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The Use of Geothermal Energy for Heating Buildings as an Option for Sustainable Urban Development in Slovakia

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Abstract: The use of geothermal energy (GE) and the green economy in the environment of Slovak municipalities and towns is significant, due to the reduction in the negative influences and impacts of human society's constant consumer lifestyle. The authors highlight the use of modern scientific knowledge, practical experience, and ever-improving technologies in the field of renewable energy sources RES. The aim of this contribution is to draw attention to the under-utilization of GE's potential in Slovakia. Given the country's commitment to meeting emission limits under EU carbon neutrality agreements by 2050, the use of this resource is very pertinent. Slovakia has significant geothermal resources that are not currently sufficiently utilized. The article suggests using GE to heat housing units of the housing estate near the geothermal source. Three scenarios (60 °C (pessimistic), 65 °C (conservative), and 70 °C (optimistic)) were considered in our energy balance and economic advantage calculations. The green economy offers a sustainable way of using the earth's resources. The financial calculations regarding the amount of investment, the expected financial return and the possible values of the saved emissions confirm the possibility of the further use of GE technology. The information under consideration can be used in other significant territories, which may be a theme for further research in this field.

Keywords: geothermal energy; renewable technology; thermal energy; investment

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1. Introduction

The necessity of achieving net zero global CO₂ emissions by 2050, to achieve the target set in the Paris Agreement, has stimulated interest in the use of low-carbon energy technologies, including geothermal energy. The constant exploitation of natural resources, excessive waste generation, the emission of harmful substances into the atmosphere (CO_x, SO_x, NO_x, etc.), seas, oceans, and soils lead to negative and often permanent changes. Climate change is manifested by an increase in average temperatures, changes in the nature of the climate, more frequent occurrences of extreme weather (melting of glaciers and permafrost, landslides, extreme drought and heatwaves, torrential rains, sudden flooding, and others). There are changes in biodiversity, the migration of animal species, extinction, excessive deforestation, changing soil composition, and the contamination of water resources (increasing the acidity of the oceans). Population migration is another important manifestation of these changes [1]. However, despite various climate agreements, CO₂ emissions reached an all-time high of 35 billion tons per year in 2019. The unprecedented nationwide COVID-19 crisis that began in China at the end of 2019 has rapidly frozen emissions growth. All these reasons, among others, have led to increased interest in the research and development of sustainable and renewable energy (RES) technologies.

Man, through his anthropogenic activity, significantly influences conditions on the planet. At present, the greatest emissions are generated by the burning of coal; for instance, more than 14 billion tons were burned in 2018. Emissions from this source totaled more

than 12 billion tons in 2018. This ranking is followed by natural gas and its increasing consumption level of almost 8 billion tons, as well as cement production. The EU is the world's largest importer of energy, relying on imports for 50% of its energy needs. With an energy demand forecast to grow 1–2% a year, this figure will rise, within the coming 20–30 years, up to 70%. Europe's energy needs are growing relatively fast compared to other parts of the world. Climate change has encouraged the inclusion of modern RES technologies in the program, to mitigate the negative impacts of fossil fuel energy production. Europe is being forced to invest in new technologies [2,3]. The overall EU average of RES production in 2019 was 20%, meeting its target for 2020. Iceland has the largest share of RES energy at almost 80%, thus meeting the target above the set limit. This was mainly helped by the geographical relief and nature of the landscape and the wide use of energy from geothermal and water sources—geothermal power plants and hydroelectric power plants. Norway meets about 73% of its energy needs from RES especially due to the hydroelectric power plants made possible by the mountainous profile of the landscape, offering a bountiful supply of rivers with a high falling gradient. Of the other EU countries, Sweden's share is almost 60%, Finland's, about 43%, and Latvia's, 40%, followed by Denmark, Austria, etc. Included in the leading countries that have not (yet) met their commitments is Slovenia, which produced more than 20% of its energy from RES in 2019, but the target for 2020 is 25%. Other such countries are Ireland, Belgium, the Netherlands, Luxembourg, the United Kingdom, and Poland. Poland relies mainly on coal production and, therefore, has long had a problem with air pollution. In 2019, Slovakia produced almost 20% of its total energy from RES, thus meeting its 2020 target [4].

Geothermal energy, as a renewable energy source, can be an important resource for numerous regions of Europe. The development of geothermal energy facilities gives people the potential to gain better control of their own local energy resources and take advantage of a secure, environmentally friendly and domestic source of energy. This energy from within the Earth can be used for different purposes to improve environmental quality and protect public health and safety. The technological and sustainable development of this type of energy will help to solve the world's energy needs and the requisite challenges [5]. For geothermal electricity production, the highest concentration of resources on the European continent is located in Italy, Iceland and Turkey; the present exploited value is only 0.3% of the whole renewable market. The possibilities for geothermal energy to expand its penetration in Europe are mainly from using the enhanced geothermal system (EGS). Some areas have been critically investigated regarding geothermal resource base assessment, recoverable EGS estimates, in-depth research on EGS technologies and the current performance, the designing of sub-surface systems, drilling technology economics, the conversion of energy using enhanced geothermal systems, the effect of this technology on the environment, and the analysis of enhanced geothermal systems and their sustainability [6,7].

Slovakia should take advantage of the potential geothermal resources it has, which are currently used to a minimal extent. It is important to use energy resources efficiently because the price of energy, in general, is rising [8].

Is geothermal energy renewable? Geothermal energy has often been described as a renewable energy resource. However, on the time scale normally used in human society, geothermal resources are not, strictly speaking, renewable. They are renewable only if the heat extraction rate does not exceed the reservoir replenishment rate. Exploitation through wells, sometimes using down-hole pumps in the case of non-electrical uses, leads to the extraction of very large quantities of fluid, and consequently to a reduction or depletion of the geothermal resources that are in place [9]. Geothermal localities can be subdivided into two categories: springs and deep boreholes. Springs are locations where geothermal water naturally flowed out or is still flowing out from the aquifer onto the earth's surface. The category of deep boreholes accounts for all the localities where there are not, nor have there ever been any natural springs, but where geothermal waters have been found during hydrocarbon exploration and exploitation [10,11].

The drilling works enable geologists to establish the rock composition of an investigated area, along with other data that are connected to the tasks needed in the eventuality of a geothermal energy plant [12]. Geothermal fields, as opposed to hydrocarbon fields, are generally systems with a continuous circulation of heat and fluid, where fluid enters the reservoir from the recharge zones and leaves through discharge areas (hot springs, wells) [7]. Heat production from GE is widespread in many countries of the world. The largest geothermal central heating systems are in the USA and China; in Europe, it is mainly found in France, Germany, Iceland or Turkey [13]. Slovakia has the greatest potential for GE in Central and Eastern Europe [3].

The aim of this article is to demonstrate how to carry out an analysis of an area examined in terms of the availability of a site suitable for GE domestic heating systems, the availability of distribution networks, and energy needs. We provide a case study of how a GE system can be used from the perspectives of investment efficiency, environmental impact, and meeting user needs. Practical information and advice on procedures can help other cities in terms of future perspectives.

2. Materials and Methods

This article addresses the issue of obtaining and using a renewable energy source (RES) for heating purposes, district heating (DH), and domestic hot water (DHW). With this energy-clean technology, it is possible to minimize the production of emission substances and replace the combustion of natural gas during heating.

Data that is publicly available and at the same time processed by us in the case study have been used for the processing of this contribution. The procedures and methods are summarized as follows:

- Based on the available information, we analyzed the possibilities of using geothermal energy in the environment of towns and villages in the area of the High Tatras (Podtatranská basin). To design a model of geothermal energy use for heating, we considered a mining well to serve a housing estate of 5500 households.
- We created a methodology for determining the profitability of a geothermal well using a flow chart. We designed a technology setup for the use of geothermal well energy. The energy potential and energy balance were calculated. The complexity and return on investment were assessed. The volume of emissions of harmful substances that can be saved by using this clean energy was calculated. Based on the findings, we assessed the usability of a geothermal well for the purpose of heating apartments.

2.1. Hydrogeological and Hydrogeothermal Conditions in Slovakia

Due to its natural conditions, the Slovak Republic has significant potential geothermal energy. Based on research and surveys to date, the energy potential of GE is important in Slovakia, and its value is at 5538 MWt. Geothermal energy sources are mainly represented by geothermal waters, which are tied to hydrogeological collectors located at depths of 200–5000 m. In Slovakia, the average temperature increase is 3–3.8 °C for every 100 m of the borehole; at a depth of 3 km, the temperature is about 100 °C. Geothermal sources are divided according to temperature (°C), into:

- Low temperature—from 20 °C to 100 °C: these are geothermal sources with a moderate temperature, suitable only for heating and recreational purposes;
- Medium temperature—from 100 °C to 150 °C: these are suitable for heating and using binary cycles, and for electricity generation;
- High temperature—above 150 °C: these are geothermal sources suitable for electricity generation (using water vapor).

In terms of well yield, geothermal sources are distinguished as follows:

- With minimum yield—up to 1.0 L·s^{−1};
- With very little yield— from 1.0 to 5.0 L·s^{−1};
- With a small yield—from 5.0 to 10.0 L·s^{−1};

- With medium yield— from 10.0 to 25.0 L·s⁻¹;
- With great yield—from 25.0 to 50.0 L·s⁻¹;
- With very high yield—above 50.0 L·s⁻¹ [14].

The wells that have been carried out so far (at depths of 92–3616 m) have verified temperatures at the wellhead of 18–129 °C. The yield of free-range wells ranged from tenths of a liter to 100 L·s⁻¹, with a predominantly Na-HCO₃-Cl, Ca-Mg-HCO₃ and Na-Cl water type, with mineralization of 0.4–90 g·L⁻¹ [15].

Slovakia, considering its small surface area (49,000 km²), is very rich in mineral and thermal waters. There are 1200 springs registered on its territory, the equivalent of one spring for every 40 km². The rich physicochemical diversity of waters and their even spread throughout the territory is conditioned by the favorable geological–tectonic construction of the territory and its geothermal activity.

From north to south, mineral and thermal waters are linked to sediments of the Flysch zone and the Klippen belt of the Paleogenic and Mesozoic eras, the crystalline rocks of the Paleozoic and Mesozoic, the dolomites and limes of the Mesozoic, and Flysch sediments of Inner Carpathian Paleogene and Neogene origin. The temperature of the waters of the springs is between 15 and 70 °C. Mining works carried out in some areas obtained water with temperatures in the range of 40–130 °C. The yield of natural springs varies between 1 and 40 L·s⁻¹. The well yield is from 5 to 90 L·s⁻¹ [16,17]. From the point of view of geothermal water sources, we can only consider as a possibility the Paleogene subsoil in the area of interest, which consists mainly of Triassic carbonates of Krížna Nappe and Choč Nappe, with Karst-fissure permeability. Overall, the geothermal activity of the area of interest can be assessed in terms of the density of the earth's heat flow as average geothermal output (65–70 mW·m⁻²). Temperatures at the depth of storage of the collectors (1400–3000 m below the surface) are about 45–95 °C. Mineral waters reflect the hydrogeological, hydrological, geological, and structural conditions in the monitored area. The nature of the waters indicates that Triassic structures correlate well with the appearance of Triassic carbonate rocks on the surface around the basin. The nature of the waters in the Paleogene subsoil may have been obviously marine in origin, i.e., waters that have been preserved after the transgression of the Paleogene Sea but are now more or less infiltrated surface waters from the peripheral parts of the basin. The total mineralization of the waters in the Mesozoic subsoil, based on the results of the pumping tests in the surrounding wells, can be expected in the range of 3–5 g·L⁻¹. Information on the hydrogeological conditions of the territory comes mainly from the quaternary sediments of Poprad, where several exploration wells were created. Several deeper wells were created in the Poprad Basin, the results of which provided valuable data on groundwater properties in individual geological units. From this point of view, valuable information can be drawn from the wells in the areas of Stará Lesná (FGP-1), Poprad (PP-1) and Vrbov (VR-1, 2, 2A, 3) and the latest from the area of Veľká Lomnica. Since the PP-1 borehole (Poprad) is relatively close to the site under examination, its results may be analogous to those of the projected well. At the PP-1 well in Poprad, the geothermal waters, of a significantly calcium-magnesium-sulfate-sulphate-hydrogen carbonate type, were verified as having an average mineralization value of 2.88 g·L⁻¹, with a pH value of 6.21. The water is over-gassed with CO₂. The increased sulfuret content is due to the dissolution of plaster stone and anhydrite. The incidence of sodium is low because it is released due to the low pH [18].

Groundwater resources and reserves in Slovakia vary not only depending on the location and time but also in terms of their quality. Although they are regularly renewed, they are not unlimited and only proper use can ensure their relative inexhaustibility. Groundwater, which is a source of quality drinking water, is the most important natural wealth in Slovakia. Therefore, the most fundamental task is getting to know the laws of groundwater creation and flow as well as its protection. This requires very close monitoring, documenting and registering their basic characteristics and parameters. The total usable amounts of groundwater in Slovakia, as documented in 2018 in all categories, represent 77,175.07 L·s⁻¹.

Those usable quantities also include usable amounts of thermal water as an integral part of groundwater and, for the sake of completeness, part of the mineral waters, in particular the usable quantities of mineral waters approved by the Hydrogeological Commission [19]. Figure 1 shows the prospective areas of geothermal waters in the Territory of the Slovak Republic.

Figure 1. Prospective areas of geothermal waters in Slovakia [19]. (1) 10/4; (2) Klippen belt; (3) prospective areas where hydrogeothermal evaluation has been carried out; (4) prospective areas where hydrogeothermal evaluation is being carried out; (5) prospective areas where hydrogeothermal evaluation has not yet been carried out.

In order to create the best possible conditions for the use of geothermal energy, regional hydrogeothermal evaluations are carried out by determining the quantity of geothermal waters and geothermal energy in the defined 27 hydrothermal areas or structures of Slovakia [20]. Current geothermal conditions in Slovakia are mapped out and reviewed in detail. There are currently 27 prospective geothermal areas that have been defined (Figures 1 and 2).

Figure 2. Partial map of geothermal wells in Slovakia.

A large proportion of geothermal reservoirs provide water with a temperature of up to 135 °C, which is optimal for use for heating buildings or for recreational purposes.

Geothermal energy (GE) is not primarily used for efficient electricity generation. Modern technologies also make it possible to generate electricity using a binary cycle [13].

2.2. Technological Description of Geothermal Well Utilization

The proposed geothermal well is GTK-1 Kežmarok, with an estimated depth of 2800 m; the relevant technological and piping equipment for the purpose of using geothermal energy for DH production and the preparation of DHW in existing block boiler rooms on the housing estate. Currently, housing estate boiler rooms are used for the supply of DH and DHW to apartment buildings, civic facilities, and other buildings in the city. Thermally treated geothermal water will be discharged into a nearby surface flow system. The physicochemical properties of geothermal water and its impact on the material of the pipes are also fully taken into account. Geothermal energy is expected to be used in an open system, with the newly proposed GTK-1 geothermal well serving as a drilling (pumping) well.

The exploitation of geothermal water by free flow has been considered, with water from the well estuary (mouth) entering the separation and storage vessel, where it will be relieved of free gases. Consequently, it will be pumped (if there is not enough pressure at the mouth of the well) and overdrawn in the ground to the isolated pipelines, then carried to an heat exchanger station situated close to the well. In the heat exchanger station, geothermal water transmits its heat to the secondary treated heating system water, by which method geothermal heat will be distributed in a closed and hydraulically separated circuit to 3 boiler rooms, in a ground-stored isolated pipe. Heat exchangers will be added in existing boiler rooms to heat the returning heating water and the preheat/heating of the DHW. After thermal use, geothermal water from the heat exchanger station will be transported under the ground by stored pipes without thermal insulation to a nearby surface stream (see Figure 3).

Figure 3. Scheme of district heating using geothermal energy.

2.3. Methodology for Determining the Suitability of Geothermal Well Usage in the Monitored Area (Podtatranska Basin)

Hydrogeologically, the projected well is situated in explored territory in the Poprad River Basin. It has a left-hand tributary from the High Tatras and the right-hand tributary is mainly from the Levoča Hills. Water management is important in the area since the surface waters of the tributary of Poprad and the groundwater from its alluvia are often used for drinking water supply. Water quality in the river is influenced by industrial enterprises and local agglomerations. The area of the Sub-Tatran Basin under investigation offers the use of several types of RES in different locations of the territory, in order to reduce negative environmental impacts, especially in terms of reducing emissions or replacing the combustion of fossil fuels. Fossil fuel heating is one of the largest sources of CO₂ emissions. The best solution is the use of thermal energy from geothermal sources.

Geothermal energy is an available local, strong energy source that is characterized by stability of supply, regardless of current climatic conditions. Geothermal energy is a long-term and sustainable energy source. Based on the geological construction of the surrounding area and the conditions of geothermal wells that have already been realized, it is possible to expect a well yield in the range of 20–30 L·s^{−1}, with a total mineralization of about 3–5 g·L^{−1} and a water temperature at the surface of 60–70 °C. One definite point of uncertainty, according to the study, may be the depth of the collectors; therefore, the study recommends counting on the final mining depth being 2800 m [21].

Based on analyses of the available data, we assume that there is potential for the practical use of GE in the monitored Podtatranska Basin. GE may replace the combustion of natural gas in the supply of housing units under the current model. This creates ideal conditions for:

- Limiting the use of energy derived from fossil and conventional fuels;
- Reducing CO₂ emissions, (NO_x, CO, SO₂, TZL)
- Stabilizing heat prices,
- Obtaining a stable, green, and renewable energy source.

The aim of the methodological procedure (Figure 4) is to choose the appropriate technology to cover the energy needs of the chosen location—a housing estate—based on sustainability, local availability, and affordability, and with a positive impact on the environment, as an exemplary model of energy independence for towns and villages.

The methodology begins with the search for theoretical knowledge in the field of RES energy. This draws attention to the call for a transition to renewable and sustainable energy sources within the European Union, which aims to achieve carbon neutrality by 2050.

Following a subsequent evaluation and the selection of appropriate information, the individual available RES technologies were evaluated for:

- The area of energy coverage of household needs;
- The types and principle of operation; and
- A large-scale and stable supply for the population throughout the year.

From the information found, geothermal energy appears to be the most suitable form of energy. With the subsequent selection of the site and the examination of existing technologies covering the energy needs of the housing estate, it is possible to proceed with an evaluation of the most appropriate RES technology. Our research has shown that the technology used has the best potential and the appropriateness of the subsequent investment is confirmed by further calculation.

Figure 4. Flowchart methodology for the work of detecting a suitable GE source.

The processing of the geothermal contribution was based on data from the technical study of the geothermal well GTK-1, which is publicly available [21]. A specific site (GTK-1, Figure 5) has been designated in which to carry out the geothermal well under investigation. Residential houses (in a housing estate with a population of 5500) were selected that met the requirements for the use of geothermal energy from the borehole. To determine the yield of a geothermal source for heating the estimated capacity needed for the source was compared with the heating volume of 3 boiler rooms in previous years (average of years 2015–2017).

Figure 5. Location of the proposed GTK-1 well area under investigation [21].

The calculation of the energy potential of the geothermal source was based on the following parameters: yield, mineralization, and water temperature at the surface. Given that it is not possible to determine the exact temperature of geothermal water on the basis of current knowledge, three variants of geothermal water temperature (60 °C, 65 °C and 70 °C) have been considered when calculating the energy potential.

2.4. Procedure for Calculating the Chosen Technology's Potential Using Geothermal Energy

A methodological procedure was used to evaluate the use of the suggested possibilities regarding suitable RES technology with the best potential and lowest subsequent investment, with a recalculation, determination, and proposal as to whether the given system (investment) is suitable. The procedure for calculating the investment technology chosen, using geothermal energy, is as follows:

- Calculation of the Return on Investment (ROI)

ROI is the most frequently used parameter for the assessment of the economic efficiency of investments. It is the total income that results from concrete investments, divided by the amount of investment funds. This indicator is completely time-independent [22].

$$\text{Return on Investment ROI} = \frac{\text{cumulative incomes}}{\text{total investments}} \quad (1)$$

- Calculation of Cash Flow (CF)

Calculation of the annual cash flow is carried out on the basis of the following relationship [22]:

$$\text{CF} = \text{incomes investments} - \text{production costs} \quad (2)$$

CF, or annual cash flow (annual income), is the product of the unit price of natural gas (EUR 0.0219/kWh, for 2021) and the amount of heat produced (DH and DHW) in kWh (MWh) with a difference in estimated annual operating costs (EUR).

The cash flow of a project is the sum of positive and negative items, incomes and costs, connected with a certain activity. The sum of all financial flows, which results from the investment into a project, is called the cash flow produced by capitalized investments.

- Calculation of Net Present Value (NPV)

$$\text{NPV} = \sum_{i=1}^n \left\{ (-I + \text{CF}_i) / (1 + a)^i \right\} \quad (3)$$

where:

NPV—net present value;

I—investments;

CF—cash-flow;

a—update rate;

i—current year;

n—project duration.

If the NPV of the first project is higher than the NPV of the second project, and vice versa—the ROI of the first project is smaller than the ROI of the second project ($\text{NPV}_1 > \text{NPV}_2$; $\text{ROI}_1 < \text{ROI}_2$). In this case, there is no precise mathematical formula defining which of the two projects is better. The volume of investments and the risk level of the project will probably play the most important role. The intuition and experience of the project evaluator, as well as other arguments, can influence investment decisions.

- Calculation of Payback Period (pBp)

A payback period is the project's duration, from its beginning until the point when the cumulative cash flow becomes positive. Although in the case of some projects, the assessment results based on the payback period may seem interesting, this indicator does

not say anything about the project's future course from the viewpoint of its cash-flow development. This could be either positive or negative.

- Calculation of Emission Values for Natural Gas Heating

The CO₂ emission factors needed to calculate CO₂ emissions from the operation of buildings (heating, hot water preparation and the operation of other appliances) are country-specific or operational (and also different for each IPCC1 category) and are derived from specific fuel characteristics. Average CO₂ emission factors are used for natural gas, hard coal, lignite by region of origin (Slovak, Ukrainian and Czech), and coke. Due to these reasons, emission factors should be revised each year [23,24].

The values of the weighted arithmetic mean of the qualitative parameters of natural gas, distributed in the territory of the Slovak Republic by SPP—distribúcia, a.s, were used according to the method followed in [25]. Density, calorific value, combustion heat and Wobbe number are given for the business unit, i.e., m³ at 15 °C, pressure 0.101325 MPa, and relative humidity $\varphi = 0$. The formula used for the conversion of units: 1 kWh = 3.6 MJ.

Annual consumption of MNG NG at a calorific value of 34,848 MJ/m³ [26]:

$$M_{NG} = \frac{\text{annual heat consumption}}{\text{calorific value} \cdot \text{boiler efficiency}} \quad (4)$$

- Calculation of Energy Potential

The energy potential is an elementary indicator of the possibility of using geothermal water. The energy potential of water, which is heated by the action of the earth's core, is its heat output [27].

$$P_t = m \cdot c_v \cdot \Delta t \quad (5)$$

where:

P_t—thermal power (kW)

m—weight (kg·s^{−1})

c_v—specific water heat (m^{−3}·K^{−1})

Δt—temperature difference (K)

- Determination of the Energy Balance

Three variants of geothermal water temperature (60 °C, 65 °C and 70 °C) were considered when determining the energy balance. Natural gas savings were assessed by comparing the average natural gas consumption for 2015–2017 and the energy balance of geothermal energy as a percentage; thus, it was also possible to assume an approximate reduction in CO₂ production.

When processing the energy balance of the GTK-1 geothermal source, we will take into account the following assumptions:

- Geothermal energy will be used for heating the housing estate of the DH and for the preparation of DHW.
- Heat loss or a temperature drop of 4 K due to the use of heat exchangers is considered.
- The daily operating time of boiler rooms is assumed to be 16 h.
- A maximum heating water temperature of 70 °C is assumed.
- A reduction factor in the use of geothermal energy for each whole 1 °C rise in the external temperature, which takes into account differences in outdoor temperatures during the day and resulting fluctuations in the temperature of the heating water. The reduction factor varies for different geothermal water temperatures.
- Thermally used geothermal water will be discharged into a nearby stream.

The energy balance will be processed for individual scenarios: the pessimistic scenario (geothermal water temperature of 60 °C), the conservative scenario (geothermal water temperature of 65 °C) and the optimistic scenario (geothermal water temperature of 70 °C).

To process the energy balance, it is necessary to know the following values:

- Number of days of temperature duration from 13 °C to −16 °C;
- Temperature of the supply and return heating water;
- Average heat output per DH;
- Amount of heat produced per DH;
- Amount of heat produced per DHW;
- Usable thermal output of the geothermal source for DH;
- Reduction factor for the use of geothermal energy for DH.

3. Results and Discussion

In the context of rising energy (heat/electricity) prices and societal pressure on environmental impacts in terms of the green economy, the interest of business owners/population/society in ecological sources of energy production (heat/electricity) is increasing. The design of a GE system for heating towns and villages is problematic, due to several of the input parameters of the calculation. The timing mismatch, the suitability of site selection in terms of the time optimization of production, the capacity of the distribution network, daily consumption, and the possibility of using GE as an energy source for building heating systems are data that has to be mutually optimized when dimensioning a balanced energy system.

3.1. Determination of the Parameters of the Proposed Geothermal Well

The predicted physicochemical properties of geothermal water from the proposed GTK-1 borehole are similar to geothermal boreholes already created in the vicinity of the Podtatranska Basin (wells Vr-1 and Vr-2 Vrbov, VL-1 Veľká Lomnica).

The mineralization type of Ca-Na-HCO₃-SO₄ is assumed, i.e., a composition similar to Vrbov; the dominant cationic components will be calcium (up to 600 mg·L^{−1}), sodium (up to 300 mg·L^{−1}) and magnesium (about 150 mg·L^{−1}), with anionic components of bicarbonate concentrations (about 2000 mg·L^{−1}) and sulfites (up to 700 mg·L^{−1}). Total mineralization is estimated to be up to 3 g·L^{−1}. The concentration of strontium (approx. 10 mg·L^{−1}) and potassium (80 to 100 mg·L^{−1}) will also be increased. Radioactivity will also be slightly increased compared to the natural background. Trace amounts of sulfide can also be expected. The expected phase ratio (dissolved gas content) will be up to 1 m³·m^{−3} of geothermal water, the main component being carbon dioxide (95 to 98% by volume), the remainder is mainly nitrogen and methane, with a small admixture of ethane, propane, isobutene, etc. [22].

Table 1 shows the predicted parameters of the geothermal borehole in the explored site of the Podtatranska Basin, based on an analogy of geothermal wells located nearby.

Table 1. Predicted parameters of the proposed geothermal well.

Scenario	Pessimistic	Conservative	Optimistic
Geothermal water temperature at the mouth of the well (°C)	60	65	70
Yield geothermal well (L·s ^{−1})	25	25	25
Mineralization (g·L ^{−1})		3–5 g·L ^{−1}	
Usable amount of geothermal water per year (L·s ^{−1})	788,400	788,400	788,400
Theoretically usable energy potential (kW)	4710.4	5233.8	5757.1
Theoretically usable annual amount of heat (MWh)	41,262.9	45,847.7	50,432.4

Table 2 shows the values of total annual heat production and NG consumption for the years 2015 to 2017.

Table 2. Total heat production and consumption of natural gas in the selected location, (source: elaborated by authors).

Year	2015		2016		2017	
Type of (MWh)	DH 17,964	DHW 9565	DH 19,084	DHW 9565	DH 18,975	DHW 9290
Total DH + DHW (MWh)	27,529		28,649		28,264	
Total consumption (NG) Total DH + DHW (kWh)	15,021,319		15,558,809		15,474,532	
Total consumption (NG) DH + DHW (m ³)	1,398,633		1,448,678		1,440,831	

- Calculation of saved emission values using geothermal energy

Table 3 shows the specific values of individual emission substances that pollute the environment by burning natural gas. The recalculation was carried out according to the literature [23]; these pollutants would be eliminated by using the thermal energy of the geothermal well. The replacement of NG with geothermal energy minimizes the greenhouse effect.

Table 3. Calculation of emissions from natural gas heating.

Annual Emissions from Natural Gas Heating (kg)	
TZL	270.8
SO ₂	32.5
NO _x	5958
CO	1997
TOC	253.9
Total emissions (kg)	8512.2

These pollutants would be eliminated annually for a housing estate with about 5500 residents. The calculation of emissions in NG heating was recalculated according to the literature [23] (see Table 3).

- Energy balance of geothermal well

Geothermal wells offer a number of positive options in terms of reducing negative environmental impacts in the long term. The presumed energy potential of the well could supply the housing estate with hot water intended for heating and hot service water preparation in full coverage, but a certain amount of natural gas usage is still envisaged by heating, to cover possible failures of the energy system.

We considered the following values:

- The specific weight of salt water of 1025 kg·m⁻³;
- Specific water heat $c_v = 4.18 \text{ MJ m}^{-3} \text{ K}^{-1}$;
- Temperature difference (for pessimistic, conservative, and optimistic scenarios) $\Delta t = 42, 45 \text{ and } 55 \text{ K}$.

The energy balance of a geothermal well at 3 different geothermal water temperatures was determined as shown in Table 4.

Table 4. Energy balance of geothermal well GTK-1.

Geothermal Water Temperature	60 °C	65 °C	70 °C
Annual amount of heat produced for DH (MWh)	8538.8	8538.8	8538.8
Annual amount of heat produced for DHW (MWh)	4676.5	4676.5	4676.5
Annual production of heat TOTAL (MWh)	13,215.3	13,215.3	13,215.3
- geothermal energy (MWh)	9763.1	11,070.3	12,091.4
- geothermal energy (%)	74	84	91
- natural gas (MWh)	3452.2	2,45	1123.9
- natural gas (%)	26	16	9
Annual average efficiency of geothermal energy (%)	24	24	24

The energy potential of geothermal water from the proposed well has been calculated. Since the energy potential of water heated by the earth's core is its heat output, the heat output formula has been used (2). The energy potential has been calculated for three temperature scenarios. Table 4 shows that as the geothermal water temperature rises, the energy potential and annual amount of thermal energy increase. Due to the large range of processed data, the evaluation of the energy potential by the authors in a conservative scenario of the implementation of a geothermal well with a water temperature of 65 °C is given in Table 5.

Table 5. Evaluation of the energy potential of a geothermal well in a conservative scenario with a water temperature of 65 °C.

Geothermal Water Temperature (°C)	65
Amount of heat produced annually from geothermal energy for DH (MWh)	7939.75
Amount of heat produced annually from geothermal energy for DHW (MWh)	4275.25
Total amount of annual heat produced from geothermal energy (MWh)	12,215
Natural gas savings (m ³)	1,136,279
Natural gas savings (kWh)	12,215,000
Price of saved natural gas (EUR/year)	354,235

The results of Tables 4 and 5 clearly show how the energy potential and the annual amount of thermal energy increase with increasing geothermal water temperature. Using data from the technical study of the geothermal well, the energy balance of the geothermal source GTK-1 was calculated for three temperature scenarios (pessimistic, conservative, and optimistic) of geothermal water.

3.2. Assessment of the Economic Feasibility of Using GE and the Payback Period of the Implemented Project

The assessment of economic profitability was recalculated by calculating the net present value, and the return-on-investment method was used. We considered two variants—a pessimistic and an optimistic scenario.

In the calculations, we considered the following input data:

1. Quantity delivered to GE per year;
2. Credit financing up to 90% of the realized investment;
3. Interest rate—0.75%;
4. Loan maturity—12 years;
5. Annual increase in operating costs—by 1% per year;
6. Discount rate—7.5%.

In Table 6, the recalculation of the evaluation of the economic efficiency of the implemented geothermal project for the pessimistic scenario is shown.

Based on the economic assessment, and assuming Tables 6 and 7 have the considered inputs, we came to the following partial conclusions:

- The project would achieve a return of 16.4 years in a pessimistic scenario.
- The project would achieve a negative cash flow in the years 2022 to 2025 until, in 2026, the cash flow would reach a positive value, which would increase in subsequent years.
- The project would achieve a return of 7.4 years in an optimistic scenario.
- In an optimistic scenario, the project would achieve a high positive cash flow from the beginning, which would increase in subsequent years.

Table 6. Calculation of the evaluation of the economic efficiency of the implemented geothermal project for the pessimistic scenario.

Pessimistic Scenario										
1.	Total Investment Costs (EUR)					2,459,687				
2.	Credit Share of Total Investment					90%				
3.	Credit Amount (EUR)					2,213,718				
4.	Interest Rate					0.75%				
5.	Credit Payment Period (Years)					12				
6.	Annual Operating Costs (EUR)					29,129				
7.	Annual Savings on NG (EUR)					228,843				
8.	Discount Rate					7.5%				
9.	Year	2022	2023	2024	2025	2026	2027	2028	2029	2031
10.	Number of Year	1	2	3	4	5	6	7	8	10
11.	Year Annual Sales/Operating CF (EUR)	228,843	228,843	228,843	228,843	228,843	228,843	228,843	228,843	228,843
12.	Annual Increase in Operating Costs	-	1%	1%	1%	1%	1%	1%	1%	1%
13.	Operating Costs (EUR)	29,129	29,421	29,715	30,012	30,312	30,615	30,921	31,231	31,858
14.	Annual Depreciation (EUR)	187,252	187,252	187,252	187,252	187,252	187,252	128,745	128,745	90,307
15.	Credit Repayment (EUR)	184,477	184,477	184,477	184,477	184,477	184,477	184,477	184,477	184,477
16.	Credit Balance (EUR)	2,213,718	2,029,242	1,844,765	1,660,289	1,475,812	1,291,336	1,106,859	922,383	553,430
17.	Annual Interest on the Credit (EUR)	16,603	15,219	13,836	12,452	11,069	9685	8301	6918	5534
18.	CF (EUR)	−4141	−3049	−1960	−873	210	1291	60,876	61,950	101,459
19.	NOPAT (CF−Income Tax 19%) (EUR)	−4141	−3049	−1960	−873	170	1046	49,310	50,180	82,182
20.	Discounted FCF (EUR)	−1270	−236	657	1425	2052	2476	−3871	−3113	−6253
21.	NPV (EUR)	−247,239	−247,475	−246,818	−245,393	−243,341	−240,865	−244,736	−247,849	−254,102
22.	Payback Period (Years)						16.4			

Table 7. Calculation of the evaluation of the economic efficiency of the implemented geothermal project for the optimistic scenario.

Optimistic Scenario											
1.	Total Investment Costs (EUR)					2,459,687					
2.	Credit Share of Total Investment					90%					
3.	Credit Amount (EUR)					2,213,718					
4.	Interest Rate					0.75%					
5.	Credit Payment Period (Years)					12					
6.	Annual Operating Costs (EUR)					29,129					
7.	Annual Savings on NG (EUR)					283,420					
8.	Discount Rate					7.5%					
9.	Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
10.	Number of Year	1	2	3	4	5	6	7	8	9	10
11.	Year Annual Sales/Operating CF (EUR)	283,420	283,420	283,420	283,420	283,420	283,420	283,420	283,420	283,420	283,420
12.	Annual Increase Operating Costs	-	1%	1%	1%	1%	1%	1%	1%	1%	1%
13.	Operating Costs (EUR)	29,129	29,421	29,715	30,012	30,312	30,615	30,921	31,231	31,543	31,858
14.	Annual Depreciation (EUR)	187,252	187,252	187,252	187,252	187,252	187,252	128,745	128,745	90,307	90,307
15.	Credit Repayment (EUR)	184,477	184,477	184,477	184,477	184,477	184,477	184,477	184,477	184,477	184,477
16.	Credit Balance (EUR)	2,213,718	2,029,242	1,844,765	1,660,289	1,475,812	1,291,336	1,106,859	922,383	737,906	553,430
17.	Annual Interest on the Credit (EUR)	16,603	15,219	13,836	12,452	11,069	9685	8301	6918	5534	4151
18.	CF (EUR)	50,436	51,528	52,617	53,704	54,787	55,868	115,453	116,527	156,036	157,104
19.	NOPAT (CF-Income Tax 19%) (EUR)	40,853	41,738	42,620	43,500	44,378	45,253	93,517	94,387	126,389	127,254
20.	Discounted FCF (EUR)	40,585	38,519	36,542	34,651	32,845	31,121	22,775	21,674	16,805	16,053
21.	NPV (EUR)	−205,384	−166,865	−130,323	−95,672	−62,827	−31,706	−8931	12,743	29,548	45,601
22.	Payback Period (Years)						7.4				

The payback period of the project in the optimistic scenario is very attractive and is advantageous for the specified parameters. A higher share of credit financing has a significant effect on the payback period.

The presented data create a synergy for the final conclusion that the implementation of this project will be an effective investment in the future.

4. Conclusions

Geothermal wells offer a number of positive options for reducing negative environmental impacts in the long term. In theory, the projected energy potential of the well would be able to supply the modeled housing estate with warm water intended for heating and the preparation of hot service water. One of the most burdensome aspects of today's society is energy. In particular, energy in households, especially heating and cooling, contributes significantly to negative impacts on the country as a whole. In the case of Slovakia, there is currently a system of supported RES and limited use of fossil resources. In the case of the specific location of the Podtatranska Basin, we propose to use the potential of geothermal energy for heating domestic housing units (housing estates). This will help to limit the combustion of natural gas and, in the long term, save money on the purchase of NG and achieve increased energy security and stability. The use of geothermal energy for housing estate heating will bring a number of benefits to this area. GE can also be used in a combined way (heating and electricity production) for greenhouse heating for growing crops and flowers, for fish farming, etc. Primarily, it will offer an ecological benefit in the form of significant emission reductions in the combustion of processes (NO_x, SO₂, CO, TZL). Currently, the city's thermal economy burns natural gas and coal. Geothermal energy is a highly ecological source; immediately after heating use, it will be drained off to a nearby surface stream. Another benefit will be that it will reduce dependence on the imports of primary heat sources (NG and coal) and replace them with a renewable energy source. Finally, the use of geothermal energy will lead to a lower heating bill for the inhabitants of the housing estate.

Currently, the aim is to use RES technology that contributes as much as possible to reducing the negative consequences of energy use on the global climate system. The topic is vital, according to current developments in energy policy in the EU and around the world. At the end of October 2021, the UN World Climate Summit was held in Glasgow; it highlighted the need to address the issue of reducing emissions in energy production. Our contribution, in terms of the use of geothermal energy, highlights a clean renewable resource and is therefore highly relevant for future generations.

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