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Analysis of the current state of the CZT system in Partizánske and the basis for its reconstruction to a modern carbon-free system 4th generation

The thesis serves as a summary of findings and recommendations for the future.

Source.

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1 Context and background of the project

District heating (DH) systems play a key role in future SMART cities as they represent the most efficient and environmentally friendly way of producing and distributing heat. In Partizánske, the current district heating system is ready for reconstruction in order to achieve decarbonisation and meet the requirements of European energy policies.

Current state of the CZT system in Partizánske

Technical Services of the City of Partizánske (TSM Partizánske), a limited liability company owned by the city, currently operates:

- *CTZ Šípok boiler house:* biomass boiler house for wood chips, located in the northern part of the Šípok housing estate. It has two boilers installed with a total rated thermal output of 9 MW. These boilers have been in operation for approximately 14 years and, with adequate maintenance, can serve for another 10 to 15 years.
- *20 gas boiler houses*: these boiler houses are located in the areas of Luhy, Centrum - Batovany, Štrkovec, Veľké Bielice and Malé Kršteňany. They use natural gas as fuel and the total installed capacity of these boiler plants is approximately 30 MW.
- *Heat distribution: a* heat distribution network with a total length of almost 30 km, which supplies heat to the points of consumption. The pipelines are a combination of two-pipe and four-pipe systems, and their age and technical condition varies from area to area.

Need for reconstruction

Many gas boilers have exceeded their life expectancy. Some have been in operation for more than 25 years, leading to reduced energy efficiency and increased maintenance and spare parts costs.

The installed thermal capacities of some boiler plants are significantly oversized, in some cases by as much as 40%. This is a consequence of the reduction in heat extraction due to better thermal insulation of buildings and rising average outdoor temperatures. This overcapacity leads to inefficient operation and increases the unit cost of heat production.

The heat distribution systems are in various states of repair. In the Šípok housing estate, they were reconstructed in 2011 and consist of pre-insulated double-pipe pipelines leading to the transfer stations in the buildings. In other areas, the pipes are of different age and material, often with partial reconstructions, which complicates their management and increases heat losses.

2 Objectives of the project

The main objective of the reconstruction is the transition to a modern, carbon-free, low-temperature CZT system

4th generation, which will:

- *Decarbonised:* will reduce CO_2 and other greenhouse gas emissions in line with European emission reduction targets.
- *Efficient and intelligent*: it implements technologies to efficiently link and balance heat production and consumption, including energy storage options.
- *Integrated*: uses different forms of energy generated in the city, including renewable sources such as biomass, geothermal energy, solar energy and waste heat.
- *Sustainable*: minimizes waste of energy resources and maximizes energy efficiency.

Compliance with European energy policies:

The project must be in line with the latest European energy policy proposals, which emphasise:

- *Increasing the share of renewables*: the aim is to achieve a higher share of RES in the energy mix, which will contribute to reducing emissions and increasing energy security.
- *Energy efficiency*: the implementation of modern technologies and optimisation of systems will contribute to reducing energy consumption and costs.
- *Decarbonisation*: switching to carbon-free heat sources is key to achieving carbon neutrality by 2050, as set out in the European Green Deal.

Importance for the town of Partizánske

The reconstruction of the CZT system will bring to the city:

- *Increase energy efficiency*: upgrading boiler and distribution systems will reduce heat losses and increase system efficiency.
- *Reduced operating costs*: more efficient operation and the use of renewable sources will reduce fuel and maintenance costs.

- *Improving air quality:* reducing emissions will contribute to a better environment and better health for residents.
- *Energy independence*: diversifying energy sources will reduce dependence on fossil fuel imports.

The CZT system reconstruction project in Partizánske is necessary to ensure sustainable, efficient and environmentally friendly heat production and distribution. By implementing modern technologies and renewable energy sources, the town will fulfil its commitments to European energy policies and contribute to a better quality of life for its inhabitants.

3 Specific objectives

Analysis of the current situation

The current status and distribution of heat distribution sources and facilities is processed interactively in a digital map, which gathers information not only geographically but also in terms of thematic breakdown and functional units. This map represents the first step towards a comprehensive archiving and digitisation of data on the central heating supply system (CHS) in Partizánske.

Assessment of future heat sources

The aim is to identify potential heat sources that meet basic criteria such as efficiency, renewability and decarbonisation. The possibilities in the city and its surroundings were analysed and a number of renewable sources that can be integrated into the CHP system were identified. However, each of these sources has its own specificities that affect its efficiency in the context of the central system. By verifying these specific characteristics, we can prepare a final recommendation for the implementation of each source and prioritize the steps that will be necessary for the system reconstruction.

Multicriteria analysis

Based on a simple model of the resources and their specific characteristics, we can investigate the impact of various input parameters on system operation, such as fuel prices, regulations, climatic conditions and energy efficiency measures. The multi-criteria analysis is not intended to make a definitive decision on the suitability of individual solutions, but to offer an illustrative view of the impact of these parameters on the selected technologies within the resource base of the CHP system.

Design of financial models and financing options

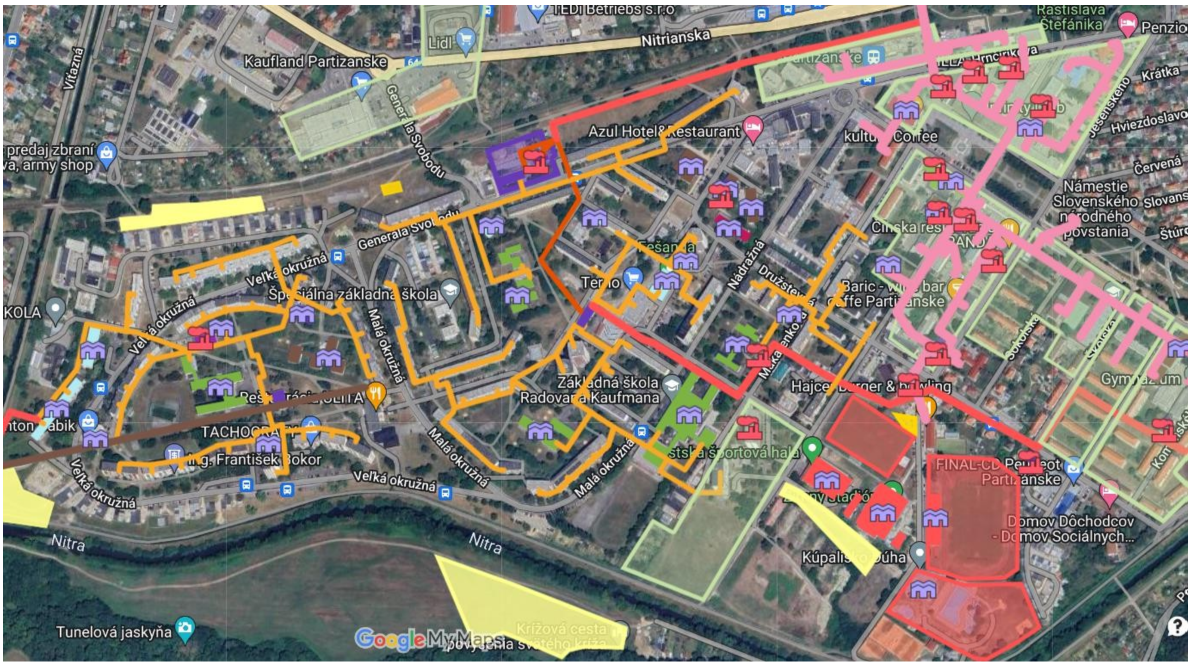
The reconstruction requires relatively high investment costs, which will have an impact on the price of heat for consumers. To minimise this impact, it is essential to identify the maximum possible financial resources from various support mechanisms, whether at national or European level. The precise identification of these instruments will greatly facilitate the planning of the different phases of the project. It is also important not to neglect the building of professional capacities, which, alongside finance, are an equally important part of a well-functioning CHP system that is able to respond to the challenges of modern energy.

4 Analysis of the current situation

A major deficiency in the city is the lack of a digital summary or archive of data on energy equipment or assets. Therefore, we have compiled an online, editable digital map that brings together the necessary data and helps to create a general view of the CZT system. The existence of such a map and archive will facilitate decision-making and increase the efficiency of working with the most basic data on the CZT system.

The map is available at: https://tinyurl.com/jwfupd4s

The map works on the GoogleMaps platform, and many people find it intuitive to use. Map objects are divided into logical units, each of which forms a separate map layer.



Heat supply in Partizánske is provided by two entities:

- Technical Services of the City of Partizánske (hereinafter referred to as TSM Partizánske),
- ESCO Servis s.r.o. (heat supply for the industrial park).

Subjects	Heat price [EUR without VAT]		
	Variable component [EUR excluding VAT/kWh]	Fixed component [EUR without VAT/kW]	Approximate total price [EUR without VAT/kWh]
Technical services of the city of Partizánske	0,0899	223,7943	132,125
ESCO Servis s.r.o.	0,1968	365,3589	265,736

Currently, TSM Partizánske operate the CTZ Šípok boiler house, which burns wood chips, and 20 gas boiler houses, some of which are block and others are house boiler houses. Heat is distributed through distribution pipelines with a total length of approximately 30 km. The installed capacity of the heat production facilities is approximately 35 MW, with natural gas and woodchip biomass as the main fuels.

The thermal management of TSM Partizánske can be divided into two main areas based on the type of fuel and the location of heat sources:

- *Šípok* - area supplied with heat from a biomass boiler house (wood chip).
- *Luhy, Centrum - Batovany, Štrkovec* - areas supplied with heat from gas boiler houses, which are mostly block or house type.

Biomass boiler house Šípok

Designation of boilers:	**K1**	**K2**
Type	Hot water conventional	Hot water conventional
Power [MWt]	6	3
Label efficiency	85 %	85 %
Year of manufacture	2008	2010

In the Šípok district there is a biomass boiler house, which contains two wood chip boilers with a total output of 9 MW. These boilers, although older, are still functional and, thanks to regular maintenance, may be in operation for another 5 to 10 years. Currently, the boiler house is about 40 % oversized, which means that it is not sufficient to cover peak demand.

one boiler is sufficient. Therefore, it is advisable to look for other consumption points in the town where the surplus heat energy from this boiler house could be supplied.

Gas boiler rooms

Other heat sources in the administration of TSM Partizánske use natural g a s . Gas boilers are divided into three groups based on their age and condition:

- *Boilers in very good condition* (less than 15 years in operation),
- *Boilers in good condition* (15 to 25 years in operation),
- *Boilers that have exceeded their service life* (more than 25 years).

The service life of gas boilers is normally set at 15 years, but with careful maintenance it can be extended up to 25 years. However, once this limit is exceeded, their operating efficiency drops significantly, which increases maintenance and operating costs.

Oversizing and reliability of boiler houses

Due to increasing thermal protection of buildings and changing climatic conditions, some boiler rooms are oversized. This means that their installed capacity exceeds actual needs. It is therefore necessary to consider whether safe and efficient operation would still be ensured when older plants are decommissioned.

Based on the analysis of the reliability of the boiler plant operation, the plants were divided into four categories: critically low, low, good, and high reliability. Boiler plants with negative oversizing are categorized as critically low reliability regardless of the age of the boilers. However, this indicator is indicative and expert judgement is required for an accurate assessment.

Plynová kotolňa	Kotly					Uvádzaná účinnosť kotolne[5] [%]	Zásobované ulice/objekty	Úroveň predimenz. [%]	Spoľahlivosť prevádzky
	Ozn.	Tepel. výkon [MW]	Rok výroby	Stav na základe životnosti	Štítková účinnosť [%]				
domová PK06	K1	0,08	2005	dobrý stav	93	88,3	Škultétyho 173	152,53%	nízka
	K2	0,125	1993	za hranicou životnosti	89				
	K3	0,024	2005	dobrý stav	92				
bloková PK07	K1	0,25	1994	za hranicou životnosti	89	87	Komenského 216, Strojárenská 196, Školská 191	224,05%	kriticky nízka
	K2	0,25	1994	za hranicou životnosti	89				
	K3	0,125	1994	za hranicou životnosti	89				

bloková PK09	K1	0,2	1997	za hranicou životnosti	92	90	Októbrová 682, 675, 661	38,87%	kriticky nízka
	K2	0,25	1995	za hranicou životnosti	92				
	K3	0,25	1997	za hranicou životnosti	92				
bloková K11	K1	0,62	2013	veľmi dobrý stav	92	92	Družstevná, Nádražná, Makarenkova	64,37%	vysoká
	K2	0,62	2013	veľmi dobrý stav	92				
	K3	0,62	2013	veľmi dobrý stav	92				
domová PK12	K1	0,045	1996	za hranicou životnosti	91	88	Rudolfa Jašíka 160	107,07%	kriticky nízka
	K2	0,045	1996	za hranicou životnosti	91				
	K3	0,045	1996	za hranicou životnosti	91				
	K4	0,045	1996	za hranicou životnosti	91				
domová PK13	K1	0,045	1996	za hranicou životnosti	91	88	Februárova 152	117,02%	kriticky nízka
	K2	0,045	1996	za hranicou životnosti	91				
	K3	0,045	1996	za hranicou životnosti	91				
	K4	0,045	1996	za hranicou životnosti	91				
domová PK14	K1	0,045	1996	za hranicou životnosti	91	88	Rudolfa Jašíka 156	90,81%	kriticky nízka
	K2	0,045	1996	za hranicou životnosti	91				
	K3	0,045	1996	za hranicou životnosti	91				
	K4	0,045	1996	za hranicou životnosti	91				
domová K15	K1	0,043	2004	dobrý stav	94	92	Hrnčírikova 222/6	71,02%	dobrá
	K2	0,043	2004	dobrý stav	94				
domová K16	K1	0,045	2005	dobrý stav	97,2	94,2	Hrnčírikova 219	37,95%	dobrá
	K2	0,045	2005	dobrý stav	97,2				
domová PK18[6]	K1	0,17	2005	dobrý stav	94	91,9	Nám.SNP 212/4 Makarenkova 213	2,61%	dobrá[7]
	K2	0,13	2005	dobrý stav	94				
	K3	0,044	2005	dobrý stav	94				
domová	K1	0,105	2005	dobrý stav	94	91,6	Nám. SNP 220	68,79%	dobrá

PK19	K2	0,105	2005	dobrý stav	94				
	K3	0,06	2005	dobrý stav	94				
	K4	0,06	2005	dobrý stav	94				
domová PK20	K1	0,2	2006	dobrý stav	93	91	Februárová 945	78,44%	dobrá
	K2	0,2	2006	dobrý stav	93				
domová PK21	K1	0,047	2005	dobrý stav	92	89	Rudolfa Jašíka 652	54,82%	dobrá
	K2	0,047	2005	dobrý stav	92				
	K3	0,047	2005	dobrý stav	92				
bloková PK22 (dva objekty)	K1	0,06	2007	dobrý stav	95	92	1.mája 220/1	103,06%	dobrá
	K2	0,06	2007	dobrý stav	95				
	K3	0,06	2007	dobrý stav	95				
	K4	0,06	2007	dobrý stav	95				
bloková K24 (rozvody v rámci areálu nemocnice)	K1	0,05	2007	dobrý stav	90	87	Nová Nemocnica 169, Malé Kršteňany	93,31%	dobrá
	K2	0,05	2007	dobrý stav	90				
	K3	0,05	2007	dobrý stav	90				
	K4	0,05	2007	dobrý stav	90				
	K5	0,05	2007	dobrý stav	90				
domová PK Veľké Bielice	K1	0,026	2016	veľmi dobrý stav	93	90	Víťazná 476	154,75%	vysoká
	K2	0,026	2016	veľmi dobrý stav	93				
domová PK ALFA	K1	0,2	1996	za hranicou životnosti	92	89,9	Februárova 1478/2	461,13%	nízka
	K2	0,2	1996	za hranicou životnosti	92				
	K3	0,2	2005	dobrý stav	92				
bloková PK B	K1	1,45	2019	veľmi dobrý stav	94	89,6	Veľká okružná, Malá okružná	3,84%	vysoká
	K2	1,45	2021	veľmi dobrý stav	92				
	K3	1,45	2021	veľmi dobrý stav	90				
bloková PK D	K1	2,65	1993	za hranicou životnosti	90	88	Generála Svobodu Malá okružná Nádražná Makarenkova	130,80%	kriticky nízka
	K2	2,65	1993	za hranicou životnosti	90				
	K3	2,65	1993	za hranicou životnosti	90				
	K4	2,65	1993	za hranicou životnosti	90				
	K5	1,7	1992	za hranicou životnosti	90				
bloková PK E	K1	0,95	2009	dobrý stav	92	92	Makarenkova Družstevná Februárová	102,04%	dobrá
	K2	0,95	2009	dobrý stav	92				
	K3	0,95	2009	dobrý stav	92				

The assessments show that 6 boiler plants with a total installed capacity of 14.1 MW are in critical condition, two boiler plants with a capacity of 0.8 MW are in low reliability condition. 9 boiler plants (4,7 MW) are in good reliability and three boiler plants are considered to be in high reliability (6,3 MW). This indicates that a significant number of plants may face problems with safe operation, which may threaten the heat supply. On the positive side, however, the largest boiler plant, PK D, is being refurbished before completion and this source will be classified as a highly reliable source with its new capacity of 5.55 MW.

Heat distribution

The heat distribution systems managed by TSM Partizánske are formed by external hot water networks that connect individual boiler rooms with consumption points. In the Šípok housing estate, the heat distribution systems were reconstructed in 2011, using 2-pipe pre-insulated pipes. In other parts of the city, where block gas boiler houses are used, the pipelines are 4-pipe and their age and technical condition vary. The frequent reconstruction of the pipelines by TSM Partizánske leads to the fact that the documentation on the condition of the pipelines may be incomplete, which makes it difficult to accurately determine the current state of these networks. This method of gradual repairs is financially efficient, but may complicate the planning of larger reconstructions and optimisations).

Paradoxically, due to the inefficiently functioning CZT system with a high share of natural gas in the fuel mix, there is a greater opportunity to overhaul the system without a major negative impact on the price of heat.

5 Analysis of future heat sources

Existing gas sources

Gas sources in Partizánske are currently highly decentralised. In the Luhy housing estate, however, there has been a partial optimisation of resources in the recent past. Boiler houses A, B and C were merged into one boiler house B, with the reconstruction meeting the latest requirements in terms of gas technology. The output of the boiler plant has been optimised according to the actual needs of the area served and, thanks to the flue gas exchangers, it achieves an efficiency of up to 98 %.

This situation creates an excellent assumption that Boiler House B will serve as a high performance and efficient heat source in the years to come. The disadvantage remains that gas is a fossil fuel, but in the future this source may only be used as a peak source during the coldest periods of the year. Alternatively, green alternatives to natural gas can be used. A similar situation has arisen in Boiler House D, where the refurbishment is now being completed and which will be an equally modern gas source meeting the highest requirements for efficiency and stability.

Without gas sources, it will not be possible to provide the necessary power and power reserve for the central heating supply system in Partizánske in the transitional period of decarbonisation (10-15 years).

During the reconstruction of boiler houses B and D, the need for power was reassessed, which means that these sources are no longer oversized. Their control and measurement are automated, which creates the prerequisites for unattended operation with detailed data collection and the ability to evaluate data in real time, and thus adapt their operation within the future CZT system.

Advantages and disadvantages of gas sources

Gas sources in the central heating system have specific advantages that make them an attractive option for cities, including Partizánske. One of the main advantages is the high efficiency of modern gas boilers. These devices reach efficiencies of more than 95%, which means that most of the energy achieved in natural gas is efficiently converted into heat. In addition, gas boilers allow for the addition of efficient power control, which is important to cover peak heat demand during cold winter days.

The investment costs of installing new gas sources are relatively low compared to other technologies. Costs are around 150 to 250 euros per kilowatt of installed capacity if a new source is built. Another advantage is the already existing infrastructure for natural gas distribution, which reduces connection and logistics costs.

Gas sources also involve fewer pollutants than fossil fuels such as coal or heavy fuel oil. Emissions of sulphur oxides (SO_2) and particulate matter are negligible when burning natural gas. However, emissions of nitrogen oxides (NO_x) and carbon dioxide (CO_2) are still significant. Natural gas combustion produces approximately 200 grams of CO_2 per kWh of heat energy produced. With an annual gas consumption of 30,000 MWh, this translates into more than 6,000 tonnes of CO_2 per year for Partizánske.

The disadvantage of gas-fired sources is also the dependence on natural gas imports. Slovakia imports almost all of its natural gas consumption, most of which comes from Russia. Geopolitical tensions and the potential for instability in world markets have led to price fluctuations and potential supply problems. In 2022, for example, natural gas prices in Europe rose dramatically, reaching an all-time high of over €150/MWh. This has led to a significant increase in heating costs for residents and industry. While subsidy schemes have reduced the price impact on consumers, subsidising the price of gas is not sustainable in the long term.

Another risk is legislative constraints and changes within the European Union. The EU has committed to achieving carbon neutrality by 2050 under the European Green Deal. This means gradually reducing greenhouse gas emissions and moving away from fossil fuels, including natural gas. The Emissions Trading Scheme (EU ETS and ETS2) is increasing the pressure on operators of gas-fired installations. The price of emission permits in 2023 exceeded €80 per tonne CO_2, which significantly increases the operating costs of gas boilers. With emissions of 200 grams CO_2 per kWh, the cost of emission permits was approximately 16 euros/MWh of heat.

The EU ETS 2 system will directly affect the gas sources in Partizánske, which will cause the price of heat produced in these sources to rise and will also cause even more pressure on the introduction of renewable energy sources into CHP systems.

Financing of new gas projects may also be an issue. The European Investment Bank and other financial institutions are gradually restricting financing for fossil fuel projects. This may have limited access to credit or higher rates. In addition, under the EU taxonomy for sustainable finance, investment in gas projects may be outside the sustainable category in terms of strict criteria such as low emissions below 100 grams CO_2 per kWh.

Public opinion is increasingly leaning towards the promotion of renewable energy sources. Citizens' initiatives and environmental organisations can put pressure on cities to prioritise green technologies.

Legislative barriers are another problem. The EU Energy Efficiency Directive and the Renewable Energy Directive set binding targets for Member States to increase the share of renewables and improve energy efficiency. This leads to stricter emission limits and new requirements for central heating systems.

From a long-term sustainability perspective, investing in gas resources is a risk. There is a real possibility that these facilities will become 'stranded assets', i.e. assets that cannot be exploited for their full planned lifetime due to legislative constraints or economic inefficiency. This would mean financial losses for the City and the need for early depreciation of investments.
An alternative may be to switch to low-emission or renewable gases such as bio-methane or green hydrogen. However, these technologies are still in the early stages of development and their availability and prices are currently not competitive with natural gas. For example, the production of green hydrogen by electrolysis requires a significant amount of electricity from renewable sources, which increases costs.

In the context of future changes to the rules on charging for emissions from small gas-fired sources, the negative impacts of these charges must be anticipated at least until 2035. This negative impact may be decisive in the process of deciding whether to include a renewable source in the scheme, when to do so and what its real benefits will be for the price of heat.

Analysis of the impact of EU-ETS2 charges on CZT in Partizánske

This analysis assesses the financial impact of the upcoming EU-ETS2 CO_2 levies on the central heating supply system in Partizánske, with a focus on small gas-fired sources. We analyse how the change in the share of natural gas in the energy mix affects the additional costs in the period from 2027 to 2035.
The impacts are quantified for a very optimistic scenario for the price of emission permits. However, we know that their price has already been and could be many times higher in the future.

Current energy consumption

- Total annual energy consumption: 40 000 MWh (in fuel)
- Energy mix:
    - *Natural gas:* 69%
    - *Biomass*: 31%

The emission factor for natural gas is approximately 202 kg CO_2/MWh.

Current CO_2 emissions (69% gas share)

- *Natural gas consumption*: 27 600 MWh/year
- *CO_2 emissions*: 27 600 MWh × 202 kg CO_2/MWh = **5 575.2 tonnes CO_2/year**

Scenarios for reducing natural gas consumption

We evaluate the additional costs for different natural gas shares:

Scenario	Share gas (%)	Consumption Gas (MWh/year)	Issues CO_2 (tonnes CO_2/year)
1	69	27 600	5 575
2	50	20 000	4 040
3	30	12 000	2 424
4	10	4 000	808

EU-ETS2 CO_2 price projections

Assuming an initial CO_2 price of 50 €/tonne in 2027 with an annual increase of 5%, the projected prices are:

Year	2027	2028	2029	2030	2031	2032	2033	2034	2035
Price CO_2 (€/tonne)	50	52,5	55,13	57,89	60,78	63,82	67,01	70,36	73,88

Additional annual costs due to EU-ETS2

Calculations for 2027

- Scenario 1 (69% gas share):Additional cost: 5 575.2 tonnes × 50 €/tonne = **278 760 €**
- Scenario 2 (50% gas share):Additional cost: 4 040 tonnes × 50 €/tonne = **202 000** €
- Scenario 3 (30% gas share):Additional cost: 2 424 tonnes × 50 €/tonne = **121 200 €**
- Scenario 4 (10% gas share):Additional cost: 808 tonnes × 50 €/tonne = **40 400 €**

Estimated costs from 2027 to 2035

The table below shows the total additional costs over this period for each scenario:

Scenario	Share of gas (%)	Cumulative cost (€)
1	69	3 073 771
2	50	2 218 660
3	30	1 331 196
4	10	443 732

Conclusions

Maintaining the current share of gas (69%) may lead to additional costs of more than €3 million by 2035.

Reducing the share of gas significantly reduces the financial impact:

- With a 50% share of gas, the cost drops to around €2.2 million.
- With a 10% share of gas, the cost is reduced to approximately € 444 000.

Strategic reductions in natural gas consumption in favour of biomass or other renewables can lead to significant cost savings.

Biomass resources

Biomass sources in Partizánske represent an important part of the central heat supply system with the potential to increase the share of renewable energy sources in the energy mix of the city. Currently, two biomass boilers, 12 and 14 years old, with a capacity of 3 MW and 6 MW are in operation. These boilers are located in the Šípok housing estate, with a total capacity that significantly exceeds the current heat demand in this location.

Thanks to the project of interconnection of piping systems in Partizánske it is possible to optimize the use of existing biomass boilers. By interconnecting the individual systems, a more efficient distribution of biomass heat energy across the city will be achieved, which will allow to increase the share of heat supplied from renewable sources. Biomass as a renewable energy source brings benefits in particular in terms of reducing greenhouse gas emissions and improving the energy efficiency of the CHP system.

The use of biomass reduces dependence on fossil fuel imports, which strengthens the energy independence of the city and the region. Locally available fuels support the local economy and create jobs. Biomass can offer more stable prices compared to fluctuating natural gas prices on world markets, which can lead to more predictable heating costs for consumers. Properly managed biomass use can promote sustainable forestry and efficient use of waste wood that is generated in and around the city that would not otherwise be used.

On the other hand, biomass sources also have their disadvantages. Biomass boilers can be more expensive to install and maintain compared to gas boilers, with investments in fuel storage and biomass handling technologies. Ensuring a reliable and continuous biomass supply chain can be challenging and requires planning and collaboration with fuel suppliers. Biomass combustion can produce higher levels of particulate pollutants such as dust particles and

fly ash, which requires efficient filtration systems and can affect air quality if the right technologies are not implemented. Biomass boilers can have lower efficiencies compared to modern gas boilers and require regular maintenance and professional servicing to ensure optimum operation.
Increasing the share of biomass in the fuel mix can contribute to reducing operating costs in the long term, as biomass can offer economic benefits through stable fuel prices and potential savings from emission charges under the EU ETS2. An increased share of renewables will also help the city to meet current and future legislative targets for energy efficiency and renewables.
However, there are also challenges in integrating biomass resources. Given the age of biomass boilers, they may need to be upgraded or replaced with newer and more efficient technologies to ensure reliable and efficient operation. A detailed economic analysis is necessary, taking into account investment costs, operating costs, savings from emission charges and potential subsidies or financial incentives. One of the major influences on the efficiency of biomass sources is the quality of the biomass.
In the conditions of Partizánske, a major negative factor is the openness of the landfill and the increase in biomass moisture due to direct precipitation.

Analysis of the impact of rainwater on the efficiency of biomass combustion in Partizánske

Source.

In Partizánske we have a problem with the fact that it directly rains/snows on the stored biomass, which increases its moisture content and reduces its calorific value. Annually, 700 m² of biomass falls on the landfill approximately 600 millimetres of precipitation. The biomass that is burned in the boiler house weighs approximately 5 300 tonnes and provides 13 000 MWh of thermal energy. The aim is to estimate the impact of rainwater on the efficiency of biomass combustion and to estimate the losses compared to the situation if it had not rained on the landfill.

Calculation of the amount of rainwater absorbed by biomass

1. The total volume of rainwater falling on the stockpile:
   - *Annual rainfall*: 600 mm = 0.6 m
   - *Landfill area*: 700 m²
   - *Rainwater volume*:Water volume = 0.6 m × 700 m² = 420 m³
   - *Weight of rainwater*: Weight of water = 420 m³ × 1 000 kg/m³ = **420 000 kg**
2. Estimation of biomass moisture increase:
   - *Original biomass weight*: 5 300 000 kg
   - *We assume that all rainwater is absorbed by the biomass*.
   - *New total weight of biomass*: Total weight = 5 300 000 kg + 420 000 kg = 5 720 000 kg
   - *Original moisture content of biomass*: assume **30 %**
   - *Original dry weight*: Dry weight = 5 300 000 kg × 0,70 = 3 710 000 kg
   - *New biomass moisture*:

New moisture content = ((420 000 kg + 1 590 000 kg) / 5 720 000 kg) × 100 % **≈ 35 %**

Effect of increased moisture on the calorific value of biomass

1. Biomass calorific value before rain (30% moisture content):
   - *Dry biomass calorific value*: approximately 19 MJ/kg
   - *Net calorific value (NCV)* : NCV_{33000} = 19 MJ/kg × (1 - 0,30) - 2,44 MJ/kg × 0,30 = **12,568 MJ/kg**
2. Biomass calorific value after rain (35% moisture content):

   NCV_{3500} = 19 MJ/kg × (1 - 0,35) - 2,44 MJ/kg × 0,35 = **11,496 MJ/kg**
3. Decrease in calorific value:

   $\Delta NCV = NCV_{3000} - NCV_{3500}$ = 12,568 MJ/kg - 11,496 MJ/kg = 1,072 MJ/kg

- Percentage decrease in calorific value: (1,072 / 12,568) × 100 % ≈ **8,53 %**

Estimated impact on heat production

1. Total energy required:

Total energy = 13 000 MWh = 13 000 000 kWh = 46 800 000 MJ

2. Amount of biomass needed before rain:

Mass before = 46 800 000 MJ / 12,568 MJ/kg ≈ 3 726 896 kg

3. Amount of biomass needed after rain:

Mass po = 46 800 000 MJ / 11,496 MJ/kg ≈ 4 073 543 kg

4. Additional amount of biomass needed:

∆Weight = Weight after - Weight before = 4 073 543 kg - 3 726 896 kg = 346 647 kg

- *Percentage increase in biomass consumption*: (346 647 / 3 726 896) × 100% **≈ 9.3%**

Losses due to rain

- *Additional cost of biomass*: If the price of biomass is for example 50 €/tonne, then the additional cost is: Additional cost = 346 647 kg / 1 000 kg/tonne × 50 €/tonne **= 17 332 €**

- *Increased operating costs:* higher costs for transporting and storing more biomass. Reduced combustion efficiency leads to more wear and tear on the boiler and more frequent maintenance. Possible increase in emissions of harmful substances.

Conclusion

Uncovered storage of biomass in Partizánske leads to an increase in its moisture content by about 5 p.p., which causes a decrease in calorific value by about 8.5%. This means that to produce the same amount of heat (13 000 MWh), 9,3 % more biomass has to be burned, i.e. about 347 tonnes more. This increase represents an additional cost of approximately € 17 000 per year, not to mention increased operating costs and possible negative environmental impacts. Investing in a biomass landfill cap could eliminate these losses, improve combustion efficiency and reduce operating costs. In the long term, such a measure would bring economic savings and contribute to the sustainability of the energy operation in Partizánske.

Geothermal resources

The existence of geothermal energy on the territory of the city is a huge advantage and opportunity. The city is the direct owner of two boreholes, which creates conditions for their energy exploitation.

The FGTZ-2 and HGTP-1 wells have been investigated to verify their geothermal potential, but are currently unreserved or have not gone through the proper approval process for their use for energy purposes. The minimum prerequisite for official exploitation is the execution of a so-called hydrodynamic test. In cooperation with the State Geological Institute, the city can

Partizánske in the near future to verify the technical parameters and potentially prepare these sources for connection to the CZT system.
Both boreholes have demonstrated the presence of geothermal waters with relatively stable temperatures that are suitable for use in such a system.

Probable drilling parameters and performance of the HGTP-1 well

- *Temperature of produced water*: 20 °C
- *Productivity*: 12.8 l/s
- *Thermal output*: 0.3 MWt

The HGTP-1 well is located at a depth of 285 to 315 m and is situated in the carbonates of the Choc fold. The water from this borehole reaches a temperature of approximately 20 °C, which allows it to be used in low-temperature district heating systems. The thermal capacity of the borehole has been estimated at approximately 0,3 MWt, which corresponds to the capacity to supply heat to smaller objects or to contribute to the wider system

Garden FGTZ-2

- *Temperature of produced water*: 33 °C
- *Productivity*: 12.5 l/s
- *Thermal output*: 1.0 MWt

The FGTZ-2 well is deeper and more productive than the HGTP-1 well. It is located in dolomite carbonates at a depth of 400-900 m. This borehole has demonstrated water production of approximately 33 °C, making it a more promising source of geothermal energy. With an installed thermal capacity of 1.0 MWt, it is able to contribute significantly to the total volume of heat supplied to the district heating system.

Combined output of both wells

The total combined thermal output of both boreholes is estimated at approximately 1.3 MWt. However, due to the low temperature, this heat source is only usable for CHP needs with the help of heat pumps that ensure the production of water at the required temperature (up to 70 °C).This source is environmentally sustainable and contributes to reducing dependence on fossil fuels.

Conceptual design of geothermal energy utilization from FGTZ-2 borehole

This proposal presents a concept of using geothermal energy from the existing borehole FGTZ-2 in the urban area of Luhy in Partizánske. The aim is to use this renewable energy source for supplying boiler room D with thermal energy, whereby the water temperature will be raised to the required 65°C(70°C) by means of a heat pump.

The source of geothermal water is about 250 meters away from boiler house D. For design purposes, we calculate the cooling of the geothermal water to a level of 10°C.

Proposed system

- *Heat pump installation*: a water-to-water heat pump will be installed in boiler room D.
- *Connection method*: installation of an insulated pipe with a distance of 250 meters for transporting geothermal water from the borehole to the heat pump.
- *Heat exchanger*: The use of an exchanger to transfer heat from geothermal water to the heat pump circuit without mixing the media. This technical solution may be necessary if the quality of the geothermal water is unsatisfactory.
- *Primary circuit*: geothermal water flows from the borehole to the heat exchanger, where it transfers heat and is then returned to the recipient - the Nitrice River, cooled to 10 °C.
- *Secondary circuit: the* heat pump extracts heat from the heat exchanger and raises the temperature in the primary distribution to 65 °C, thus supplying the heating system of boiler room D or the entire district heating system in the case of interconnection of individual networks.
- *Components:* circulation pumps, control systems and safety features ensure efficient and safe operation.

Method of operation

The system will operate as the primary heat source for the CHP and will therefore operate continuously, for calculation purposes, for 8,000 hours per year. The heat pump will automatically regulate its operation according to the actual heat demand, which will ensure a stable heat supply at the required temperature.

Cost estimate

- *Equipment* (heat pump and related technology): €600 000
- *Heat exchangers:* €50 000
- *Other equipment*: €200,000 (includes piping, pumps, control systems, safety features)
- *Total estimated cost*: € 850 000

Estimation of the amount of heat produced and the price of the heat output

- *Amount of heat produced per year* (with real COP = 4 and electricity price at 200 €/MWh)
- *Heat output*: $Q = m \times {}_{cp} \times \Delta T$ = 1 201,75 kW

- *Annual heat production*: **9 614 000 kWh**
- *Electricity consumption*: **2 403 500 kWh**
- *Electricity costs*: €480 700
- *Output heat price*: **50 €/MWh**

The use of geothermal energy is an environmentally friendly and sustainable solution that contributes to the reduction of greenhouse gas emissions. There are various programmes and funds promoting renewable energy sources that can provide financial subsidies or soft loans for the implementation of such projects. Taking advantage of these opportunities can significantly reduce investment costs and accelerate the return on investment.

The implementation of this geothermal heating system will provide a sustainable and economically viable solution for the district heating system. The proximity of the D boiler plant and the geothermal source will minimize infrastructure and necessary construction costs.

Waste heat from waste water treatment plant

On the territory of the town of Partizánske there is a wastewater treatment plant, which can be a source of waste heat. The use of waste heat is an important topic for the future and is therefore also being considered in Partizánske. In fact, the treated waste water from the waste water treatment plant represents an additional source of heat, although its temperature is only between 14 and 20 degrees Celsius depending on the season. The residual heat from this water can be reused by heat pumps, similar to a geothermal source. The production of wastewater is relatively constant and does not fall below 100 litres per second. The potential power delivered from this waste heat source is in the order of 2,5-5 MW. If necessary and convenient, this source can be expanded to use river water without major intervention, especially during periods when the river is warmer than the waste water from the treatment plant.

The advantage for Partizánske is the proximity of the treatment plant to the Luhy housing estate. The WWTP is located less than 600 metres from the existing heat distribution systems, to which waste heat from this source could be supplied. In terms of efficiency and location of the technology, it is more efficient to design a system where the heat is not generated directly at the treatment plant and delivered through a twin-pipe heat distribution system. Instead, the purified water will be piped through a single insulated pipe to where the district heating (CHP) pipes are, and there the heat will be extracted by heat pumps and then delivered directly to the grid.

In this way, the investment in the pipeline that would have to bring heat from the treatment plant to the CHP system is minimized. The technology and method of operation will be very similar to that of a geothermal source, however, due to the lower water temperature, the expected efficiency will be about a quarter lower. Nevertheless, this source can suitably complement the CHP system, as it is a renewable source for which various non-refundable financial contributions can be obtained.

Heat accumulation

Heat storage is a key element of modern district heating systems. It enables efficient management of heat energy production and consumption, increases system flexibility and contributes to its economic and environmental sustainability. With the increasing trend towards electrification of district heating, the introduction of heat pumps and renewable energy sources, the importance of heat storage is even more emphasised.

Short-term heat accumulation

Short-term heat storage is used to compensate for the daily difference between heat production and consumption. It allows the storage of surplus heat produced at times of low demand and its subsequent use during periods of peak consumption.

Benefits

- *Production efficiency*: improves the operating conditions of heat sources by allowing them to operate stably at optimum performance.
- *Economic savings*: reduces the need for investment in high-end resources and lowers operating costs. It also enables production during periods of low prices and sales during periods of demand.
- *Renewable integration:* enables better use of renewable energy sources that may have unstable production.

Seasonal heat accumulation

Seasonal heat storage allows heat to be stored during periods of low demand (e.g. summer) and used during periods of high demand (winter). It is typically used for systems that generate excess heat in the summer months, such as solar thermal systems.

Seasonal heat accumulation is not relevant for the city of Partizánske for the following reasons:

- *Lack of suitable land*: seasonal storage systems require large areas or volumes for storage, which is not available near the city.
- *High investment costs*: seasonal storage technologies are costly and do not currently represent an economically viable solution for the city.

Example of a storage tank for CZT in Partizánske

Consider a storage tank with a volume of 1 500 m^3. The amount of heat that can be stored in this tank at the temperature difference between the supply and return pipes:

Tank capacity (V): 1 500 m^3

Water density (ρ): 1 000 kg/m^3

Specific heat capacity of water (c): 4 186 J/(kg-K)

Temperature difference (ΔT): 70 °C - 40 °C = 30 K

Amounts of heat that can be stored in the tank(Q): $Q = V \times \rho \times c \times \Delta T$

$Q = 1\,500\ m^3 \times 1\,000\ kg/m^3 \times 4\,186\ J/(kg\text{-}K) \times 30\ K$

$Q = 188\,370\,000\,000\ J \approx$ **52 000 kWh**

One charge: The 1 500 m^3 storage tank can store approximately 52 MWh of thermal energy when fully charged.

Annual usage: Assuming that the tank is charged and discharged to at least 50% daily (which is common for short-term storage), it can mediate up to:

26000 kWh/day × 365 days = **9 490 MWh/year**

This amount of heat would significantly contribute to cover the peak heat consumption in CZT in Partizánske. The tank volume between 1000 and 2000 m3 seems to be sufficient in the context of future heat sources.

Short-term heat accumulation represents a realistic and effective option for the city of Partizánske to increase the flexibility and sustainability of the district heating system. In the context of modern trends in the energy sector, especially with an emphasis on electrification and the use of renewable sources, the implementation of storage tanks is a strategic step towards a more environmentally friendly and economically advantageous operation of the central heat supply system.

Source: pixabay.com

Use of solar energy

Photovoltaics

Photovoltaic systems convert sunlight directly into electricity using solar panels. In recent years, photovoltaics have made significant advances, which are reflected in falling prices and increasing panel efficiency. It is increasingly being used in cities not only to generate electricity but also for central heating needs.

In order to increase the share of renewable sources in Partizánske, we also count on partial use of energy from the sun for the needs of the district heating system.

Current trends:

- *Price drop*: prices of photovoltaic panels have fallen by more than 80 % in the last decade %, which reduces investment costs.
- *Increasing Efficiency:* new technologies enable panel efficiencies of over 20 %, which means more energy produced in a smaller area.
- *Integrated solutions*: photovoltaic panels are increasingly being integrated into building elements such as roofs and facades.
- *Energy communities*: groups of energy consumers and producers emerge to share the electricity they produce with each other.

Benefits of photovoltaics:

- *Renewable energy source*: it uses solar radiation, which is inexhaustible and environmentally friendly, and non-repayable funding can be used for its installation.
- *Cost reduction*: self-generation of electricity reducesdependence onexternal suppliers and can lead to savings.
- *Flexibility of location*: the panels can be installed on roofs, facades or open areas.
- *Low running costs*: once installed, maintenance costs are minimal.

Disadvantages of photovoltaics:

- *Weather Dependency*: electricity generation depends on the intensity of sunlight.
- *Initial investment*: even if prices have fallen, upfront costs can still be high.
- *Space required*: sufficient space is required for larger installations.

Battery systems:

To use the electricity generated efficiently, it is important to ensure that it is available even when the sun is not shining. Battery systems make this possible:

- *Physical batteries*: allow excess energy to be stored on-site.
- *Virtual batteries*: surplus energy is fed into the grid and drawn back as needed

Thermosolar panels

Thermosolar systems use solar radiation to heat a heat transfer medium, most often water, which is then used for heating or hot water.

Unsuitability for Partizanske:

Thermosolar energy is not suitable for the town of Partizánske due to the absence of large plots of land near the CZT distribution lines. The installation of large-scale thermosolar arrays would be spatially and economically inefficient.

Use of former landfill for photovoltaics Site description:

The former landfill site in Šimonovany, with a usable area of approximately 40,000 m², is an ideal location for the installation of a photovoltaic power plant. This area is otherwise difficult to use for other purposes, which increases the attractiveness of the project.

Estimate of electricity generation:

- *Installed capacity*: 1.5-2 MW using standard panels

- *Annual energy production*: a conservative average annual yield is approximately 1 050 kWh/kWp.
- *Estimated annual production*: 1.5 MWp × 1 050 kWh/kWp = **1 575 MWh.**

Benefit for CZT and the city:

- *Energy supply for CHP*: The generated electricity can be used to drive heat pumps or other equipment in the CHP system, thus reducing the costs of heat production.
- *Energy communities*: thanks to legislative possibilities, municipal organisations and businesses in the city can use the energy produced through balance groups or energy communities.
- *Reducing emissions*: replacing fossil fuels with renewable energy will reduce CO_2 emissions and contribute to a greener environment.
- *Efficient use of land*: Transforming an unusable landfill into a source of clean energy.
- *Proximity to infrastructure*: easy connection to the existing electricity network, either through the West Slovak Distribution or by connecting to the

  the local distribution system, which is operated in an industrial area within reach of the landfill site.
- *Economic benefit*: Potential revenue from the sale of surplus electricity and savings on energy costs.

The use of the former landfill for the installation of a photovoltaic power plant represents a strategic opportunity for the town of Partizánske. It is independent from the upcoming reconstruction of the CZT system, but it complements it very well. The project brings ecological, economic and social benefits that support the sustainable development of the city and increase energy independence.

Involvement of external heat suppliers

In modern cities, it is essential not only to reduce own energy consumption, but also to make efficient use of the total energy production and surplus within the city. The integration of external heat suppliers into the district heating system is one of the basic prerequisites for a functioning low-temperature 4th generation system, which we are also striving for in Partizánske.

Potential heat sources in the city

In Partizánske, as in any medium-sized town, there are a number of potential heat sources, especially seasonal ones, which can be connected to the CZT system. These sources include:

- *Commercial operations with refrigeration*: supermarkets, logistics centres and other commercial operations often use large capacity refrigeration systems that generate a significant amount of waste heat during their operation. This heat can be captured and diverted into the district heating system, reducing the energy demand of the buildings and increasing the overall efficiency of the system.
- *Businesses* and institutions that use photo*voltaic* systems can generate *surplus electricity* on sunny days. This surplus can be used to operate heat pumps that supply heat to the district heating system.
- *Industrial plants with waste heat*: production processes in industrial plants often produce waste heat that can be captured and used for heating. Working with these businesses can bring mutual benefits - the businesses reduce their cooling costs and the city gains an additional source of heat.
- *Data centres and server rooms*: with increasing digitalisation, the number of data centres generating large amounts of heat is increasing. This heat can be efficiently integrated into the district heating system.

Legal framework and heat pricing

For the successful integration of external heat suppliers, it is essential to create a legal framework that:

- *Modify the conditions for the purchase of surplus heat:* It is necessary to define the contractual relations between heat suppliers and the CZT operator, including technical specifications, quality of heat supplied and responsibilities of both parties.
- *It shall determine the method of setting the price for heat*: The price should be fair and motivating for both parties. Models based on cost-based pricing, market energy prices or a combination of several approaches can be used. Transparency and predictability of prices are key for long-term cooperation.
- *Ensure compliance with legislation:* The legal framework must comply with national and European legislation on energy, competition and environmental protection.

Technical aspects of integration

Technical challenges need to be addressed when engaging external heat suppliers:

- *Connection to the CZT system*: design and implementation of the connection of external heat sources, including the necessary technologies for temperature and pressure adjustment of the heat transfer medium.
- *Measurement and control*: implementation of systems to accurately measure the delivered heat and control it in real time to ensure the stability and efficiency of the entire system.
- *Heat quality*: Ensuring that the heat supplied meets the required technical parameters, particularly in terms of temperature and purity of the medium.

Necessary steps for implementation

- *Identifying potential suppliers*: mapping local businesses and institutions with the potential to supply surplus heat.
- *Techno-economic studies*: assessment of the technical feasibility and economic viability of individual projects.
- *Establishing the legal framework*: Preparation of contractual conditions and legislative measures to support the integration of external resources.
- *Financing*: seeking financial resources for the necessary investments, including the possible use of grants and subsidies from national and European funds, or contractor financing.

The involvement of external heat suppliers in the CZT system in Partizánske represents a significant step towards sustainable and efficient energy in the city. The use of local heat sources increases energy security, reduces costs and contributes to environmental protection. For successful implementation, it is necessary to create appropriate legislative conditions, establish fair pricing mechanisms and ensure the technical readiness of the system for the integration of new sources.

Interconnection of systems as a necessary condition for an efficient multi-source CZT system 4th generation

Connection of the current decentralized heat supply systems in Partizánske into a unified whole is a necessary step to increase the efficiency and safety of heat supply. The centralisation will lead to a more efficient use of renewable energy sources and existing fuel sources, such as natural gas and wood chips, thus reducing the oversizing of the heat outputs of individual boiler plants. The interconnection of the main supply areas and the different energy sources will improve the variability of heat production and supply, which will have a positive impact on economic efficiency and operational safety.

When implementing a new centralised system, it is important to use pre-insulated pipes, which are characterised by low heat loss, long service life and high resistance to external influences. Integrating a pipe fault detection system into the future solution will allow early identification and repair of potential leaks or damage, thereby increasing the reliability and efficiency of the entire heat supply system.

In the town of Partizánske, there are several options for routing new interconnectors, which must be carefully assessed not only from a technical and economic point of view, but also from the perspective of limitations on life in the town, feasibility in the area and also collision with other projects.

6 Multicriteria analysis of future resources

In this section we focus on the multicriteria analysis of different heat sources and their impact on the efficiency and economics of the centralized heat supply system (CHP) in the city of Partizánske. The aim is to present in a simple and clear way what are the impacts of potential technologies on cost and ecology compared to the current situation.

The analysis examines the efficiency of new heat sources based on a number of criteria:

- *Annual heat production*: How much heat a given source can produce in a year.
- *Investment cost*: how much it costs to build and operate a resource over its lifetime (depreciation)
- *Depreciation*: how the cost of the resource is reflected in the price of heat through the increased fixed component of the heat price.
- *Fuel and raw material prices*: they change over time and are the biggest question mark in any system.

The analysis results in an understanding of the impact of each source on the variable, fixed and hence the impact on the overall average heat price. It is the impact on the price of heat that is the most important factor when deciding on future investments.

The analysis compares the future situation with the current one, where the share of natural gas in the fuel mix is 69% and biomass 31%. This gives a clear picture of how the different sources will affect the efficiency and affordability of the system.

In the multicriteria analysis, we consider the following sources:

- *Old gas sources* : Sources that are obsolete and show an efficiency level of about 90 %. These resources are currently present in the system in large numbers and are inefficient not only in terms of operation but also maintenance.
- *New gas sources* : Upgraded boiler houses, which will be part of the future system, and which have a high efficiency of around 98%
- *Biomass sources:* the analysis assumes a current biomass source with a capacity of 9 MW and an efficiency of 88 percent.
- *Geothermal borehole with a temperature of 33 °C, Geothermal borehole with a temperature of 20 °C*: the analysis assumes that the heat from these boreholes is recovered using heat pumps. The analysis also examines the impact of the efficiency of the heat pumps on the resulting heat price.
- *Waste heat from wastewater treatment plants:* waste heat recovery also by heat pumps.
- *Heat from external suppliers:* the analysis also examines the impact of direct heat purchases and prices from external suppliers
- *Impact of network interconnection on efficiency and heat price* : this measure affects the overall efficiency of the system, but also contributes significantly to the increase in the fixed component of the heat price.

Thanks to the ability to change input parameters such as fuel prices or investment costs, we can model various potential situations such as changes in the energy market or the prioritization of individual resources in the CHP system.
It is evident from the partial results that geothermal sources in conjunction with biomass, heat storage and own electricity production, significantly influence the stability of the heat price of the CZT system and their positive contribution compensates for the higher investment costs for the installation of the technologies. However, all this is based on the assumption that the future system is interconnected to allow efficient use of each source connected to the system.

The multicriteria analysis provides us with a comprehensive view of the possibilities of optimization of the heat supply system in Partizánske. It helps to identify the most suitable heat sources and their combinations, which is crucial for planning and ensuring an efficient, reliable and affordable district heating system for the future of the city.

Source	Power	Effectiveness / COP	Annual heat supply	Consumption	EE ZSE	EE community	Inv. costs	Inv. costs	Var.component	Impact on VZ	Impact on FZ
Old gas sources	Power	Effectiveness	Annual heat supply	Gas consumption			Inv. costs	Inv. costs	Var.component	Impact on VZ	Impact on FZ
	kW	%	MWh	MWh			depreciation 20r	write-off 8r	€	€/MWh	€/kW
	10000	90%	0	0,0			-	-	0,00	0,00	0,00
New gas sources	Power	Effectiveness	Annual heat supply	Gas consumption			Inv. costs	Inv. costs	Var.component	Impact on VZ	Impact on FZ
	kW	%	MWh	MWh			depreciation 20r	write-off 8r	€	€/MWh	€/kW
	9900	97%	8000	8247,4			-	400 000,00	65,80	-1,05	7,57
Biomass resources	Power	Effectiveness	Annual heat supply	Biomass consumption			Inv. costs	Inv. costs	Var.component	Impact on VZ	Impact on FZ
	kW	%	MWh	MWh			depreciation 20r	write-off 8r	€	€/MWh	€/kW
	9000	88%	17234	19584,1			-	20 000,00	60,44	-4,74	0,38
Geothermal FGTZ-2 source	Power	COP	Annual heat supply	EE consumption	EE ZSE	EE community	Inv. costs	Inv. costs	Var.component	Impact on VZ	Impact on FZ
	kW		MWh	MWh	MWh	MWh	depreciation 20r	write-off 8r	€	€/MWh	€/kW
	1100	3,7	6500	1756,8	1506,8	250,0	-	450 000,00	53,41	-3,01	8,52
Geothermal HGTP-1 sources	Power	COP	Annual heat supply	EE consumption	EE ZSE	EE community	Inv. costs	Inv. costs	Var.component	Impact on VZ	Impact on FZ
	kW		MWh	MWh	MWh	MWh	depreciation 20r	write-off 8r	€	€/MWh	€/kW
	700	3	4500	1500,0	1250,0	250,0	-	350 000,00	65,01	-0,69	6,63
Waste heat (ext.supplier)	Power	Effectiveness	Annual heat supply	Heat consumption			Inv. costs	Inv. costs	Var.component	Impact on VZ	Impact on FZ
	kW	%	MWh	MWh			depreciation 20r	write-off 8r	€	€/MWh	€/kW
	1000	98%	1000	1020,4			80 000,00	40 000,00	37,99	-0,88	1,36
Treatment plant OV	Power	COP	Annual heat supply	EE consumption	EE ZSE	EE community	Inv. costs	Inv. costs	Var.component	Impact on VZ	Impact on FZ
	kW		MWh	MWh	MWh	MWh	depreciation 20r	write-off 8r	€	€/MWh	€/kW
	1500	2,8	0		0,0		-	-	0,00	0,00	0,00
New wiring heat	Power	Effectiveness	Annual heat supply				Inv. costs	Inv. costs	Var.component		Impact on FZ
	kW	%	MWh				depreciation 20r	write-off 8r	€		€/kW
		94%	37234				2 000 000,00	20 000,00	67,67		15,52

ALL MEASURES

Impact on Variable component (€/MW)	Impact on Fixed Component (€/kW)
-10,36	3G,G8

CHANGE IN AVERAGE HEAT PRICE (€/MWh)

-2,82 €

Energy prices	€/MWh
Gas price	60
Biomass price	50
EE ZSE price	200
Price EE community	100
Waste heat price	35

Heat consumption	MWh
Annual heat demand	35 000
Losses of old wiring	10%
Annual heat production	38 88G
Regulating power (kW)	6 604

New fuel mix	%
Natural gas	21%
Biomass	46%
Waste heat	3%
Heat pumps	30%

Original fuel mix	%
Natural gas	6G%
Biomass	31%

The multicriteria analysis is available at:

https://docs.google.com/spreadsheets/d/1Vi280eRSxtxQSgf4IgXAEGsZfUTcrXdlktaoxJlj8_E/edit?usp=sharing

7 Project funding options

The project will undoubtedly be very resource intensive, but if invested appropriately these resources can provide a very positive overall impact on the price of heat and the sustainability of the whole system. The big advantage that Partizánske has is that it is part of the transformed regions, which means it is eligible to participate in calls and support schemes addressed to these regions.

In addition to its own resources, which are not available to a large extent to municipalities in Slovakia today, the city has to rely on external financing. The ideal is to use grant schemes and non-repayable financial contributions. However, these grants usually provide support for up to 50 per cent of the investment costs. The city must therefore obtain a large part of the funds from repayable schemes, which include very favourable schemes, for example from the European Investment Bank.

If convenient and necessary, there are also public-private partnerships that operate thanks to the input of private capital into the CHP system, or also Guaranteed Energy Service Companies (ESCO, GES) that provide a system of services under pre-agreed financial and non-financial conditions.

In addition to repayable and non-repayable schemes that can provide direct financial support for project implementation, we recommend focusing on projects that provide support for design, research, innovation, capacity building, advice and assistance.

For the project of decarbonisation of the CZT system in Partizánske we are still considering joining the calls for tenders:

Modernisation Fund

The Modernisation Fund is an EU financial instrument designed to support the modernisation of energy systems and improve energy efficiency in Member States; for more information see: https://www.minzp.sk/modernizacny-fond/

Fair Transformation Fund

The Just Transition Fund provides financial support to regions affected by the transition to a climate-neutral economy to mitigate the social and economic impacts; for more information see: https://www.mirri.gov.sk/sekcie/investicie/spravodliva-transformacia/

Operational Programme Slovakia

The Operational Programme Slovakia is the framework programme for the use of European Structural and Investment Funds to support the development of Slovakia; for more information see: https://www.mirri.gov.sk/sekcie/programy/program-slovensko/

Just Transition Mechanism

The Just Transition Mechanism is an EU initiative to support regions in the transition to a green economy to ensure a fair transition for all; for more information see: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/finance-and- green-deal/just-transition-mechanism_en

CINEA - LIFE

LIFE is the EU's financial instrument supporting environmental and climate projects, managed by CINEA; for more information see: https://cinea.ec.europa.eu/life_sk

CINEA - CEF

The Connecting Europe Facility (CEF) supports investment in trans-European networks in the energy, transport and telecommunications sectors, managed by CINEA; for more information see: https://cinea.ec.europa.eu/connecting-europe-facility/energy-infrastructure_sk

CINEA - HORIZON

Horizon Europe is the EU's framework programme for research and innovation, also managed by CINEA for energy projects; for more information see: https://cinea.ec.europa.eu/horizon-europe_sk

EU City Facility

The EU City Facility provides financial support to cities and municipalities to develop investment concepts for sustainable energy; for more information see: https://www.eucityfacility.eu/home-sk.html

EIB - TARGET

TARGET (Tailored for Regional Growth and Environmental Transition) is an initiative of the European Investment Bank to provide technical support to regional projects promoting environmental transformation; for more information see: https://www.eib.org/en/products/loans/target/index.htm

EIB - ELENA

ELENA (European Local Energy Assistance) is technical assistance provided by the EIB for the preparation of investment programmes in the energy and transport sectors; for more information see: https://www.eib.org/en/products/advising/elena/index.htm

EEEF - European Energy Efficiency Fund

The European Energy Efficiency Fund (EEEF) provides funding for energy efficiency and renewable energy projects; more information at: https://www.eeef.lu/

European Urban Initiative

The European Cities Initiative promotes sustainable urban development through innovative actions and knowledge exchange; for more information visit: https://www.urban-initiative.eu/

Interreg Europe

Interreg Europe is an interregional cooperation programme promoting the exchange of experience and best practice between European regions; for more information see: https://www.interregeurope.eu/

Professional capacity building

Along with the issue of funding, the training of professional capacities is also a very important part. The city of Partizánske faces a significant opportunity to modernise its district heating systems and become a model for other cities in the region. The key to success is investment in professional capacity and human potential. Keeping up with modern technologies and a dynamic energy market requires qualified professionals who can effectively implement innovative solutions and ensure the sustainable development of the city.

We recommend that the official authorities focus on strategic human resources planning, support for education and research, and the creation of an environment conducive to innovation. This will not only increase the efficiency of the CZT systems, but also strengthen the economic and social development of Partizánske.

8 Summary

The conclusions of this study clearly point to the necessity of modernization and transformation of the CZT system in Partizánske. The current infrastructure is significantly outdated in terms of age, efficiency and environmental requirements. Oversized boiler plants that operate inefficient, they are a burden not only in terms of operating costs, but also in terms of maintenance costs and greenhouse gas emissions. It is therefore essential for the city to embark on a path of gradual renovation and optimisation of existing facilities.

One of the main objectives of the proposed transformation is the decarbonisation of the CHP system, which requires the integration of renewable energy sources such as biomass, geothermal energy, photovoltaic systems and the use of waste heat. These sources will not only reduce the city's dependence on fossil fuels, but will also reduce carbon dioxide and other pollutant emissions. The proposal foresees the use of local energy sources, which will strengthen the energy independence of the city and at the same time support the sustainable development of the region.

The flexibility of the new grid and the use of storage technologies are another key factor for a successful transformation. The ability to store surplus heat and use it at the time of need gives the city a strategic advantage. Such solutions will allow the city to better respond to changing market energy prices, ensuring that the city will be able to benefit from cheaper electricity and heat when it is available.

At the same time, the technical and financial aspects of this transformation need to be taken into account. Investments in upgrading heat distribution systems and building new sources, including technologies for energy storage and management, are key to the long-term sustainability of the project. It is important that the financing of these measures is based on a combination of European, national and own resources, which will reduce the financial pressure on the city and consumers.

The transformation of the CZT system is not only a technical challenge, but also a strategic investment in the future of the city, which will improve the quality of life of its inhabitants, contribute to environmental protection and strengthen economic stability. In this way, Partizánske clearly demonstrates its readiness for future energy challenges and its ambition to become a sustainable and innovative city.

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