Analysis and Calculation of MMRS and Primary Gas Distribution Network in Urban Environment – Case Study Kučevo

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ANALIZA I PRORAČUN GMRS I PRIMARNE GASNE DISTRIBUTIVNE MREŽE U URBANOJ SREDINI – STUDIJA SLUČAJA KUČEVO

ANALYSIS AND CALCULATION OF MMRS AND PRIMARY GAS DISTRIBUTION NETWORK IN URBAN ENVIRONMENT - CASE STUDY KUČEVO

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Abstract Serbian:

Oblast primene prirodnog gasa je veoma široka. Kao energent može se koristiti za proizvodnju energije u elektranama, toplanama i postrojenjima za kombinovanu proizvodnju energije ili za zadovoljavanje različitih toplotnih potreba u industriji i širokoj potrošnji. Gas se može upotrebiti i kao sirovina u hemijskoj i petrohemijskoj industriji, a tokom poslednjih decenija nalazi primenu i u saobraćaju kao pogonsko gorivo u SUS motorima.

Sa ekološkog stanovišta, prirodni gas predstavlja najprihvatljiviji izvor energije u poređenju sa drugim fosilnim gorivima. Pri sagorevanju prirodnog gasa, zbog njegovog hemijskog sastava, emituje značajno manje ugljendioksida po jedinici proizvedene toplotne energije, nema pepela i emisije čestica, a emisija sumpordioksida je zanemarljiva.

Prirodni gas često se naziva „energentom 21. veka“ jer osim ekoloških prednosti poseduje i izražene tehničke i ekonomske pogodnosti u odnosu na druga konvencionalna goriva. Sa tehničkog i ekonomskog aspekta, prednosti korišćenja gasa su niski investicioni troškovi i cena, visok stepen iskorišćenja, pouzdanost i fleksibilnost upotrebe, lakše i bezbednije skladištenje u odnosu na druga fosilna goriva. Ovaj energent raspoloživ je tokom cele godine, a njegov kvalitet je standardizovan i garantovan.

Iako su dokazane svetske rezerve obilne, racionalno upravljanje i korišćenje prirodnog gasa je od izuzetne važnosti uzimajući u obzir činjenicu da se radi o neobnovljivom izvoru energije. Kako se radi o zapaljivoj i eksplozivnoj smeši, pažljivo rukovanje i odorizacija gasa predstavlja preduslov za bezbedan rad u svim postrojenjima koja koriste ovaj tip goriva u svojim operativnim procesima. Kao nedostatak može se i izdvojiti i doprinos gasa povećanju efekta staklene bašte.

Cilj ovog rada jeste pronalaženje optimalnog oblika trase primarne distributivne mreže gasovoda u opštini Kučevo, definisanje lokacija i položaja GMRS i MRS, usvajanje prateće opreme za GMRS, dimenzionisanje cevi zasnovanim na normativima i pravilnicima za distributivne mreže srednjeg i visokog pritiska, uz postizanje bezbednosti i sigurnosti u snabdevanju kako sadašnjih, tako i budućih potrošača.

Ključne reči: *distribucija gasa; projektovanje gasovoda; analiza potrošnje*

Abstract in English:

The field of application of natural gas is very wide. As an energy source, it can be used for energy production in power plants, heating plants and cogeneration plants or for meeting various heat needs in industry and mass consumption. Gas can also be used as a raw material in the chemical and petrochemical industries, and during the last decades it has also been used in traffic as a propellant in SUS engines.

From an environmental point of view, natural gas is the most acceptable source of energy compared to other fossil fuels. Due to its chemical composition, the combustion of natural gas emits significantly less carbon dioxide per unit of heat produced, there is no ash and no particulate emissions, and sulfur dioxide emissions are negligible.

Natural gas is often called the "fuel of the 21st century" because, in addition to environmental advantages, it also has pronounced technical and economic advantages over other conventional fuels. From a technical and economic point of view, the advantages of using gas are low investment costs and price, high degree of utilization, reliability and flexibility of use, easier and safer storage compared to other fossil fuels. This fuel is available throughout the year, and its quality is standardized and guaranteed.

Although the world's proven reserves are abundant, the rational management and use of natural gas is extremely important, given the fact that it is a non-renewable energy source. As it is a flammable and explosive mixture, careful handling and odorization of gas is a prerequisite for safe operation in all plants that use this type of fuel in their operational processes. The contribution of gas to increasing the greenhouse effect can also be singled out as a disadvantage.

The aim of this paper is to find the optimal shape of the route of the primary distribution network of gas pipelines in the municipality of Kučevo, defining locations and positions of MMRS and MRS, adoption of supporting equipment for MMRS, pipe sizing based on norms and regulations for medium and high-pressure distribution networks. in supplying both current and future consumers.

Key words: *gas distribution; gas-pipeline design; consumption analysis*

1 Introduction

The field of application of natural gas is very wide. As an energy source, it can be used for energy production in power plants, heating plants and cogeneration plants or for meeting various heat needs in industry and mass consumption. Gas can also be used as a raw material in the chemical and petrochemical industries, and during the last decades it has been used in traffic as a fuel in internal combustion engines.

From an environmental point of view, natural gas is the most acceptable source of energy compared to other fossil fuels. The reason for this is that the combustion of natural gas, due to its chemical composition, emits significantly less carbon dioxide per unit of heat produced, no ash and particulate emissions, and sulfur dioxide emissions are negligible. Coal, which is the most represented energy source in the consumption of primary energy in Serbia, has twice the emission factor of carbon dioxide in relation to natural gas for the same achieved thermal effect [1].

Natural gas is often called the "energy source of the 21st century" because, in addition to environmental advantages, it also has significant technical and economic advantages over other conventional fuels. From a technical and economic point of view, the advantages of using gas are low investment costs and price, high degree of utilization, reliability and flexibility of use, easier and safer storage compared to other fossil fuels. This fuel is available throughout the year, and its quality is standardized and guaranteed.

Although the world's proven reserves are abundant, the rational management and use of natural gas is extremely important, given the fact that it is a non-renewable energy source. As it is a flammable and explosive mixture, careful handling and odorization of gas is a prerequisite for safe operation in all plants that use this type of fuel in their operational processes. The contribution of gas to increasing the greenhouse effect can also be singled out as a disadvantage [2].

In Republic of Serbia there is a trend of gasification of small places and urban availability of natural gas. About 70% of the population of Serbia, i.e., about five million people live in areas close to the distribution network [3]. Thus, there are technical preconditions for the use of gas in most of the country, as well as the potential for further development of distribution systems and increase in natural gas consumption in households in the future. One of the goals of the paper is to point out the process of designing the gas pipeline network and to discover the stages that need to be implemented in the analysis. At the same time, the paper, by making a realistic survey, reveals the needs for gasification, but also its shortcomings. The aim of this paper is to find the optimal shape of the route of the primary distribution network of gas pipelines in the municipality of Kučevo, defining locations and positions of MMRS and MRS, pipeline dimension based on norms and regulations for medium and high-pressure distribution networks, in supplying both current and future consumers.

2 Natural gas sector in Republic Serbia

After coal and oil, natural gas is the third most used primary source of energy in the Republic of Serbia. Its share in total primary energy consumption in 2020 was 13.25% [4]. The total consumption of natural gas in 2020 amounted to 2,481 million m^3, which is 4% less than in 2019 [4]. The source of natural gas in Serbia is primarily represented by international gas pipelines from Russia, via Ukraine and Hungary, while only a small part (~ 10%) is obtained from own sources. The gas pipeline system of Serbia includes main, distribution and supply gas pipelines, main metering, and regulation stations (MMRS), metering and regulation stations (MRS), main distribution nodes (MDN), low and medium pressure distribution networks, gas receiving and transmitting stations, compressor stations and other facilities located on the pipelines themselves. Natural gas transmission system of the Republic of Serbia is a linear system with two inputs and two outputs with other natural gas pipelines systems [3]. The Republic of Serbia has four interconnections with gas pipeline systems in other countries, and these are the points of interconnection [3]:

- Hungary - Republic of Serbia (Kiskundorozhma) - entry point;
- Republic of Serbia - BiH (Zvornik) - exit point;
- Bulgaria - Republic of Serbia (near Zaječar) - entry point;
- Republic of Serbia - Hungary (under construction near Horgos) - exit point.

The first two interconnections are part of the Transprotgas Serbia transport system, the other two belong to the Gastrans transport system, while the Yugorosgaz-Transport transport system does not have gas pipelines connected to the transport systems of neighbouring countries [3]. Main technical characteristics of transmission system are presented in Table 1.

Table 1 Main technical characteristics of transmission system [3]

Main technical characteristics	*Transportgas Serbia*	*Yugorosgaz-Transport*	*Gastrans*
Capacity (mill. m^3/day)	≈ 18	≈ 2.2	34
Pressure (bar)	16–75	16–55	74
Length (km)	2414	125	402
Nominal diameters (mm)	DN 150–DN 750	DN 168–DN 530	DN 1200
Compressor station	1	-	1 (near Velika Plana)
Compressor station power (MW)	4.4	-	24
Entry in transmission system	13	1	1
1. from other transmission system	4 (Horgoš,Karadjordjevo brdo, Pančevo, Gospodjinci)	1	1 (near Zaječar)
2. from production field	9	-	-
3. from underground storage	1	-	-
Number of exits from the transport system	241	6	3
Measuring and regulating stations at the exit from the transport system	238	6	3
Handover stations	2	-	4
Exit to the Yugorosgaz-Transport system	1	-	-
Exit to the Transportgas Serbia transport sys-	-	-	3

tem			
Interconnector to BiH	1	-	-
Interconnector to Hungary	-	-	1 (near Horgoš)
Natural gas storage	1	-	-

The main weakness of the transmission system in the previous period was only one entry point on the transmission system, which allowed the import of the required quantities of natural gas. This shortcoming was taken over by the construction an interconnection pipeline from the Bulgarian-Serbian border to the Serbian-Hungarian border. During 2020, this gas pipeline was mostly completed, connected to the transport system in Bulgaria and the transport system of Transportgas in Serbia. The first quantities of gas for the Serbian market were delivered from the direction of Bulgaria through this gas pipeline at the beginning of 2021, and it becomes fully operated in October 2021 [3].

According to data from 2020, the total length of the transmission network system pipeline is 2.941 km. Operating pressure ranges from 16 bar to a maximum of 75 bar [3]. The main gas pipeline for the transport of natural gas through Hungary has a capacity of 6.1 billion m^3 per year, of which 5,340 million m^3 for the area supplied by the company "NIS", and the remaining 760 million m^3 for Bosnia and Hercegovina. The main gas pipeline transports gas that is picked up at the receiving station in Horgoš and gas from domestic gas fields. These pipelines were built with diameters from 219.07 mm to 762 mm and are designed for operating pressures of 50 bar. Gas produced on domestic gas fields is delivered to the supply gas pipelines. They are built of steel pipes with a diameter of 50.8 mm to 304.8 mm. Most of these pipelines are in the eastern part of the system. The connection between the main gas pipelines and the distribution gas networks made of steel pipes with a diameter of 50.8 mm to 508 mm is realized through the distribution gas pipelines. The distribution gas pipeline through which gas is transported to the Republic of Bosnia and Herzegovina is 406.4 mm in diameter and was built from Batajnica to Zvornik. The gas transported by this system is raised to a maximum pressure of 50 bar, which allows a pressure of at least 26 bar in Zvornik. 5 compressor units have been installed at the station, and the power of each of them is 882 kW, with a capacity of 33,000 m^3/h [3].

Thirty-one distributors are present on the territory of Serbia, delivering natural gas to end consumers. Among them, the company "Srbijagas" stands out as the largest. The length of the distribution network is 19,883 km. Currently, 278,947 households are connected to the gas distribution network, which is approximately 15% of the country's population. In addition, 149 heating plants were connected to the network, as well as 14,491 industrial consumers [3].

The underground gas storage Banatski Dvor (UGS Banatski Dvor) is positioned on the site of a former gas reservoir with a capacity of 3.3 billion cubic meters of natural gas and is very important for the safe supply of natural gas in Serbia. The total area of the warehouse is about 54 square kilometres. The working volume of the storage is 450 million cubic meters of natural gas. The nominal production of UGS is 5 million cubic meters per day, while in 2020 the maximum realized production was 4.95 million cubic meters [4].

The Banatski Dvor warehouse was put into operation in November 2011. The commissioning of the Banatski Dvor underground warehouse achieved greater reliability of natural gas supply in Serbia and alleviated the problem of uneven consumption (ratio of winter and summer consumption 4: 1) [4].

3 Case study Kučevo

The municipality of Kučevo is located in the northern part of eastern Serbia, within the Braničevo district. In its central part, it covers the Zviška valley and the Zviška mountains, through which the river Pek flows, in the south the slopes of the Homolje mountains, while in the north there is a gradual transition to the Stiška plain and the Braničevo area. The territory of the municipality covers an area of 721 km^2. It consists of 26 settlements, and the city of Kučevo is the economic, administrative and cultural center of the municipality [5]. The urban settlement is of a compact type, triangular in shape with a tendency to expand to the east, along the main road Požarevac - Majdanpek - Negotin, and south along the regional road Kučevo - Petrovac na Mlavi.

In terms of relief, Kučevo consists of a small plain part and a hilly-mountainous part that includes the forested areas of the Homolje and Zviski mountains, as well as the area of northern Kučaj. The altitude in the municipality ranges from 110 meters (Zelenik) to 920 meters (Stubej, Ceremosnja). The city itself is located at an altitude of 156 meters above sea level. The characteristic climate of these areas is temperate-continental to mountainous, with four seasons [5].

According to the census of the Republic Bureau of Statistics from 2011, the number of inhabitants in the municipality of Kučevo is 22.290, distributed in 6.360 households and 9.384 apartments. However, according to the estimates of the same body from 2018, there are 13.272 permanent residents in the municipality. The city settlement of Kučevo has 3.950 inhabitants, and including suburban settlements and persons residing abroad, the total number of inhabitants on the territory of the city is 4.823. It is expected that this number will further decrease in the next census [5].

The industry in the municipality of Kučevo can be considered only relatively developed, although one of the main characteristics of the economy in this area is the insufficient utilization of existing capacities. Currently, the only major entrepreneur in the municipality is the company "Krecana", owned by the Chinese company "HBIS Group". In addition, the factory for the production of mineral water "Duboka" in the village of Neresnica and several smaller entrepreneurs in the field of wood industry can be singled out.

The areas of forestry and agriculture represent great potential and the key to further industrial development of Kučevo. Thanks to its position, the municipality of Kučevo has over 35.000 hectares of agricultural land and 40.000 hectares of forests [5]. As there are currently no large entrepreneurs in these areas, and based on great real potentials, two new companies will be presented in the future - the company "Forestry and industrial complex - FIC" and the dairy "Kučevo"; as future industrial consumers.

3.1 Justification of gasification

Since Kučevo does not have a city heating plant, the satisfaction of heat needs is currently done from individual fireplaces in all existing facilities. The dominant energy sources, with a share of 77%, are coal and wood. In the public utility sector, coal-fired boilers of different capacities are primarily represented, depending on the size and purpose of the facility. Most households use wood as an energy source (66%), pellet heating 7%, while electricity construction is present in 11% of households.

Until recently, the company "Limekiln" used fuel oil boilers for its needs, but two of the four boilers in use have been replaced by boilers that will use natural gas in the technological process. During the autumn and winter months, a combination of coal and wood is used to heat the rooms.

From the above, it can be concluded that the use of solid fuels is by far the most common type of meeting the heat needs in Kučevo. This, along with the fact that almost all fireboxes are of an individual character, leads to a relatively high content of pollutants in the air during the winter months. Outside the heating season, the air quality index is in the good area, in the range of 51-100. During the winter months, this index is significantly higher, and the reason for that is the increased concentration of PM 10 (particles smaller than 10 microns) and PM 2.5 (particles smaller than 2.5 microns). During the summer, the concentration of PM 10 is about 2.5 $\mu g/m^3$, and the concentration of PM 2.5 is about 2 $\mu g/m^3$. These values during the heating season exceed 100 $\mu g/m^3$, which puts the air in the category of moderately polluted. The main causes of this situation are energy inefficient individual boiler rooms and the use of energy sources with high emission factors [6].

By using natural gas, i.e., substituting solid energy sources for heating needs, this problem could be largely eliminated, because natural gas is a significantly more responsible and acceptable option from the environmental aspect.

Priority zones for gasification in the city would be industrial zones within which the company "FIC" and the number of small entrepreneurs, the route to the company "Limekiln", as a consumer with the greatest needs, and then the city center as the area with the most densely populated population and the largest by the number of communal - public facilities. The mentioned consumers would have the advantage of connecting to the gas pipeline network, while the rest of the city settlement and facilities would be gradually connected [5].

The existence of a reliable and efficient gas pipeline system on the territory of Kučevo would represent a great progress in the technical and ecological sphere, and the option of using natural gas as an energy source would be suitable for both the population and industrial consumers. These facts are good reasons for gasification of the city.

4 Consumer definition

The basis of the calculation and sizing of the gas distribution network is the determination of normative needs for gas. The key factors in this process are the size and need of consumers for gas, the purpose of gas use and security in its delivery. Based on the size of gas needs, consumers are divided into three categories: industrial consumers, public utility facilities and households.

4.1 Industrial consumers

The industrial scene of the municipality of Kučevo can be considered only relatively developed. The company "Limekiln - HBIS Group" stands out as the largest and at the same time the only active consumer. Considering the potential for industrial development that the municipality has, the assessment will show two more companies as future large consumers. The first is "Forestry and industrial complex - FIC", a company that in the past performed various activities within the forestry and wood industry and is currently in bankruptcy. The second consumer would be a completely new company "Dairy Kučevo", with the aim of activating and developing the agricultural sector of the municipality.

For the purposes of the assessment, it is considered that technological processes in all industrial consumers would be performed using natural gas as a fuel. Also, it was assumed that the heating of the company's business premises would be done using the same energy source.

4.1.1 Consumption assessment for Limekiln

The company "Limekiln - HBIS Group" is the largest company in the municipality of Kučevo and is located at about three kilometers outside the city settlement, near the village of Kaona. The primary activity of the plant is the production of piece lime for the needs of the Smederevo ironworks, which is owned by the same company - the Chinese HBIS Group. The technological process was performed using four furnaces that used a combination of coal and fuel oil as fuel. However, at the beginning of 2020, the realization of the project of replacing old furnaces with new furnaces that use natural gas began. For now, two of the four furnaces have been replaced, while the other two will also be modernized in the coming period. The power of each of these furnaces is 9 MW. The projected production is 600 tons of lime in 24 hours, or 200.000 tons per year. The work in the plant takes place in 3 shifts during 320 working days, including the time spent on overhaul and mechanical maintenance of the plant. The calculation of the required amount of gas is based on the total burner power of 36 MW. The hourly gas flow is determined according to the following formula [7]:

$$Qgh = \frac{3.600 \cdot N}{\eta \cdot H_d} = \frac{3.600 \cdot 36.000}{0{,}85 \cdot 33.300} = 4.551{,}36 \tag{1}$$

Where:

Q_{gh} - gas flow [m^3/h];

N - burner power [kW];

η - coefficient of efficiency of the thermal device;

H_d - lower thermal power of natural gas [kJ/m^3].

Assuming that there are no unexpected and unplanned interruptions during the work, the daily consumption would be 109.232,64 m^3. Annual gas consumption depends on the number of working days of the plant, and the estimated number is 320 days. Possible unplanned delays due to external influences should also be considered. Therefore, it can be considered that the annual gas consumption for the needs of the technological process would amount to 34.972.571,9 m^3. Heating of business premises would also be done using natural gas. The company's facilities cover an area of 900 m^2, with a total volume of 2.700 m^3. The basis for the calculation of the required quantities of gas are the specific heating needs of the building Q_{st} [W/m^3], using the following expression [7]:

$$Qst = V \cdot q = 2.700 \cdot 58 = 156.600 \tag{2}$$

Where:

V - volume of the building [m^3];

q - specific heat demand [W/m^3].

Hourly consumption can be determined using equation 1, ie:

$$Qgh = \frac{3.600 \cdot 156.600}{0{,}85 \cdot 33.300} = 19{,}9\ \frac{m^3}{h} \tag{3}$$

Based on the Number of degrees days method, which is also used in determining the annual gas needs in the consumer sector and public utility facilities, the calculation of the annual heating gas consumption is performed [7]. Annual gas consumption is:

$$Qgg = 24 \cdot Qgh \cdot SD \cdot e \cdot \frac{Y}{(tu - ts)} = 18.120{,}6 \tag{4}$$

4.1.2 Consumption assessment for FIC

The company "FIC" used to be the largest employer and industrial producer in the municipality of Kučevo. The plant and the company's premises are located within the industrial zone, at the exit from the city in the direction of Majdanpek. As it has been in bankruptcy for many years, the resumption of industrial activities and production in this company would require investments in new equipment and modernization of the plant. From that point of view, the use of two gas furnaces, with a capacity of 1,8 MW, is planned, for the needs of technological processes. Heating the company's premises of 1.800 m^2 (volume 5.400 m^3) would also be done with natural gas. The number of working days, including the time required to perform repairs and mechanical maintenance, is 300 days. The calculation algorithm used is the same as for the previous industrial consumer and is based on equations 1, 2 and 3. Hourly gas flow for the needs of the technological process:

$$Qgh = \frac{3.600 \cdot N}{\eta \cdot H_d} = \frac{3.600 \cdot 3.600}{0{,}85 \cdot 33.300} = 455{,}14\ \frac{m^3}{h} \tag{5}$$

If the work was performed on a daily basis during two 8 hours shifts, the gas consumption per day would be 7.282,18 m^3, while the level of annual consumption would be 2.185.653,2 m^3.

For the needs of heating business premises:

$$Qst = V \cdot q = 5.400 \cdot 50 = 270.000 \frac{W}{m^3} \tag{6}$$

$$Qgh = \frac{3.600 \cdot 270.000}{0{,}85 \cdot 33.300} = 34{,}3\ \frac{m^3}{h} \tag{7}$$

$$Qgg = 24 \cdot 34{,}3 \cdot 2.600 \cdot 0{,}81 \cdot \frac{0{,}63}{(20-(-15))} = 31.242{,}5\,\frac{m^3}{god} \tag{8}$$

4.1.3 Consumption assessment for the company "Dairy Kučevo"

This company would represent a completely new consumer in the municipality of Kučevo and the only large company in the field of agriculture and livestock. The position of the company would be not far from the industrial zone in Kučevo, in the lowland area where most of the agricultural land within the city is located.

The parameters according to which this plant was designed were adopted on the model of similar companies in the region from this activity (such as the dairy in Pozarevac). The company's premises would occupy 2.100 m^2, with a volume of 6.300 m^3, while one 1,2 MW furnace would be used for the needs of technological processes. The work would take place during 290 days a year, and the daily schedule would be 16 hours. The algorithm for calculating gas consumption is identical to previous industrial consumers and based on the same patterns. Hourly gas consumption for the needs of the technological process [7]:

$$Qgh = \frac{3.600 \cdot N}{\eta \cdot H_d} = \frac{3.600 \cdot 1.200}{0{,}85 \cdot 33.300} = 151{,}7\,\frac{m^3}{h} \tag{9}$$

Based on the Qgh value, the daily gas consumption is 2.427,4 m3, while the annual consumption would be 703.943,8 m^3. Gas would also be used to heat the premises, and the consumption is [7]:

$$Qst = V \cdot q = 6.300 \cdot 50 = 315.000\,\frac{W}{m^3} \tag{10}$$

$$Qgh = \frac{3.600 \cdot 315.000}{0{,}85 \cdot 33.300} = 40{,}1\,\frac{m^3}{h} \tag{11}$$

$$Qgg = 24 \cdot 40{,}1 \cdot 2.600 \cdot 0{,}81 \cdot \frac{0{,}63}{(20-(-15))} = 36.449{,}5\,\frac{m^3}{god} \tag{12}$$

Table 2 shows the hourly and annual gas total needs of industrial consumers.

Table 2 Total consumption of industrial consumers by hour and year

Consumer	*Heat consumption*		*Technological process*		*Total (m^3)*	
	hourly	annual	hourly	annual	hourly	annual
Limekiln	19.9	18,120.6	4,551.36	34,972,571.9	4,571.26	34,990,692.5
FIC	34.3	31,242.5	455.1	2,185,653.2	489.4	2,216,895.7
Dairy	40.1	36,449.5	151.7	703,943.8	191.8	740,393.3
Total (m3)					5,252.46	37,947,981.5

4.2 Consumer sector

The category of consumer goods includes consumers from the public utility sector and households. The gas supply of these facilities ensures that the following needs of consumers in this sector are met:

- heating of residential and business premises;
- preparation of hot water consumption and cooking;
- operation of small (home) appliances;
- lighting.

Given the specifics and different possibilities of using natural gas, determining the consumption of individual consumers in this category is a very complex process. However, the largest share in consumption is the energy used to heat the premises. It can be considered that up to 70% of the energy consumed is used for this purpose.

4.2.1 Setting gas standards for the consumer sector

Consumption of natural gas by households in individual and collective housing facilities is determined as the sum of gas consumption for heating and gas consumption for cooking and preparation of hot water consumption, according to the following relation [7]:

$$Qg = Qdg + Qdk \quad \left[\frac{m^3}{h}\right] \tag{13}$$

The norm of needs in natural gas for the needs of heating the apartment is determined by the equation [7]:

$$Qg = \frac{3.600 \cdot Qst}{\eta \cdot H_d} \left[\frac{m^3}{h}\right] \tag{14}$$

The parameter Q_{st} represents the specific heat needs for heating the apartment and is expressed in W/m^3. It depends on the values of specific heat needs, which are adopted from the norms based on the design external heat and energy characteristics of the building, and the volume of the apartment being heated. Heat losses are higher in collective housing facilities than in individual buildings, and the reason for this is the poor quality of thermal insulation. Also, there is a noticeable difference in the energy efficiency of buildings built in the past thirty years compared to older buildings. For newer buildings it can be considered that the specific heat needs are reduced by 25% to 30%, i.e., that they average 35 W/m^3 for an outdoor design temperature of -15 °C, while for an outdoor temperature of -20 °C they are about 40 W/m^3. Along with these data, for the case of old buildings, these values are 50 W/m^3 and 64 W/m^3 at outdoor temperatures of -15 °C and -20 °C, respectively [7].

Considering the time of using gas for cooking and preparation of hot water consumption, as well as the factor of simultaneous consumption, the norm for cooking and hot water preparation is 0,4 m^3/h in our conditions. As a quantity of gas needed to meet these needs, a value of 400 m^3 is adopted annually, 150 m^3 for cooking and 250 m^3 for preparation of hot water consumption [7].

Annual consumption of natural gas per household is a very important starting point in assessing the economic justification of the transition to the use of gas in a particular urban area. The calculation is based on the use of Number of degrees days method. This method calculates the energy consumption for heating based on the value of the outdoor temperature, and the use of correction factors considers the effect of all other important factors. The annual gas consumption for heating an apartment can be determined using the equation [7]:

$$Qgg = 24 \cdot Qgh \cdot SD \cdot e \cdot \frac{Y}{(tu - ts)} \tag{15}$$

Where:

Q_{gg} - annual gas needs for heating, [m^3/year];

Q_{gh} - needs for heating gas per hour of the specified apartment at the given conditions of external and internal temperature, [m^3/h];
SD - number of degrees of the day
e - limitation coefficient;
Y - coefficient related to transmission losses;
t_u - temperature inside the apartment, [°C];
t_s - outside air temperature, [°C].

The number of degrees of the day (DD) is a parameter that evaluates the impact of outdoor air temperature on energy consumption for heating. Some of the assumptions of this method are that the average indoor air temperature is 19 °C, and the heating limit temperature is 12 °C. Parameters that differ from place to place are the flow of outdoor air temperature, the average temperature of the heating period and the length of the heating season. The value of DD used in this calculation is 2.600 for the city of Kučevo.

The limiting coefficient "e" is a correction factor that takes into account heating interruptions, considering that within 24 hours there is a heating interruption of about 8 hours. It consists of the coefficient of temperature "et" and exploitation "eb" limitation, i.e.,

$$e = et \cdot eb \qquad (16)$$

The first coefficient includes daily interruptions of heating, and the second coefficient takes into account cases where the internal heating conditions are not the same every day (restrictions on heating during weekends, holidays, vacations, etc.). The values of these coefficients depend on the type and purpose of the object to which they are applied. Individual values in this paper will be listed in the assessment of each of the facilities. The correction factor of simultaneity "Y" is related to transmission losses, ie conditions in which the facility is located, but also the fact that all adverse effects (high wind speed, high clouds, etc.) do not occur simultaneously, and in the calculation of heat losses are taken into account. Since Kučevo is classified as a normally windy landscape with a sheltered position, the adopted value of this parameter is 0.63 [7].

The range of external design temperature for most cities in Serbia ranges from -15 °C to -20 °C. Based on these values, the specific heat needs are defined, i.e., the heat required for heating at a unit temperature difference. For the purposes of calculations in this paper, the value of outdoor temperature of -15 °C is used, based on when the values of specific thermal needs for old buildings of 50 W/m^3 are adopted, while in the case of new buildings this value is 35 W/m^3. The adopted value of the internal design temperature of 20 °C is used based on the purpose of the facility [7].

4.2.2 Consumption calculation of public utility facilities

The needs in energy for heating and ventilation of communal and public buildings are significantly higher than the needs in residential buildings. The consumption of natural gas in public utility facilities is determined based on the norms of gas consumption in them. In conditions when there is not enough data on their structure, size, and number, as is the case with the concept of development of new settlements and rough consideration of the needs of settlements for the needs of assessing the justification of gas, the required amount of gas is determined by standards that define that the size of annual consumption of the commercial sector is 15% of household gas needs [7].

Kučevo has twelve buildings of this category. According to the fact that the characteristics and purposes of these facilities are significantly different, a separate calculation of gas consumption was performed for each of them. The calculation for the Elementary school "Ugrin Brankovic" is shown in this paper, while other results are in Table 3.

The primary school consists of the main school building which covers about 3.000 m^2 and the city sports hall which occupies about 1.900 m^2. This space is heated by three pellet boilers, whose power is 215 kW. The average height of the room is 3 m, which means that the total volume of the heating space would be 14.700 m^3. The calculation of the value of the required gas are:

$$Qs = V \cdot q = 14.700 \cdot 50 = 735.000 \frac{W}{m^3} \quad (17)$$

$$Qgh = \frac{3.600 \cdot 735.000}{0,85 \cdot 33.300} = 93,48 \frac{m^3}{h} \quad (18)$$

Classes at the school take place during one shift, while the sports hall is active until the evening hours for private use. Therefore, the adopted value of the limitation coefficient is 0,6375, and the annual gas needs are:

$$Qgg = 24 \cdot 93,48 \cdot 2.600 \cdot 0,6375 \cdot \frac{0,63}{40} = 66.936,65 \frac{m^3}{year} \quad (19)$$

The remaining objects were similarly analyzed. Table 3 shows the hourly and annual values of gas needs of public utility facilities, as well as the total (maximum) needs of these facilities.

Table 3 Total consumption of public utility facilities

Consumer	*Hourly consumption*	*Annual consumption*
	[m^3/h]	[m^3/year]
Primary school	93.482	66,936.649
High School	62.747	42,286.605
Hotel "Rudnik"	62.671	66,872.364
Nursing home	47.695	53,570.747
Municipality	11.129	10,124.871
Cultural Center	33.068	30,085.332
Local community	12.401	11,281.999
Community Health center	46.741	52,499.332
Police station	8.585	7,810.615
The court	7.154	6,508.846
Kindergarten "Lane"	15.453	9,763.269
Bus Station	9.539	8,196.324
In total	410.665	365,936.953

The values in the attached table represent the maximum gas needs of the public utility sector, ie the quantities of gas that would be needed in the event that all consumers use gas at the same time. Since this case rarely happens in practice, the calculated values are reduced by 20%, i.e., a coefficient of simultaneous consumption of 0,8 is applied. By applying this correction factor, the hourly consumption of 328,53 m^3/h was obtained, while the annual consumption is 292.749,56 m^3/year.

Comparing the calculated quantities of gas consumption in facilities in this category with the consumption of gas in households, it is obtained that the consumption of public utility facilities is 13,81% of the total needs of households. This value is in line with the expected normative consumption, and the results can be considered satisfactory.

4.3 Household natural gas consumption

According to the collected data, there are slightly less than 1.750 households in the city settlement of Kučevo, all with individual fireboxes. The total area of residential buildings is 145.250 m^2 [5]. As a significantly higher percentage of households are family houses, the average number of square meters per household is 83 m^2. It was also adopted that the average height of the room is 2,5

m. Therefore, the volume that needs to be heated is 207,5 m^3 per apartment, ie the total heating volume is 363.125 m^3. Also, it should be considered that 1.305 existing buildings are classified as old buildings, while the other 445 belong to the category of new buildings. Using the algorithm and equations listed in the previous chapter, the calculation of hourly gas consumption is performed for old and new buildings, respectively [7]:

$$Vst = 83 \cdot 2{,}5 = 207{,}5\ m^3 \tag{20}$$

$$Qstold = 207{,}5 \cdot 50 = 10.375 \frac{W}{unit} \tag{21}$$

$$Qghold = \frac{3.600 \cdot 10.375}{0{,}85 \cdot 33.300} = 1{,}32 \frac{m^3}{h} \tag{22}$$

$$Qstnew = 207{,}5 \cdot 35 = 7.262{,}5 \tag{23}$$

$$Qghnew = \frac{3.600 \cdot 7.262{,}5}{0{,}85 \cdot 33.300} = 0{,}92 \frac{m^3}{h} \tag{24}$$

0.4 m^3/h of gas intended for cooking and preparation of hot water is added to the calculated values of gas consumption for heating purposes [7]. The obtained total hourly consumption is 1,72 m^3/h for old buildings, while in new construction this value is 1,32 m^3/h. The calculation of the annual gas consumption is performed using the degree day method, and the calculated values for old and new buildings, are, respectively [7]:

$$Qggold = 24 \cdot 1{,}72 \cdot 2.600 \cdot 0{,}95 \cdot \frac{0{,}63}{40} = 1.408{,}02 \frac{m^3}{year} \tag{25}$$

$$Qggnew = 24 \cdot 1{,}32 \cdot 2.600 \cdot 0{,}95 \cdot \frac{0{,}63}{40} = 985{,}61 \frac{m^3}{year} \tag{26}$$

Another 400 m^3/year is added to the obtained values for the needs of cooking and hot water [7]. The total annual consumption at the annual level for the building in the old building is 1.808,02 m^3/year, and 1.385,61 m^3/year for the new building. Table 4 shows the total gas consumption in households on an hourly and annual basis. However, these values represent the maximum gas needs of these consumers, which means that all consumers would use gas at the same time. As this is not the case in practice, the calculated values are reduced by 20%. By reducing the calculated quantities of gas to real values, it is done by applying a correction factor for the simultaneity of consumption, and thus reduces the investment costs of the pipeline.

Table 4 Total consumption of natural gas in households

Households	*Hourly consumption [m^3/h]*	*Annual consumption [m^3/year]*
Old building	2,244.02	2,359.463
New construction	589.04	616.598
Maximum needs	2,833.06	2,976.061
Simultaneity coefficient = 0.8		
Total	2,266.448	2,380,848.8

The total hourly and annual natural gas needs for all three sectors are shown in Table 5.

Table 5 Hourly and annual needs in the natural gas consumption sector

Sector	*Total consumption*	
	Hourly [m³/h]	Annual [m³/year]
Households	2,266.45	2,380,848.80
Consumers	328.53	292,749.56
Industry	5,252.53	37,928,860.91
Σ	7,847.51	40,602,459.27

5 Conceptual solution of the MMRS and distribution network

The main metering and regulation station (MMRS) is the basic element of the gas pipeline system which supplies individual distribution areas or larger consumers. They reduce the pressure, from the working pressure in the main or distribution gas pipeline (30 - 112 bar) to the distribution pressure (1 - 12 bar), and in addition, flow measurement and regulation, purification and heating of natural gas can be performed [4,7].

5.1 Dimensioning of MMRS

The basic characteristics of the main measuring and regulating station (MMRS) are:

- Inlet gas pressure: 16 - 50 bar;
- Exhaust gas pressure: 16 - 8 bar;
- Maximum gas flow: 7,847.51 m^3/h;
- Minimum gas flow: 5,746.96 m^3/h.

The minimum amount of gas flow is gas consumption during the summer months, when gas is not used for heating but only for hot water preparation and cooking. Using the norm of 0.4 m^3/h for the needs of cooking and preparation of hot water and the fact that there are 1,750 households in Kučevo, the hourly amount of gas for these needs is 560 m^3/h, including the coefficient of simultaneous consumption of 0.8 [7]. A consumption value of 2 m^3/h was adopted for all facilities in the public utility sector. Also, when the quantities of gas needed to perform technological processes in industrial consumers are added to these figures, the total amount of 5,746.96 m^3/h is added.

In this paper, the calculation of the minimum inner diameter of the pipes for GMRS, the adoption of pipes according to the API 5L standard and the check of the wall thickness of the adopted pipes will be performed. For the purposes of the calculation, it is considered that standard conditions prevail in the MMRS, and the obtained values correspond to the flow under standard conditions.

The following equations are used in the MMRS for dimensioning pipes at the entrance and at the exit, respectively [4,7].

- MMRS inlet pipe:

$$Q = Qmax \cdot \frac{Pb}{Pb + Pmin} \cdot \frac{273 + t}{273} = 7848{,}51 \cdot \frac{1{,}01325}{1{,}01325 + 16} \cdot \frac{273 + 15}{273} = 493.11 m^3/h \quad (27)$$

$$Duin = \sqrt{\frac{354 \cdot Q}{Wdoz}} = \sqrt{\frac{354 \cdot 493{,}11}{20}} = 93{,}42\ mm \quad (28)$$

Where:

Q - gas flow at operating conditions [m^3/h];

Pb - barometric pressure [bar];

Pmin - minimum pressure at the MMRS inlet [bar];
t - gas temperature [°C];
Du - inner diameter of the pipe [mm];
Wdoz - permissible flow rate [m/s].

Based on the minimum required diameter, a steel seamless pipe measuring 114.3 x 4.4 mm is adopted at the entrance to the MMRS. The maximum gas flow rate at the MMRS inlet is:

$$Wmax = \frac{354 \cdot Q}{du^2} = \frac{354 \cdot 493{,}11}{105{,}5^2} = 15{,}68 \frac{m}{s} < 20 \frac{m}{s} \quad (29)$$

Checking the pipe wall thickness is based on defining the nominal thickness:

$$tn = tr + C1 + C2 \quad (30)$$

Wherein:
• t_r - calculated pipe wall thickness;
• C_1 - allowance to compensate for tolerances of wall thickness due to transport;
• C_2 - additive for corrosion or wear (approx. 1 mm).

$$tr = \frac{P \cdot D \cdot S}{2 \cdot K \cdot T \cdot V} = \frac{51{,}01325 \cdot 0{,}1143 \cdot 2}{2 \cdot 2.400 \cdot 1 \cdot 1} = 0{,}002429\ m = 2{,}429\ mm \quad (31)$$

Wherein:
• P - maximum absolute pressure [bar];
• D - outer diameter of the pipe [m];
• S - safety factor (adopted 2);
• K - maximum yield strength (for steel 1212 K is 2,400 bar);
• T - temperature factor (for t <120 °C T = 1);
• V - longitudinal weld factor (mandatory 1).
The tolerance is:

$$C1 = (tr + C2) \cdot \frac{C1}{100 - C1} = (2{,}429 + 1) \cdot \frac{10}{100 - 10} = 0{,}381\ mm \quad (32)$$

Additive for corrosion or wear: $C_2 = 1$ mm.

$$tn = 2{,}429 + 0{,}381 + 1 = 3{,}81\ mm \quad (33)$$

Based on the obtained results, it can be concluded that the wall thickness of the adopted pipe at the entrance to the MMRS meets the required criteria.

- MMRS outlet pipe:

$$Q = 7.848{,}51 \cdot \frac{1{,}01325}{1{,}01325 + 8} \cdot \frac{273 + 15}{273} = 930{,}79\ m^3/h \quad (34)$$

$$Du = \sqrt{\frac{354 \cdot 930{,}79}{20}} = 128{,}35\ mm \quad (35)$$

Based on the minimum required diameter, a steel seamless pipe measuring 168.3 x 4.4 mm is adopted at the exit from the MMRS. The maximum gas flow rate at the MMRS outlet is:

$$Wmax = \frac{354 \cdot Q}{du^2} = \frac{354 \cdot 930{,}79}{159{,}5^2} = 12{,}95 \frac{m}{s} < 20 \frac{m}{s} \quad (36)$$

Checking the pipe wall thickness is based on defining the nominal thickness:

$$tr = \frac{17{,}01325 \cdot 0{,}1683 \cdot 2}{2 \cdot 2.400 \cdot 1 \cdot 1} = 0{,}001193\ m = 1{,}193\ mm \tag{37}$$

$$C1 = (1{,}193 + 1) \cdot \frac{10}{100 - 10} = 0{,}245\ mm \tag{38}$$

Additive for corrosion or wear: C_2 = 1 mm.

$$tn = 1{,}193 + 0{,}245 + 1 = 2{,}438\ mm \tag{39}$$

Based on the obtained results, it can be concluded that the wall thickness of the adopted pipe at the exit from the MMRS meets the required criteria. Depending on the amount of gas flow, inlet pressure gauge and nominal diameter, a catalog selection of accompanying equipment for equipment MMRS has been done.

5.2 Distribution network

The conceptual solution of the distribution network implies the conception of the network of primary and secondary gas pipelines in the entire area or part of the area of one urban unit. The primary gas pipeline network connects the sources of supply with the areas in which the consumers are located, ie the connection of the GMRS with all metering and regulation stations is realized. The secondary distribution network serves to deliver (distribute) gas to consumers within one area. Depending on the operating pressure in them, distribution pipelines are divided into low (0.1 bar), medium (3-4 bar) and high (6-12 bar) pressure pipelines. Low pressure gas pipelines are used to supply households and smaller communal facilities, ie as service gas pipelines - for consumers' internal installations. Medium and high-pressure gas pipelines are used to supply the medium and low-pressure distribution network through metering and control stations. They supply industrial and communal consumers. The conceptual solution of the primary distribution gas pipeline network is based on the gas needs of households, commercial and industrial consumers, while the solution of the secondary gas distribution network solution (networks with operating pressure up to 4 bar) is based on gas needs of households and commercial consumers. Gas needs, which are used in the sizing of secondary gas pipelines, are defined because of data on existing housing and other facilities, data from the general urban plan such as number of dwellings, population, population density, usable area, number of public utility users, number, and purpose of small business facilities, etc. Also, when designing the capacity of the gas pipeline, the expected (planned) needs in the next period of 15 to 20 years must be discuss. Having in mind the dynamics of the development of the urban environment in which the gas network is constructed, defining additional capacities for future consumers is extremely important, especially because of the additional costs that can potentially arise due to the inability of the distribution network to satisfy all consumers. As the construction of primary gas pipelines is the first step in the construction of the entire network, it is often justifiably oversized so that after the completion of later stages of network construction, all the necessary needs of gas consumers can be met. Sizing of the primary network of gas pipelines, operating pressure 6 - 12 bar, is performed based on data on the needs of industrial consumers, household needs and the needs of commercial consumers in the current and future period of 15 to 20 years.

The selection of the route of distribution gas pipelines is done in the process of designing the city's gas supply system and defining the type of gas pipeline network. When choosing the route of primary gas pipelines, one should strive for:

- that the primary gas pipelines pass through the middle of the consumption area, a route should be chosen that will enable the delivery of gas to individual consumers with gas pipelines of the smallest diameter and with the shortest possible length;
- that the routes be chosen so that the gas pipelines satisfy both existing and future consumers whose development is expected in the coming period;

• that the dynamics of gas pipeline construction can take place in stages, i.e., that gasification of individual consumer zones can take place in phases;

• to ensure the greatest possible security of gas supply.

Measuring and regulating stations are an integral part of the primary gas pipeline system. They are located near or in the consumer's circle. They reduce the pressure in the primary gas network to the value needed in the gas network of consumers and supply the gas network to supply households. The number and location of metering and regulation stations are especially considered when designing the secondary gas pipeline system [4,7].

The ring type was chosen as the shape of the primary gas pipeline for the purposes of this paper. The conceptual design of the ring-type gas pipeline has proven to be the safest option for a safe and guaranteed supply of gas to consumers. The difference in length between this and the variant of the branched type was 1.73 kilometers, but the higher investment costs can be justified by the previously mentioned benefits that this type of system provides.

5.3 MRS position and primary pipeline route selection

Consumers in the urban settlement of Kučevo are divided into three zones, in such a way that in each of them there is approximately the same number of consumers and that the levels of consumption are uniform. Each of the three units would be covered by one MRS, whose task would be to deliver gas to all individual consumers in those zones. Industrial consumers would be supplied with gas directly through the primary gas network. The number of consumers per zone and their hourly consumption are attached in Table 6.

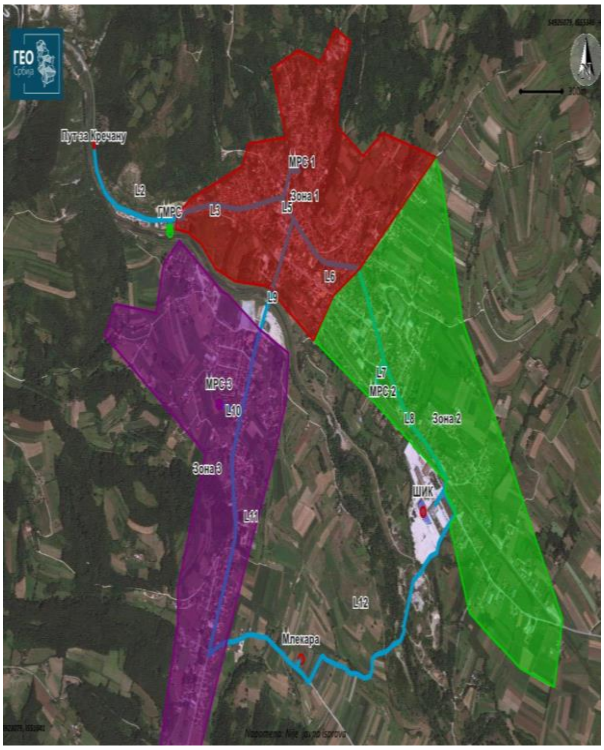
Caption 1 shows a map of marked coverage zones of metering and control stations and locations of industrial consumers. The primary distribution network of Kučevo consists of gas pipelines that connect GMRS with industrial consumers (Limekiln, FIC and dairy "Kučevo") and three MRSs that cover the zones shown on the map. The total length of the pipeline is 10.995 meters. There are several causes that lead to a large length of the primary network.

Table 6 Consumption zones according to MRS

Supplier	*Number of consumers*	*Hourly consumption*
		[m^3/h]
Zone 1 - MRS Center	606	900.00
Zone 2 - MRS Peck	604	900.00
Zone 3 - MRS Colony	552	794.98
Limestone	1	4,571.28
FIC	1	489.48
Dairy	1	191.78
Total	1,765	7,847.51

First, as the company "Limekiln" is located outside the city settlement, its direct connection with GMRS requires a section 3,3 km long. The geographical location of the plant also makes it impossible to connect to the network at two ends, but as the company has already decided to solve the problem of security of supply by purchasing large gas storage facilities, this shortcoming has not been further analyzed. This part of the gas pipeline is designed so that it can always withstand the required amount of 4.571,28 m^3/h, but also more in case of increasing consumer needs.

The second reason is the specific triangular shape of the settlement, as well as the great disunity of the population and the settlements in which they are located, which is the result of geographical features and poor spatial planning in the city.



Caption 1 Coverage zone of measuring and regulating stations [8]

In direct connection with the MMRS is the MRS - Center, which covers the first zone, or city center. This zone has the largest number of public utility facilities, and it is the most densely populated part of the settlement. The distance between the two facilities is a little more than 1 km, and this section can also be considered crucial, considering that gas is delivered to all other consumers through it. This route stretches along St. Sava Street. The branching of the gas pipeline takes place at the intersection of Sveti Sava Street and Slobodana Jovića Street, where one branch continues along the main street towards the industrial zone and MRS - Pek, i.e., the exit from the city in the direction of the road to Majdanpek. The route transports 1,013.26 m3 / h and is 1,914 meters long. The second branch is 2,845 meters long and is intended for the supply of gas to MRS - Colony and dairy "Kučevo". The formation of the ring structure of the distribution network and the connection of the two branches of the gas pipeline is achieved by a section of 1,730 meters long, which would extend from the company "Dairy Kučevo" to the industrial zone, i.e., the company "FIC". The irregular shape of the section is caused by the winding structure of the road that this route follows, and its reconstruction or correction would reduce the length of the section and improve the appearance of the pipeline route. The names of the gas pipeline section their lengths and the amount of hourly gas flow are shown in Table 7.

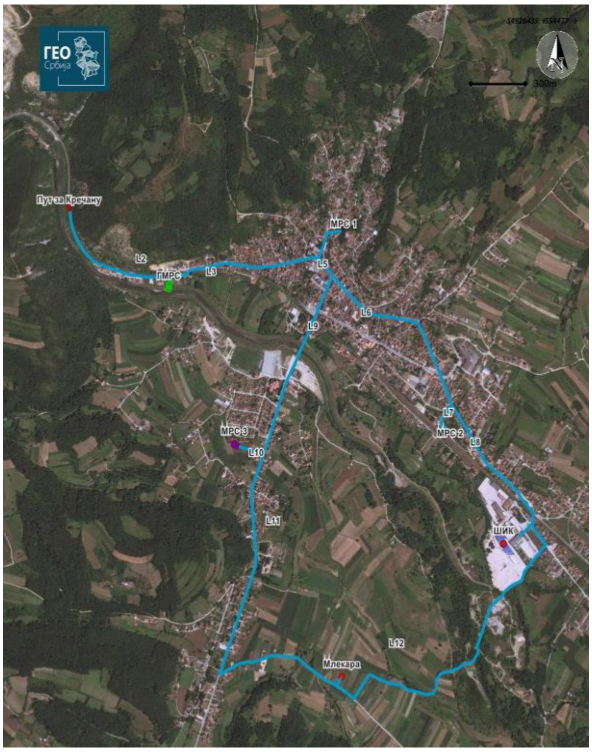
Table 7 Primary gas pipeline route with basic characteristics

Section	*Consumer*	*Section length*	*Flow*	
			By consumer	*Total*
		km	m^3/h	m^3/h
L1		0.022		7,847.510
L2	Limekiln	3.3	4,571.278	4,571.278
L3		0,825		3,276.232
L4	MRS Center	0,247	900,000	900.000
L5		0.112		2,376.232
L6		0.956		1,381.100

L7	MRS PEK	0.151	900.000	900.000
L8	FIC	0.807	507.600	481.100
L9		0.906		995.132
L10	MRS Colony	0.139	794.980	794.980
L11	Dairy	1.8	191.776	218.276
L12		1.73	934.100	934.100
		10.995		

It should be noted that section L12 represents the backup section of the pipeline. To ensure the optimal pressure, drop at the node points, it is planned to always deliver 26,5 m^3 of gas to the company Limekiln through section L12. The section itself is designed so that with this flow, it can transfer the amount of gas needed to cover the needs of companies from the second branch of the primary network and part of the gas needs of the zone where the MRS is located from the other branch. The reason for this sizing of the section is to ensure security of supply and reserves in the event of a breakdown in one of the operational sections of the pipeline

The conceptual design of the route of the primary gas pipeline network is presented in Caption 2.



Caption 2 Conceptual design of the route of the primary gas network [8]

5.4 Dimensioning the distribution gas pipeline

Based on the calculated needs in the natural gas of consumers and the planned route of the primary gas network, the sizing of the gas pipeline is performed. The two basic requirements that must be met during this procedure are:

1) in order to reduce construction costs to a minimum, we should strive for the most favorable structure of the pipeline diameter;

2) the required amount of gas must be delivered to each consumer with a satisfactory level of pressure.

The input data for the sizing process are:

- gas flow [m^3/h];
- relative density;
- length of gas pipeline sections [km];
- initial pressure in the pipeline [bar].

The inner diameter of the pipe is determined using the allowable gas speed (adopted value of 15 m/s) and flow. After obtaining the calculated value of the diameter, the choice of standardized diameter based on the data from the API - 5L standard is approached. Standard, the calculated and adopted values of diameter are given in Table 8.

Table 8 Calculated and adopted (standard) diameters of the gas pipeline section

Section	*Consumer*	*Diameter (estimate)*	*Diameter (standard)*			*Speed*
		Inner diameter	Outer diameter	t	Inner diameter	
		m	mm	mm	mm	m/s
MMRS	-	-				-
L1	-	0.4303	457.0	7.9	441.2	15
L2	Limekiln	0.3284	355.6	7.9	339.8	15
L3	-	0.2780	355.6	7.9	339.8	15
L4	MRS Center	0.1457	168.3	4.4	159.5	15
L5	-	0.2368	273.1	5.6	261.9	15
L6	-	0.1803	273.1	5.6	261.9	15
L7	MRS Pek	0.1457	168.3	4.4	159.5	15
L8	FIC	0.1061	114.3	4.4	105.5	15
L9	-	0.1535	168.3	4.4	159.5	15
L10	MRS Colony	0.1369	168.3	4.4	159.5	15
L11	Dairy	0.0723	114.3	4.4	105.5	15
L12	-	0.1487	168.3	4.4	159.5	15

To be able to deliver gas to all consumers, a satisfactory pressure drop should be achieved in the relevant sections. In case the calculated pressure drop does not meet the set conditions, the procedure is repeated with the first higher value of the pipe diameter. There are many equations that can be used to calculate the pressure drop in pipelines, and the following have been applied in this paper: Basic equation and Renouard equation, respectively [7]:

$$P_1{}^2 - P_2{}^2 = 1{,}7108 \cdot 10^6 \cdot \frac{z \cdot \lambda \cdot \rho r \cdot Q^2 \cdot L}{du^5} \; [bar^2] \tag{40}$$

$$P1^2 - P2^2 = 46.742 \cdot \frac{\rho_r \cdot Q^{1.82} \cdot L}{du^{4.82}} [bar^2] \tag{41}$$

For the purposes of this calculation, the values of the Reynolds number and the coefficient of friction in the pipeline were calculated using the following expressions [7]:

$$Re = 1{,}2326 \cdot 10^{-3} \cdot \frac{Q \cdot \rho_r \cdot Ps}{du \cdot \mu \cdot Ts} \tag{42}$$

$$\lambda = \frac{0{,}3164}{Re^{0.25}} \tag{43}$$

The used formulas and parameters will be shown below, and the results in the table of pressure drop calculations according to the Basic formula (Table 9). Section L12 represents the node point of the gas pipeline and will therefore be highlighted in the following tables. The inlet and outlet pressures of this section (outlet pressures of sections L8 and L11) must be approximately equal to successfully meet the condition for the formation of the annular structure of the network. The values of this parameter will be marked in red in the appropriate sections.

Table 9 Calculation of pressure drop by the Basic equation

Section	*Pressure (Basic equation)*				*λ*	*Re*
	P1	$P1^2$-$P2^2$	P2	ΔP		
	bar	bar^2	bar	Bar		
MMRS	8	-	-	-	-	-
L1	8.00000	0.00097	7.99994	0.00006	0.0127	385,219
L2	7.99994	0.19493	7.98775	0.01219	0.013619	291,357.1
L3	7.98775	0.02721	7.98604	0.00170	0.014801	208,815.4
L4	7.98604	0.03084	7.98411	0.00193	0.016922	122,206.2
L5	7.98411	0.00725	7.98366	0.00045	0.015028	196,500.9
L6	7.98366	0.02384	7.98216	0.00149	0.017222	113,919.7
L7	7.98216	0.01885	7.98098	0.00118	0.016922	122,206.2
L8	7.98098	0.23681	7.96613	0.01485	0.017881	98,044.48
L9	7.98366	0.13570	7.97515	0.00850	0.016488	135,598.9
L10	7.97515	0.01397	7.97428	0.00088	0.017456	107,946.1
L11	7.97428	0.13797	7.96562	0.00866	0.02166	45,527.44
L12	7.96562	0.23205	7.95104	0.01458	0.01675	127,311.7

The results of the calculation according to the Renouard equation are shown in the Table 10.

Table 10 Calculation of pressure drop by the Renouard equation

Section	*Pressure (Renouard equation)*			
	P1	$P1^2$-$P2^2$	P2	ΔP
	bar	bar^2	bar	bar
MMRS	8	-	-	-
L1	8.00000	0.00121	7.99992	0.00008
L2	7.99992	0.23971	7.98493	0.01500
L3	7.98493	0.03268	7.98288	0.00205
L4	7.98288	0.03569	7.98065	0.00224
L5	7.98065	0.00868	7.98010	0.00054
L6	7.98010	0.02746	7.97838	0.00172
L7	7.97838	0.02182	7.97701	0.00137
L8	7.97701	0.26983	7.96008	0.01693

L9	7.98010	0.15818	7.97019	0.00992
L10	7.97019	0.01602	7.96918	0.00101
L11	7.96918	0.14899	7.95993	0.00935
L12	7.95983	0.26928	7.94289	0.01693

To determine whether the adopted value of the pipe wall thickness is appropriate, it is necessary to calculate the minimum value of the thickness that will withstand the anticipated effort. As pipes are made of steel according to API-5L standard, the following form is used [7]:

$$t = \frac{P \cdot D \cdot S}{20 \cdot f \cdot V \cdot T} + C\ [mm] \qquad (44)$$

The parameters used are:

- P - operating pressure in the pipeline [bar];
- D - outer diameter of the pipeline [mm];
- S - safety factor (adopted 2.5);
- F - elastic limit (241 MPa for Grade A and Grade B according to API - 5L);
- B - weld factor (1 for seamless pipes);
- T - temperature factor (T = 1 for temperatures less than 120 °C);
- C - corrosion additive (adopted 2mm).

The calculation results are shown in Table 11.

Table 11 Calculated and standard values of wall thickness and pipeline diameter

Section	*Consumer*	*Diameter (estimate)*			*Diameter (standard)*		
		outer	t	inner	outer	t	inner
		m	mm	m	mm	mm	mm
MMRS	-	-	-	-			
L1		0.4381	3.8963	0.4303	457.0	7.9	441.2
L2	Limekiln	0.3353	3.4755	0.3284	355.6	7.9	339.8
L3		0.2850	3.4733	0.2780	355.6	7.9	339.8
L4	MRS Center	0.1511	2.6971	0.1457	168.3	4.4	159.5
L5		0.2430	3.1309	0.2368	273.1	5.6	261.9
L6		0.1865	3.1309	0.1803	273.1	5.6	261.9
L7	MRS Pek	0.1511	2.6968	0.1457	168.3	4.4	159.5
L8	FIC	0.1111	2.4731	0.1061	114.3	4.4	105.5
L9		0.1589	2.6969	0.1535	168.3	4.4	159.5
L10	MRS Colony	0.1423	2.6962	0.1369	168.3	4.4	159.5
L11	Dairy	0.0773	2.4727	0.0723	114.3	4.4	105.5
L12		0.1541	2.6953	0.1487	168.3	4.4	159.5

The last parameter that should be checked in this procedure is the speed at which the gas flows, depending on the adopted value of the pipe diameter and the gas flow through it. As the design speed was 15 m / s, it is considered that any speed above this is not appropriate and could affect the stability of the installation. A speed of less than 5 m/s would also be considered inappropriate, as such a slow gas flow could cause unforeseen problems. The calculated values are shown in Table 12. The speed is checked by the following expression [7]:

$$v = \frac{4 \cdot Q}{\pi \cdot Du^2} \left[\frac{m}{s}\right] \tag{45}$$

Table 12 Gas flow rate by sections

Section	*Flow*	*Diameter (standard)*	*V*
		inner	
	m^3/h	mm	m/s
L1	7,847.510	441.2	14.26556
L2	4,571.278	339.8	14.00937
L3	3,276.232	339.8	10.04051
L4	900.000	159.5	12.51840
L5	2,376.232	261.9	12.25874
L6	1,377.600	261.9	7.10690
L7	900.000	159.5	12.51840
L8	477.600	105.5	15.18404
L9	998.632	159.5	13.89031
L10	794.980	159.5	11.05765
L11	221.776	105.5	7.05078
L12	937.600	159.5	13.04140

Based on the results shown in the tables of the distribution pipeline sizing procedure, it can be concluded that the designed pipeline route and adopted diameters meet all requirements regarding final distribution pressure and gas velocity through the system, since none of the sections exceeded the values defined as inappropriate. The annular structure of the gas pipeline was also successfully performed, considering that the appropriate values of pressure drop at the node points were achieved.

To perform the presented conceptual pressing of the gas pipeline network, it would be necessary to procure the following pipes: 2,600 m pipes with a diameter of 114.3 mm, 3,173 m with a diameter of 168.3 mm, 1,068 m with a diameter of 273.1 mm, 4,125 m with a diameter of 355.6 mm and 22 m with a diameter 455.7 mm. There is still place for corrections of savings, but in such a situation, the impact of these changes on key parameters must be monitored.

6 Conclusion

This paper presents the conceptual solution for the gasification of the city of Kučevo. Determining the optimal route of the primary gas network and dimensioning it was done with the aim of minimizing investment costs and investments. Hourly and annual gas needs of all existing consumers have been defined, and potential future consumers are also foreseen. The positions and capacities of MMRS and MRS were determined, with the accompanying equipment adopted. In this process, all requirements regarding security of supply and security were monitored and complied with.

The realization of the gasification project requires large financial resources, and in the case of Kučevo it would be justified only if there would be further development of the industrial sector and the emergence of new plants as planned, or if most of the consumer sector would be connected to the gas network. The relief in this process is that the company "Limekiln" has expressed its intention to use only natural gas as an energy source for its needs soon, and the process of procuring the necessary equipment has already begun.

A survey was conducted on the territory of the city for the purposes of this paper. The aim of the survey is to gain insight into the attitudes and commitment of the public to the gasification of the city. In a sample of one hundred and fifty respondents, ninety-two said they would use the natural gas heating system, when it was available to them. As this represents 57% of the sample, it is possible to establish the existence of certain difficulties related to the gasification process. As potential obstacles or reasons why, they would not use natural gas, the respondents point out the high price of connection to the gas network (40%) and the costs related to the purchase of heaters, boilers, and furnaces (38%). Also, 11% of respondents said they would not use natural gas because they have their own energy sources, primarily wood. Twenty-two expressed concerns for the safety and security of the installation as a potential obstacle to the introduction of natural gas heating. As a conclusion of the examination, one can get the impression that the financial aspect is the main reason for the relatively low public interest in gas heating, and it would be necessary to find an adequate solution to overcome this obstacle.

The advantages of performing gasification on the territory of the city are reflected in the existence of a reliable heating system and the reduction of air pollution. Reducing the emission of harmful particles would be achieved by more rational use and reduction of the amount of consumed solid energy sources, as well as a gradual decline in the number of individual combustion plants.

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