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# HYBRID – RES DISTRICT HEATING SYSTEM

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**Abstract:** Utilization of geothermal resources for heat supply of a district heating system is many times more efficient when compared with conventional heat sources. In order to overcome certain problems that arise during the heating season with a low–temperature geothermal district heating system, the possibility of including another renewable energy source is studied. The data from conducted analysis of the economic efficiency and related performance of the hybrid plant, confirm the economic viability of the investments. The analysis of the ecological benefits shows substantial potential for $CO_2$ emissions reduction given the fact that the hybrid plant utilizes two types of renewable energy sources (RES).
**Keywords:** renewable energy sources, hybrid thermal system, energy efficiency, environmental benefits

## 1. INTRODUCTION

The global transition towards sustainable energy systems has become increasingly urgent in response to climate change and the finite nature of fossil fuel reserves. District heating and cooling (DHC) systems represent a significant opportunity for decarbonization, particularly in urban and peri–urban areas where centralized heat production and distribution can achieve substantial energy efficiency gains [1][2]. The heating and cooling sector accounts for approximately 50% of final energy consumption in Europe, yet renewable energy sources still represent a relatively small share of this sector [3]. Traditional district heating systems have historically been powered by fossil fuels—natural gas, coal, or oil—which continue to dominate the heat supply infrastructure in most developed nations [4].

The integration of renewable energy sources (RES) into district heating systems presents a viable pathway to reduce carbon dioxide emissions and improve energy security. Recent research demonstrates that hybrid thermal systems, which combine multiple renewable energy sources, offer improved technical performance and economic viability compared to single–source renewable heating systems [5]. Geothermal energy provides consistent, baseload heating capability suitable for district heating applications, as it is not subject to the intermittency challenges associated with solar or wind energy [6]. However, low–temperature geothermal resources in many regions are insufficient to meet peak heating demands during the coldest periods of the heating season [7].

Biomass emerges as a complementary renewable energy source to address the limitations of geothermal heating systems. Agricultural residues, including rice straw, corn stems, and wheat straw, represent an underutilized renewable resource with significant energy potential in agrarian regions [8]. The utilization of biomass for thermal energy production not only provides a sustainable heat source but also addresses agricultural waste management issues, reducing environmental pollution and creating potential economic value from agricultural byproducts [9]. When combined with geothermal energy in a hybrid configuration, biomass combustion can supply additional thermal capacity during high–demand periods, enabling the hybrid system to meet year–round heating requirements efficiently [10].

The Kochani municipality in Macedonia presents a compelling case study for hybrid renewable energy district heating implementation. The region benefits from accessible geothermal resources

and significant agricultural biomass potential due to extensive rice cultivation and other grain production [11]. The existing geothermal district heating system "Geoterma" currently operates at limited capacity, primarily serving greenhouse heating and limited commercial applications [12]. The technical challenge of maintaining adequate water temperature during the low–temperature phase of the heating season necessitates the integration of supplementary heat sources. A hybrid approach utilizing both geothermal water and agricultural biomass has been identified as a technically feasible and economically viable solution for expanding district heating coverage to municipal buildings and industrial facilities [13].
The technical performance of hybrid geothermal–biomass heating systems depends on optimal system design, which has been the subject of increasing research attention [14]. Configuration options include serial and parallel flow arrangements, each presenting different thermal efficiency characteristics and operational flexibility [15]. Recent advances in district heating technology emphasize the importance of intelligent system integration, real–time monitoring, and adaptive control strategies to maximize energy efficiency while minimizing operational costs [16].
From an economic perspective, renewable energy projects typically face higher capital investment requirements than conventional fossil fuel systems; however, declining operational costs, potential government support mechanisms, and quantifiable environmental benefits increasingly justify investment in hybrid renewable heating systems [17]. Life–cycle cost analysis and discounted cash flow evaluation methods provide frameworks for assessing the financial viability of such projects [18].
Environmental considerations substantially influence the case for hybrid renewable district heating implementation. The substitution of fossil fuels with renewable energy sources directly reduces greenhouse gas emissions, contributing to climate change mitigation objectives at both local and national levels [19]. The avoided emissions from utilizing geothermal and biomass energy compared to equivalent conventional heating systems can reach thousands of tonnes of $CO_2$ annually, depending on the replaced fuel source [20].
This paper presents a comprehensive analysis of a proposed hybrid geothermal–biomass district heating system for the Kochani municipality. The study incorporates technical feasibility assessment, thermodynamic performance modeling, economic efficiency analysis, and environmental impact evaluation. The integration of both renewable energy sources within a parallel–flow configuration is evaluated as the optimal technical solution, considering seasonal heating demand patterns, resource availability, and system operational requirements.

## 2. STATE OF THE ART

For the geothermal district heating system in Municipality of Kochani a feasibility study has been realized in order to investigate the possibility to be operated with additional renewable energy source [13]. The initial problem that the system faces is the temperature decrease of the heat carrier during distribution, so the technology–energy mix (geothermal and biomass) could obtain the necessary functional temperature setting [7]. The main objective and purpose of the study have been gathering data and information on the feasibility of hybrid plant realization for heat supply of the district heating system of Kochani while assessing the real available potential of biomass (agriculture residues) to be used in combination with the geothermal energy [8][11].
On the base of the adopted geo–filtration model of Kochani geothermal field, the annual capacity and the dynamic reserves are assessed [12]. In real heating season the necessary available flow is known and the geothermal system can supply 87% of the requirements. When the outside air temperatures are below 0$^{o}$C, the heat requirement for the district heating is predicted to be covered by biomass combustion while the geothermal energy is used exclusively for greenhouse heating needs [22]. Based on the performance analysis, it is adopted geothermal water to be used in the hybrid system only when the outside air temperature is higher then –1$^{o}$C [6].


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The hybrid plant for heat supply is consisted of: boiler room, heat substation, geothermal heat exchangers, heating water treatment unit, economizer and waste gas treatment department, biomass warehouse and heat energy consumers (public buildings and households) [13]. Based on the conducted analysis of the possible temperature profiles of the hybrid heating system, a parallel–flow layout concept is recommended [15]. The thermal capacity of the biomass boilers should be 100% of the hybrid heating system capacity. When the outside air temperature is 0°C, the required boiler capacity is 55% of the total, while the total capacity will be required when the outside air temperature is below –14°C [22].

During the heating season, for the climate conditions of Kochani, the anticipated consumption of the hybrid system is approximately 1700 tons of rice husk/straw and/or corn stems and 400 thousand cubic meters of geothermal water. The combustion properties of biomass fuels have been extensively studied [10], demonstrating that rice straw and corn stover can be effectively utilized in adapted boiler systems [22]. To ensure the sustainability of the geothermal resource, injection of the total amount of used geothermal water within the hybrid plant is anticipated [6][12]. The use of geothermal resources for heat supply is many times more energy efficient compared to conventional systems for heat and power generation [6].

The economic efficiency and the corresponding performance of the hybrid heating plant can be described by common economic feasibility indicators [18] The obtained indicators of the internal rate of return of investment confirm the profitability of all considered scenarios. Environmental analyses show essential potential to reduce $CO_2$ emissions [19], bearing in mind that the hybrid plant uses two types of renewable energy sources [4][20].

## 3. AVAILABLE RESOURCE POTENTIAL FOR THE HYBRID PLANT

### Available geothermal potential

Currently, the Kochani geothermal district heating system "Geoterma" is consisted of the following basic units: 5 production wells (EBMP–1, EB–2, EB –3, EB –4 and D–1), 2 injection wells (P–10 and ZD–2), distribution station, pump station and pipeline network. The geothermal water produced from "Geoterma" is used for: heating greenhouses, low–temperature applications and heat supply to public (communal and administrative) buildings in the city of Kochani (Fig.1) [12].

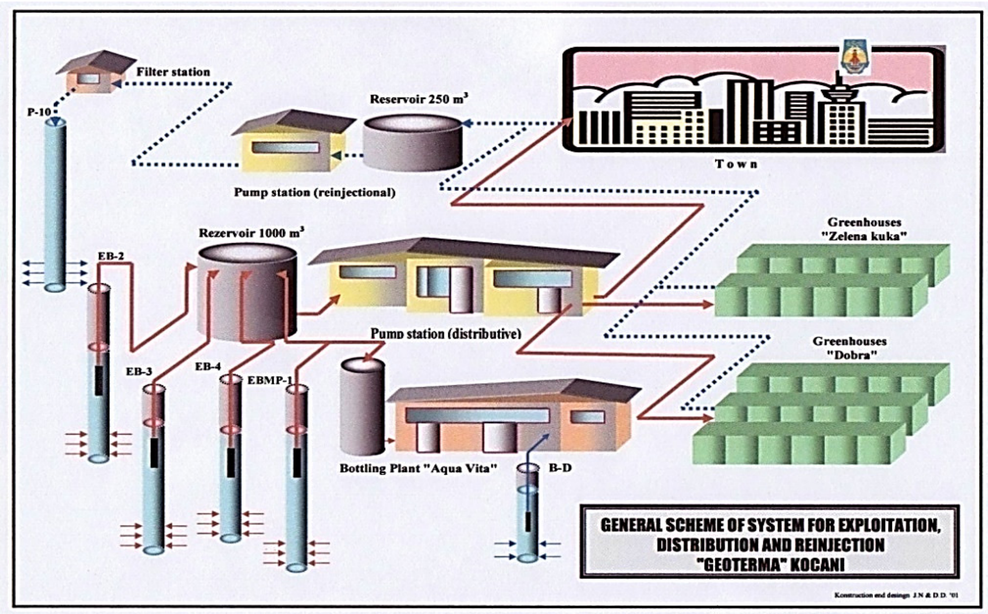

Figure 1. Functional scheme of "GEOTERMA"–Kochani – the system for exploitation, distribution and injection [12]

Assessed capacity of the Kochani geothermal water field (based on accepted geo–filtration model) is $1.3{\cdot}10^6$ $m^3$ annually including $0.24{\cdot}10^6$ $m^3$ static reserves and $1.1{\cdot}10^6$ $m^3$ dynamic reserves. Within actual heat supply season duration of 4200 hours amount of total productive reserves secure instant water intake of 87 l/sec. Currently this parameter for the geothermal system is 76 l/sec.

Injection of the effluent/used geothermal water increases total operative reserves for 1.7 times and makes $2.23 \cdot 10^6$ $m^3$ annually. Maximum permitted ground water level decline in the productive aquifer of Kocani geothermal water field according to the accepted geo–filtration model is 320 m. Current water production flow of 76 l/sec is secured. Water level reduction by the end of operation period (under conditions of complete effluent water injection) will not exceed the maximal permitted level and should be 38.3 m. Injection of the spent fluid improves operation conditions of the geothermal water field and decreases calculated level decline by almost 3 times [6][12]. Currently accepted geo–filtration model of Kochani geothermal field requires updating, refinements and empirical confirmation of adopted preconditions and parameters.

Energy demand (average through 2008–2013) of the existing consumers is $1.143 \cdot 10^6$ $m^3$/an. Main consumers are the greenhouses. The exploited quantities of geothermal water are varying between minimum of 75.58 l/s to maximum of 132.24 l/s or in average 1.15 million cubic annually.

The annual average heat production from the geothermal fluid for the "Geoterma" consumers is calculated as follows:

$$Q_T = V \cdot C \cdot \left(T_e - T_i\right) \cdot \eta_{tr}\,[GJ] = \\ 1.143 \cdot 10^9 \cdot 4.19 \cdot (75 - 30) \cdot 0.86 = 185341\ [GJ] \quad (1)$$

where: $Q_T$ – annual heat production from geothermal water (GJ);

$V$ – quantity of extracted geothermal water annually (kg);

$C$ – specific heat of water (kJ/kgK);

$T_e$ – inlet temperature of geothermal water (average temperature from the 5 wells) ($^oC$);

$T_i$ – outlet temperature of used geothermal water (effluent water) ($^oC$);

$\eta_{tr}$ – heat transfer coefficient of performance (from the geothermal water to the heating water).

Annual average of heat production is 185341 [GJ] or 4427 toe. The (geo)heat requirements are not constant over the years and heating seasons. From the available data obtained from "Geoterma" for the 5–year period (from 2008 to 2013) the dynamic of the annual requirements for geothermal water could be captured, for the existing consumers by the use of monthly data over the years. The resulting chart clearly shows that the maximum demand for geothermal water coincides with the coldest months of the year, i.e., December, January, February and March. During these months, 81% of the annually produced heat is consumed [12].

It has been estimated that additional heat production from geothermal water is possible without significant interventions in existing pumping equipment. According to that estimate, the additional capacity of 300,000 $m^3$ of water annually would allow the production of additional 48650 GJ heat and allow for a substitution of 1186 toe conventional fuel annually [6].

Provided that the duration of the heating season for the hybrid heating plant is 143 days (3440 hours), the additional production of geothermal water of 300,000 $m^3$/yr. yields 24.2 l/s or 2098 $m^3$/day. Thus, the total production of geothermal water at annual level would be 6566 + 2098 = 8664 $m^3$/day, and the decline in the water level at the end of the operational period with complete injection of the used geothermal water into the production horizon would be 90.4 m. At the present state of re–injection, the water level would drop by 154 m, therefore the establishment of complete re–injection is of particular importance for improving the operational conditions and mitigating the level of decline in the productive aquifer by about 3 times [6][12].

### Available biomass potential

The territory of Kochani Municipality is characterized with agricultural fields and gardens prevalent in the valley area, slopes covered by bushes and poor grass cover and sparse forests on the hills. Total area of agricultural lands in Kochani area makes 57000 ha, of which grain growing occupies up to 12000 ha, wheat occupies 24% of sowing area, rye – less than 1%, barley – up to 30%, rice – more than 34%, and corn for grain near 10% of sowing area. Rice is grown on irrigated lands, and other cultures on low lands and plain foothills. Atmospheric water precipitations make 400–500 mm per year and mainly in cold seasons, summer is dry and is not favourable for agriculture at non–irrigated lands [11].

Table 1. Total biomass resources potentially available for energy production in Kocani, possible production of heat and level of infrastructure availability for biomass exploitation [11]

| Type of biomass | Current biomass resources (toe/yr) | Heat generated (GJ/yr) | Infrastructure level |
|---|---|---|---|
| Excess of grain straw (wheat, barley, rye) | 588 | 21014 | 2 |
| Excess of rice straw | 1015 | 36286 | 4 |
| Excess of rice husks | 790 | 28242 | 1 |
| Excess of corn stems | 430 | 15393 | 6 |
| Grape branches | 214 | 7648 | 5 |
| Grape seeds | 121 | 314 | 3 |
| Total | 3157 | 112897 | |

The data on the biomass resources available for energy generation in the region of Kocani are summarized in Table 1. As can be seen, the greatest potential for energy supply has the excess of rice straw and husks, then moderately from corn stems and wheat straw, and some of the vineyards residues and seeds [8][21]. The current available potential for producing biomass energy is 3157 toe/yr. The combustion properties and characteristics of different biomass types have been investigated [10][22], demonstrating that agricultural residues can be effectively utilized in appropriately designed boiler systems[22].

## Energy requirements of existing and future consumers

The dominant economic branch in the municipality of Kocani is agriculture, especially the cultivation of rice as a traditional product, then fruits and vegetables produced in greenhouses heated with geothermal energy. The Kocani Valley, also known as the valley of rice, at the end of the 1970s, gets another symbol of recognition – called a geothermal region. The first research of this resource was conducted in the 1980s when the first geothermal well has constructed [12][25].

The municipality of Kocani that extends through the Kocani valley, is divided into three zones (defined long time ago): the old and the new industrial zone, and the core city. Existing and future potential consumers of thermal energy are considered according to these zones (Fig.2) [13].

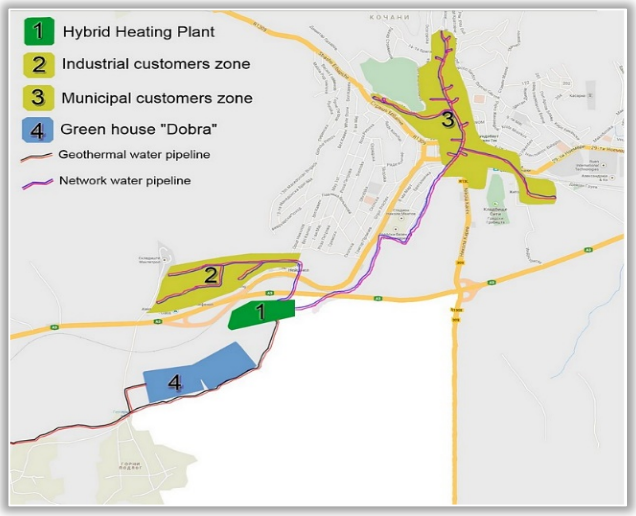

Figure 2. Location of the hybrid heating plant and potential consumers' zone [13]

From the existing users represented by greenhouses, public buildings and industry, the largest consumers are the greenhouses, and the total average amount of used geothermal water annually is 1.15 million m$^3$, with variable flow from minimum 75.58 l/s to maximum 132.24 l/s. The main resource for space heating in the city is firewood, whose average consumption per household is 9 m$^3$.

From the obtained data (existing and acquired with the conducted survey) the following required heating capacities were determined:

1. Buildings under the jurisdiction of the municipality (mainly located in the central part of the city) – approximately required maximum capacity 10 MW.
2. In the old and new industrial zone, the existing buildings already have space heating systems (they would like to join the district heating system, but are not ready to pay for the connection and adjustment of the heating installation). The new industrial zone compared with the so called old industrial zone has many more companies and potential for building new ones. The existing

required heating capacity is estimated at 6 MW for the new and 4 MW for the old industrial zone [13]. To achieve an optimal solution for the location and capacity of the hybrid heating plant, extensive research has been performed of the terrain, infrastructure, energy needs that can be realistically covered, the environmental impact of collection and biomass processing, etc. Regarding the location of potential consumers in relation to the Geoterma system, Zone 1 (new industrial zone) and Zone 2 (urban area, where most of the municipal buildings are represented) are the closest ones, and are also the most reliable ones for joining the district heating. The most appropriate location of the hybrid plant (Fig.2) is near the greenhouses Dobra, a position easily accessible from the main road, close to the main distribution pipe, no inhabitants whose environment would be affected by the supply, processing and biomass combustion [13].

## 4. HYBRID PLANT CONCEPT AND DESCRIPTION

The idea of the project to create a hybrid heating system is to combine the use of low–temperature geothermal water in a geothermal heat exchanger to pre–heat water for district heating and reheat to the desired level in the biomass boilers [13]. The realization of the hybridization idea could be carried out by two conceptual technological schemes, which are shown in the fig.3 [15]:

- With serial arrangement – heating water flows through the geothermal heat exchangers and continues in the biomass boilers;
- With parallel arrangement – heating water flows through the geothermal heat exchangers or biomass boilers.

Based on the analysis of the possible temperature profiles of the hybrid heating system, a parallel–flow concept (the flow of hot water from the closed circle through geothermal heat exchangers and biomass boilers – Fig.3) is recommended [15]. In parallel flow of heating water, geothermal energy can provide full coverage of heat demand at external ambient temperatures from 12°C to ± 1°C. The use of geothermal water in the hybrid district heating system would be activated at ambient air temperatures above –1°C [6].

The maximum required capacity of geothermal heat exchangers in the hybrid system at an external air temperature of 0°C is 54.5% of the rated capacity of the heating system or 6545 kW. At the beginning of the heating season, when the outside air temperature is 12°C, the required heat capacity of the geothermal heat exchangers would be 2180 kW [6].

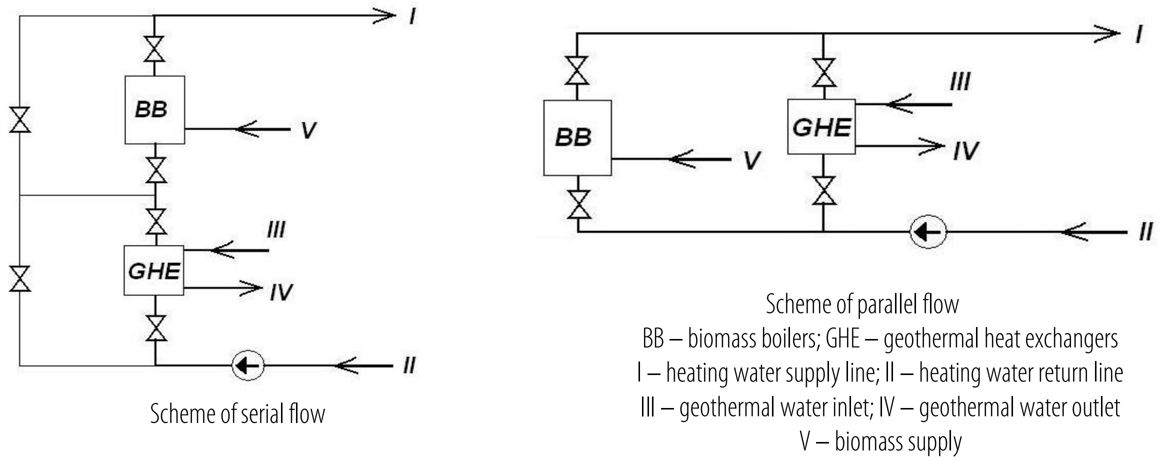

Figure 3. Flow concepts in the hybrid heating system

Thermal load of the heating system is equal to the estimated 11 089 kW at the design outdoor temperature of –15°C, and at temperatures higher than estimated, it decreases proportionally to the decrease of the temperature difference between inside and outside air. Fig.4 shows a graph of variation of the heating load of the hybrid plant depending on the outdoor temperature. From this graph it can be concluded that at the beginning of the heating period, the heating load is 18.2% from the design load, and at an outdoor air temperature of 0°C the heating load of the system will be 54.5% [13].


Figure 4. Thermal load of the hybrid plant depending on the outside air temperature

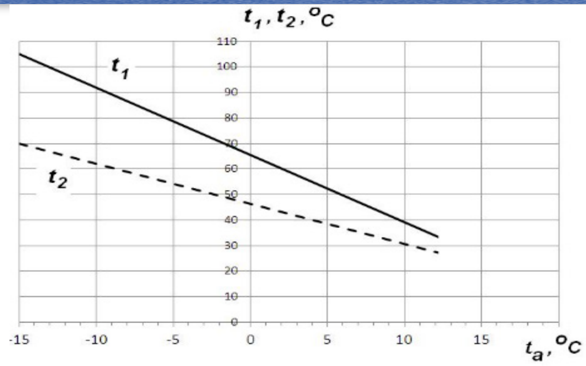


Figure 5. Required temperature of the supply ($t_1$) and return ($t_2$) heating water depending on the outside air temperature

The calculated inlet temperature $t_1$=105°C of the heating water (from the hybrid heating system) and the return temperature $t_2$=70°C must be provided at the design outdoor temperature of –15°C, and at outdoor temperatures higher than estimated, they are reduced proportionally to the decrease in the temperature difference between inside heated air in the buildings and outdoor air. Fig.5 shows the estimated required schedule of temperature change in the supply $t_1$ and return pipelines $t_2$ of the hybrid heating system, depending on the outdoor temperature. From this graph can be concluded that at the beginning of the heating season, the heating water temperature should be $t_1$ = 33.8°C and $t_2$ = 27.5°C and when the outdoor air temperature drops to 0°C than $t_1$ = 65.5°C and $t_2$ = 46.4°C [13].

The thermal capacity of the boilers (for biomass) should be 100% of the rated power of the hybrid heating system or 12 MW. When the outside air temperature is 0°C, the required boiler capacity is 6545 kW, and the total capacity will be required when the outside air temperature is below –14°C (Fig.6) [22] [13].

From the analysis of the duration of outside air temperatures in the municipality of Kochani, it can be obtained that for a heated period of 4200 hours, the duration of ambient temperatures above 0°C is 3440 hours, while the duration of temperatures below 0°C is 760 hours (Fig.7) [13].

From the analysis of the duration of outside air temperatures in the municipality of Kochani, for a heated period of 4,200 hours, the duration of ambient temperatures above 0°C is 3,440 hours, while temperatures below 0°C occur for 760 hours[13]. Consequently, biomass boilers will operate 760 hours during the heating season, and around 1,700 tonnes of rice straw and/or corn stems are needed. During the heating season, the average thermal power provided by the boilers is only 392 kW or less than 3.5% of the installed capacity. Under the assumed operational capability of the boilers of 40,000 hours, their durability would be about 50 years [22].

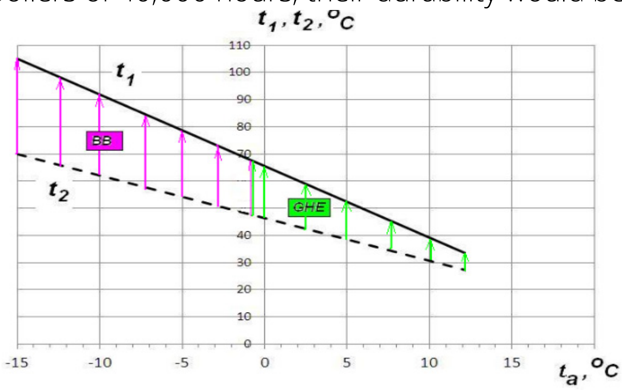


Figure 6. Hybrid plant operational temperature regimes with parallel flow arrangement


Figure 7. Load duration curve for the hybrid heating system

The hybrid heating plant consists of four boilers of equal characteristics that provide for interchangeability of components, significant availability and a wide range of heat output produced [22]. The maximum hourly consumption of geothermal water at 0°C outside air temperature would be 260 tonnes, and the minimum 46.3 tonnes at a temperature of 12°C. The annual consumption of geothermal water by the hybrid plant would be 400 thousand tons. The required flow of geothermal water for the hybrid system would be 31.44 l/s, whereas for the protection and sustainability of the geothermal aquifer,r injection of the entire utilized quantity is necessary[6][12]. The assessment of the geothermal energy utilization efficiency in the hybrid heating plant is made on the basis of comparison with conventional heat and power plants. The total annual heat production of the hybrid system is $234{\cdot}10^3$ GJ or 5613 toe. The power demand for production of geothermal energy is 1.55 GWh/year. For production of 1.55 GWh electricity, 380 toe are required. Therefore, for production of 5613 toe thermal energy, 380 toe of electricity are consumed or the application of geothermal energy for heat supply is many times more efficient than equivalent conventional installations for the production of heat and electricity [6].

## 5. ECONOMIC EFFICIENCY AND PERFORMANCE

The economic efficiency and the corresponding performance of the hybrid heating plant can be described by the following indicators: capital investments, heat production costs, net present value (NPV), simple payback (SP), discounted payback (DP), internal rate of return (IRR). All calculations are made according to the procedures of UNIDO, international prices of materials and equipment [18]. All obtained financial indicators for the hybrid plant relate to the actual current economic conditions (in 2013) in North Macedonia [13]. Two scenarios with three types of boilers (from different companies) were considered.

Three construction options of the hybrid heating plant with a capacity of 12 MW were analyzed. In all cases, energy source is rice straw/corn and corn stems, generally identical boiler equipment, including pumps, mechanical equipment and water treatment equipment, machinery and fuel supply systems and ash removal. In the three variants, the required capacity of 12 MW is divided into 4 boilers, and the difference is in the boiler plant's producers. The ultimate choice for an option remains for the user/developer [13].

The capital investment includes: materials and basic equipment for the boiler house and fuel store, construction of a closed facility for the installation of the boiler plant, a supply and return pipeline for geothermal water, a pipeline construction, works for the construction of the plant/pipeline/building, annual costs for the operation of the hybrid plant and its maintenance (procurement of biomass, procurement of geothermal water, salaries, electricity, equipment maintenance and repair, depreciation charges, etc.). The determined costs of the produced heat are 225.72 €/GJ and 239.54 €/GJ. The minimum tariff for industrial consumers (2013) in North Macedonia for heating energy is 373.48 €/GJ, and the maximal 420.33 €/GJ [13] – these two tariffs are taken as reference for the analysis of economic efficiency.

The first considered scenario assumes the investor is capable of financing 100% of the investment. The following indicators were obtained:

- The obtained results for the NPV confirm the economic feasibility of the investment for the three sub–units.
- SP ranges from 9.4 to 12.9 years. It should be noted that renewable energy projects normally have a greater period for return of investment, in fact, like any other energy project.
- DP ranges between 12 and 18 years.
- IRR indicates economic efficiency for all three sub–sscenarios.
- All financial indicators for the heating plant are obtained for the current real economic conditions in Macedonia.

The second scenario (most common) recognizes that RES projects are typically implemented with state support in the form of grants for construction, subsidies, or feed–in tariffs [17]. In such cases, specific financial indicators would be improved and make the project more attractive to investors [18].

## 6. ENVIRONMENTAL IMPACT

The ecological efficiency of the RES use is determined by reducing the need for conventional fuels and reducing greenhouse gas emissions, and as a consequence – reducing the negative impact of the energy sector on the environment [19]. It is also necessary to do the same for the concrete project in order to determine its ecological and economic effectiveness [19].

$CO_2$ emissions that would be produced when operating a hybrid plant:

- From biomass – 39.5 tonnes of $CO_2$ (from indirect sources, such as transport, treatment, equipment for supplies) [20],
- From geothermal energy – 99.6 tons of $CO_2$ (from the equipment used for extraction and supply),
- Total annual – 139 tons of emitted $CO_2$ due to heat production technology [20].

$CO_2$ emissions during construction:

- From biomass – ~ 4 tons of $CO_2$ (one time during construction),
- From geothermal energy – ~ 15 tons of $CO_2$ (once in construction, in this case = 0 because the resource is already established) [20].

Avoided $CO_2$ emissions annually due to the application of the RES:

- In case natural gas is. used – 3903.9 tons [20],
- In case of heavy fuel oil – 5100.8 tons [20],
- In case of using electricity – 17689 tons [20].

## 7. CONCLUSIONS

A hybrid plant that uses geothermal water and biomass for production of thermal energy for district heating of Kocani is a reasonable and sustainable solution [13]. The required flow of thermal water with newly connected customers would be 31.44 l/s. It is obligatory to predict injection of the total used quantities for heat production in the hybrid plant [6].

The use of geothermal resources for heating energy supply to the consumers of "Geoterma" is many times more energy efficient than the use of conventional plants for heat and electricity production.

Considering the trends in the growth of world energy prices, the efficiency of this project will increase [4][17]. The general overview of the financial analysis for investment efficiency for the implementation of the hybrid heating plant is the following: the obtained data on NPV confirm the economic feasibility of capital investments for all variants; SP is from 9.4 to 12.9 years; DP is from 12 to 18 years; the IRR data obtained confirm the economic viability of investments in all variants.

Normally, projects with RES in most countries are implemented with state support in the form of grants for construction; subsidies or feed–in tariffs for the renewable energy generation. In the case of such support, the financial indices will be better and more attractive, making the project more attractive to investors [18].

The analyzed hybrid plant has great environmental value due to the contribution to the local and global reduction of carbon dioxide emissions and appropriately in climate change mitigation. Namely, depending on the comparison, annually avoided $CO_2$ emissions would be in the range of 4000 tons (if natural gas is replased), 5000 tons (if oil is replased) or 17,000 tons (if heat prodiceed by electricity is replased) [19][20]. Additionally, the use of excess agricultural biomass contributes to better handling and management of agricultural waste.

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