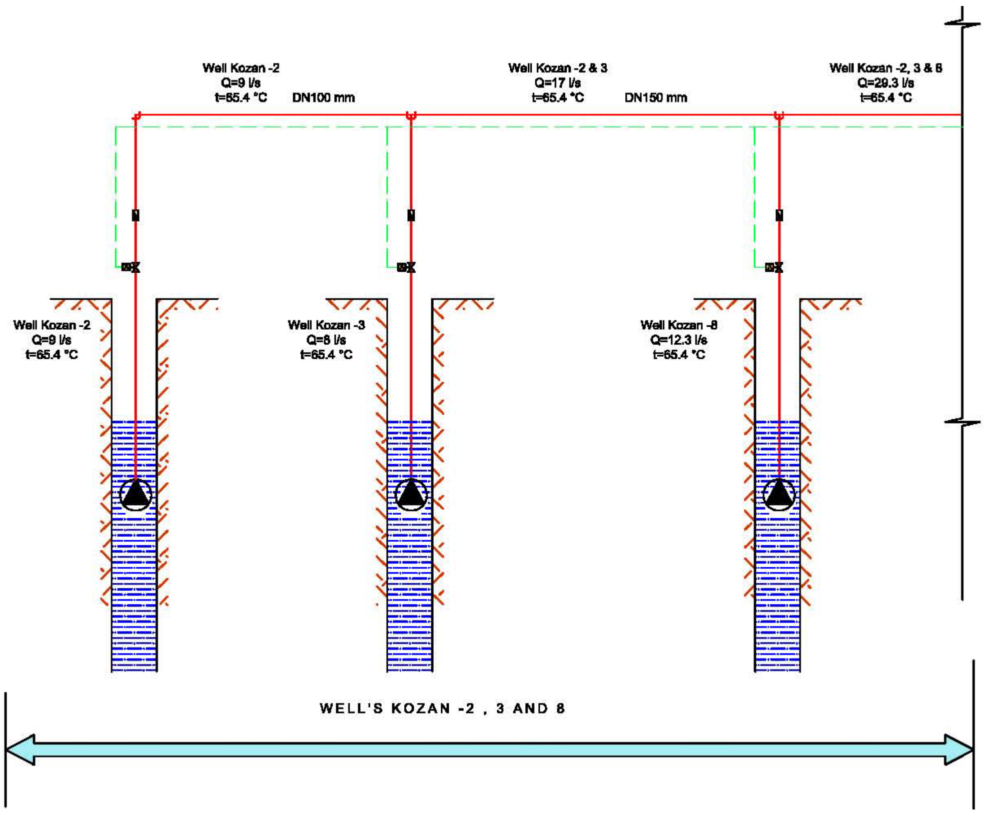


FIGURE 4: Principal scheme – of the wells

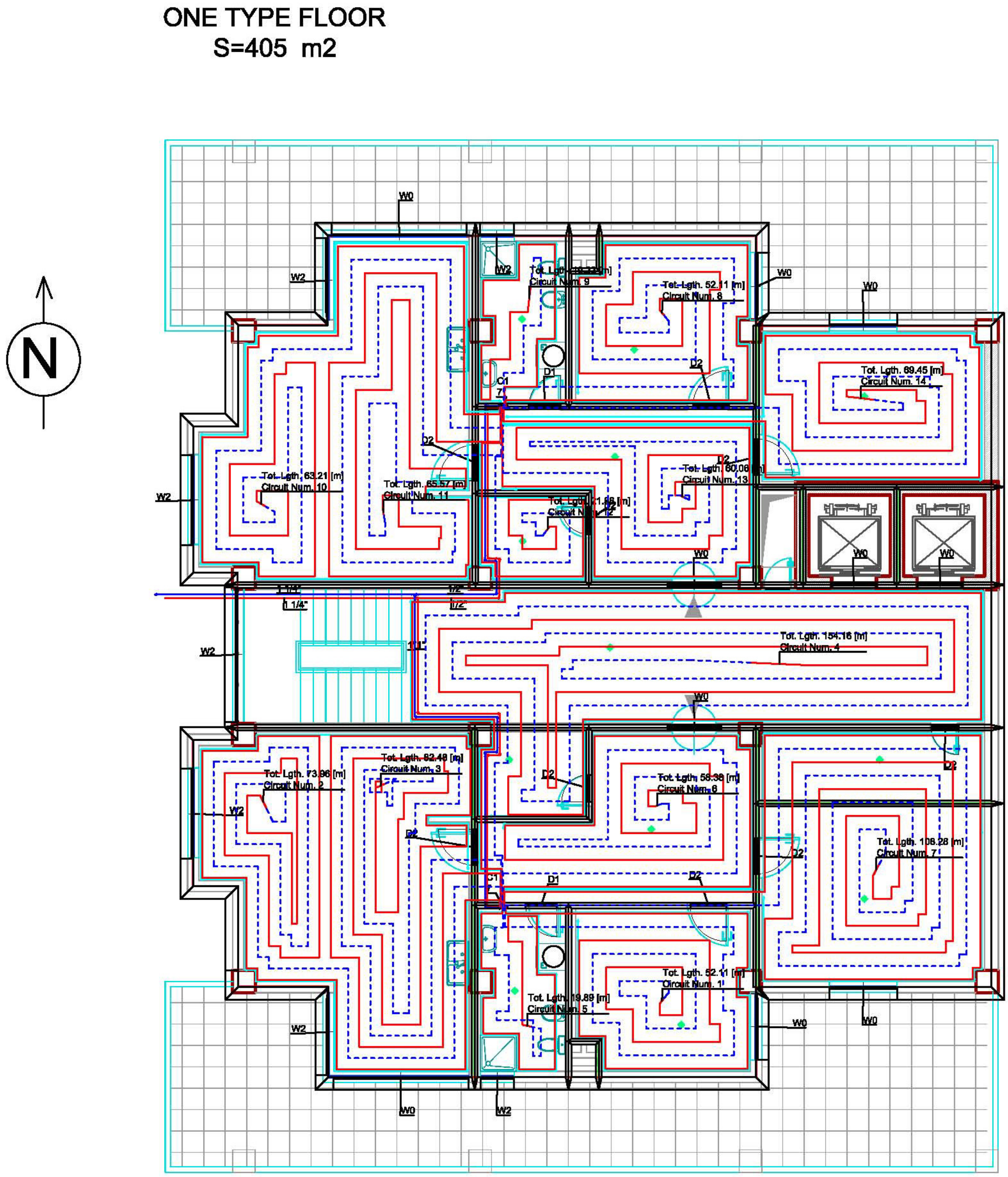


FIGURE 5: Example of a typical floor system with an area of 405 m$^2$ and radiant panel system, the pipeline system inside the building will be a combination of radiant panels and radiators

| | |
|---|---|
| 1. Maximum velocity in the most demanding path (m/s): | 1 |
| 2. Maximum dp (Pa/m): | 100 |
| 3. Balancing Maximum velocity (m/s): | 2 |
| 4. Maximum dp (Pa/m): | 400 |

| Section | Pipe | For. | Diameter | Velocity | Flow rate | Length | Dh | Dp distrib | Dp localiz | Dp totals | Dp progres | Unbal. | Terminal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N. | Code | Code | Code | (m/s) | (l/s) | (m) | (m) | (kPa) | (kPa) | (kPa) | (kPa) | (kPa) | Code |
| 1 | 1 | 1 | 1 1/4" | 0.3 | 0.28 | 5.62 | 0 | 0.2 | 0 | 0.2 | 0.2 | 0 | |
| 2 | 1 | 1 | 1/2" | 0.4 | 0.1 | 6.59 | 0 | 1.2 | 6.5 | 7.6 | 7.8 | 0 | C1 |
| 3* | 1 | 1 | 1" | 0.3 | 0.18 | 9.25 | 0 | 0.4 | 54.6 | 55.1 | 55.2 | 0 | C1 |

The (*) symbol indicates the ending section of the most demanding system path.

Total flow rate (l/s): 0.28
Total flow rate (kg/s): 0.3
Total Dp (Most dem. path + Dp of the terminal) (kPa): 110.42

**Local losses:**

| S | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trunk N. | Type | Diameter | Velocity (m/s) | Ashrae X | Ashrae Y | K coeff | Dynam. pression (Pa) | Loss (kPa) |
| 2 | Wye | 1 1/4" | 0.1 | 4.000 | 37.000 | 0.900 | 4.9 | 0 |
| | Adapter | 1 1/4" | 0.4 | 90.000 | 4.740 | 0.174 | 78.4 | 0 |
| | Elbow | 1/2" | 0.4 | 1.000 | 17.000 | 1.940 | 78.4 | 0.2 |
| | Elbow | 1/2" | 0.4 | 1.000 | 17.000 | 1.940 | 78.4 | 0.2 |
| | Elbow | 1/2" | 0.4 | 1.000 | 17.000 | 1.940 | 78.4 | 0.2 |
| | Elbow | 1/2" | 0.4 | 1.000 | 17.000 | 1.940 | 78.4 | 0.2 |
| | C1 | 1/2" | 0.4 | | | | 78.4 | 0 |
| | C1 | 1" | 0.2 | | | | 19.6 | 5.7 |
| 3 | Wye | 1" | 0.3 | 5.000 | 37.000 | 1.640 | 44.1 | 0.1 |
| | Elbow | 1" | 0.3 | 1.000 | 28.000 | 1.410 | 44.1 | 0.1 |
| | Elbow | 1" | 0.3 | 1.000 | 28.000 | 1.410 | 44.1 | 0.1 |
| | Elbow | 1" | 0.3 | 1.000 | 28.000 | 1.410 | 44.1 | 0.1 |
| | Elbow | 1" | 0.3 | 1.000 | 28.000 | 1.410 | 44.1 | 0.1 |
| | Elbow | 1" | 0.3 | 1.000 | 28.000 | 1.410 | 44.1 | 0.1 |
| | C1 | 1" | 0.3 | | | | 44.1 | 54.3 |

## APPENDIX III: Tap water demand

| Sanitary water supply | | | | | |
|---|---|---|---|---|---|
| Number of apartments | 1200 | app | | | |
| One apartment needs: | | Cold water | | Hot water | Theoretical capacity (l/s) |
| | 1 | WC | | | |
| | 1 | Washing basin | | Washing basin | 0.16 |
| | 1 | Bathtub | | Bathtub | 0.25 |
| | 1 | Sink | | Sink | 0.2 |
| | 1 | Bide | | | |
| | 1 | Washing machine | | | |
| Total sum of theoretical capacity | 410 | l/s | | | |
| Maximum capacity for all apartments taken into account the simultaneity factor | 1.6 | l/s | 5.7 | m³/h | |
| Total heating capacity: | | V=Q/ρ×cp×Δt | | | |
| V | 1.6 | l/s | | | |
| Δt= 60 °C - 10 °C | 50 | °C | | | |
| Average heating power ( Q ) | 336<br>0.336 | kW<br>MW | | | |

## APPENDIX IV: Comparison between use of coal, diesel and LPG gas for the pressurized hot water boiler

| Cost of use coal, diesel or LPG for one pressurized boiler for heating up the water from 63 to 90°C | | | | |
|---|---|---|---|---|
| No. | In Albania | | | |
| | **Pressurized boiler 3,400 kW** | **Specific Calorific Value** | **Units** | **Result for 6 month work** |
| 1 | Coal | 15-27 kW/kg | kg/hr | 227 |
| 2 | Diesel | 44.8 kW/kg | kg/hr | 76 |
| 3 | LPG | 55.5 kW/kg | kg/hr | 61 |
| 4 | Utilisation hours of max. power | | hour (hr) | 1314 |
| | **Cost per one kilogram of fuel** | | | |
| 5 | Coal | | Euro (€/kg) | 0.15 |
| 6 | Diesel | | Euro (€/kg) | 0.95 |
| 7 | LPG | | Euro (€/kg) | 1.20 |
| | **Total cost of fuel burned in one year** | | | |
| 8 | Coal | | Euro (€/y) | 44,741.70 |
| 9 | Diesel | | Euro (€/y) | 94,737.05 |
| 10 | LPG | | Euro (€/y) | 96,596.76 |

## APPENDIX V: Comparison between uses for all district heating; a) Geothermal water + pressurized steel boiler; b) Pressurized steel boiler; c) Air conditioning split type

| No. | Comparison of energy use for three different system | | |
|---|---|---|---|
| 1 | Surface | 119,964.0 | (m²) |
| 2 | Capacity per m² | 50.0 | (W/m² ) |
| 3 | Capacity of heat | 5,998.2 | (kW) |
| **Cost of geothermal water + pressurized steel boiled** | | | |
| 4 | Utilisation hours of max. power for 6 month (from Figure 5) | 1,314.0 | hour (hr) |
| 5 | Consumption of boiler if we use diesel fuel | 76.0 | l/h |
| 6 | Price of diesel fuel | 0.95 | €/l |
| 7 | Hours work of the geothermal pump for 6 month (from Figure 5) | 3,474.0 | hour (hr) |
| 9 | Consumption of electrical energy for all pumps | 49.5 | kWe |
| 9 | Price of electricity | 0.07 | €/kWeh |
| 10 | **Cost of Geothermal water + Boiler / 6 month** | **106,898.5** | **€/6 month** |
| **Cost of pressurized steel boiler for hot water** | | | |
| 11 | Utilisation hours of max. power for 6 month (from Figure 5) | 3,474.0 | hour (hr) |
| 12 | Consumption of boiler if we use diesel fuel 6000 kW | 76.0 | l/h |
| 13 | Price of diesel fuel | 0.95 | €/l |
| 14 | **Cost of Pressurized steel boiler for hot water / 6 month** | **250,822.8** | **€/6 month** |
| **Cost of heat pump - split type** | | | |
| 15 | Utilisation hours of max. power for 6 month (from Figure 5) | 3,474.0 | hour (hr) |
| 16 | Consumption of electrical energy for one Split | 1.2 | kWe/h |
| 17 | Price of electricity | 0.07 | €/kWeh |
| 18 | Number of split | 3,600 | pcs |
| 19 | **Cost of heat pump - split type / 6 month** | **1,050,537.6** | **€/6 month** |

# **APPENDIX VI:** Feasibility calculations for the Elbasan project

| **Installation costs for geothermal district heating in Elbasan** | | | | |
|---|---|---|---|---|
| | | | | |
| Flow from well Kozan-2 | 9 | l/s | With pump stimulation | |
| Flow from well Kozan-3 | 8 | l/s | With pump stimulation | |
| Flow from well Kozan-8 | 12,3 | l/s | With pump stimulation | |
| **Total three well** | 105,480 | l/h | | |
| **Distance wells - city "Elbasan"** | 10,500 | m | | |
| **Bill of quantity** | | | | |
| **Description** | **Unit** | **Quantity** | **Price** | **Total cost** |
| Three wells to put in work | compl | 3 | 20,000.0 € | 60,000.0 € |
| P.I. Three well pump | compl | 3 | 5,000.0 € | 15,000.0 € |
| P.I. Cost estimates for a single distribution pipeline system, prices are given per length of trench, diameter of pipeline DN100 -200 mm. | ml | 10,500 | 143.0 € | 1,501,046.1 € |
| Machinery room, building construction | m² | 100 | 400.0 € | 40,000.0 € |
| P.I Pressurized steel boilers, heat output max. 3400 kW, equipped with all safety and control equipments + necess. access. Burner (2 stages) for fuel, firing range 3,676 kW | compl | 1 | 28,000.0 € | 28,000.0 € |
| P.I Fuel reservoir, completed with all necessary accessories + the earth work etc. | compl | 1 | 22,500.0 € | 22,500.0 € |
| P.I Installation inside the building for heating system (radiant panel, radiator, pipes, accessories etc). | m² | 119,964 | 35.0 € | 4,198,752.0 € |
| P.I Installation inside the building for tap water (equipment, pipes, manifolds, accessories etc). | m² | 119,964 | 15.0 € | 1,799,465.1 € |
| P.I Install. outside the building for heating sy.& tap water | compl | 1 | 856,000.0 € | 856,000.0 € |
| **Total cost** | | | | **8,520,763.2 €** |
| **Total cost for geothermal company** | | | | **2,522,546.1 €** |
| **Total Heating capacity** | | | **V=Q/ρ×cp×Δt** | |
| V | 29.3 | l/s | | |
| Δt= 63°C - 40°C (geothermal water) | 23 | °C | | |
| Δt= 90°C - 63°C (boiler water) | 27 | °C | | |
| Heating (Q) from geothermal water | 2,770,168 | W | | |
| | 2770,17 | kW | | |
| | 2.77017 | MW | | |
| Heating (Q) from gas boiler | 3,228,049 | W | Q=3400 kW standard boiler | |
| | 3228,05 | kW | | |
| | 3,22805 | MW | | |
| Total capacity from geothermal + boiler water (Q) | 5,998,217 | W | | |
| Total capacity from geothermal + boiler water (Q) | 5998,22 | kW | | |
| | 5.99822 | MW | Total energy | |
| | 0.00000 | MW | Total energy for tap water | |
| | 5.99822 | MW | Total energy for space heating | |
| **How many m² can be covered** | | | | |
| Approximate we calculate | 50.0 | W/m² | Heat lost from the building | |
| Surface ( S ) | 119,964 | m² | | |
| **How many apartments can be covered** | | | | |
| Approximate size of an apartment | 100.0 | m²/app | Apartment surface | |
| Total apartments | 1200 | pcs | | |
| **How much yearly income can be expected from only heating** | | | | |
| One apartment cannot pay more than | 50 | €/month | | |
| Heating is used for | 6 | month | | |
| Cost / year | 300 | €/year | | |
| **How much is yearly income for only tap water** | | | | |
| One apartment cannot pay more than | 10 | €/month | | |
| Tab water is used for | 12 | month | | |
| Cost / year | 120 | €/year | | |
| **Total income / year for heating + tap water** | 6 | month | | |
| Cost / year | 420 | €/year | | |
| **How much is the income for all the apartments** | | | | |
| Total income /app. for 6 month | 503,850.2 | €/total app. year | | |
| Total cost per 6 month use of pressurized steel boiler | -106,898.5 | €/total year | | |
| Total operational cost per 1 year use of the system (avg. 10% total income) | - 50,385.0 | €/total year | | |
| Total maintenance cost per 1 year use of the system (avg. 2 % total investment) | - 50,450.9 | €/total year | | |
| Total income /year for 6 month use of the system | 296,115.8 | €/total year | | |
| **How many years is there negative balance** | | | | |
| For 6 month heating and 12 month tap water. | 8.5 | years | | |