Summary of the study 'Analysis of Sustainable Heating Options for the City of Tuzla, Federation of Bosnia and Herzegovina'

Full study by Bernhard Schneider, consulting engineer for urban planning, commissioned by CEE Bankwatch Network

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Contents

Author Full study by Bernhard Schneider, consulting engineer for urban planning, commissioned by CEE Bankwatch Network
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Acknowledgements Amel Husić, Centralno grijanje d.d. Tuzla
Denis Žiško, Center for ecology and energy Tuzla

Design Peter Slingiert **Cover image** Tuzla, Bosnia and Herzegovina
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Summary

At present, the air quality of the city of Tuzla, Bosnia and Herzegovina (BiH) is among the **worst** in the EU and Western Balkans. Because Tuzla's coal-fired power and heat plant, Tuzla 4, must be closed by the end of 2023, and Tuzla 5 and 6 must close in the next decade, the city faces a unique **window of opportunity to gain a place among the cleanest and technologically smartest cities** with respect to heat supply and air quality in southeast Europe.

Apart from the upcoming end of the present heat plant's operations, **several further preconditions** qualify Tuzla to **take the lead** as a clean heat model city:

- the presence of underground **salt mine pits and caverns** which are disused or will become disused in the coming decade, thus offering the conditions for sub-surface heat storage using brine as a medium; the fact that these mines are located in the district heating area is unique in Europe.
- rather high **solar irradiation**, qualifying the city for solar thermal energy harvesting.
- untapped biomass potential.
- a well-working and widely used **district heating grid**, owned by the city, which can be the backbone of future heat distribution.
- a city administration with the **proven ability** to successfully implement big projects.
- the opportunity to gain access to international and EU **funding** needed for Tuzla's coal exit.

On the other hand, there are certain challenges that will need to be addressed in order to implement ambitious heating projects:

- the lack of fully consistent legislation, an efficient and clear distribution of decision-making competences, quick and user-friendly public administration procedures, and detailed roadmaps and programmes for reaching climate objectives.
- a lack of the data needed to pre-assess the feasibility of advanced heating solutions (e.g. size, geological parameters and availability of sub-surface heat storage facilities).
- the low income of many local households. As a consequence, it will be difficult for citizens to co-finance the required initial investment for new district heating solutions. In addition, they have other priorities than energy efficiency measures, and there is no collective experience of successful joint implementation of large ecological and/or social projects.
- the lack of information on state-of-the-art heating technologies among the majority of the public, often combined with a passive mentality and distrust; at the same time, the public is exposed to massive pro-coal propaganda which does not always carefully disclose the facts about the industry.
- the widespread prejudice that advanced model solutions are only fit for the richest countries. With Bosnian engineers competitively educated and qualified, and given the above-mentioned strengths, this prejudice should be abandoned, as it only perpetuates the country's present development lag.
- the danger of overexploiting forests when increasing biomass combustion due to a lack of rules, monitoring and sanctions in the forestry sector.

A study was carried out by Bernhard Schneider, consulting engineer for urban planning, commissioned by CEE Bankwatch Network, to examine possible solutions for heating in Tuzla, which currently relies on an outdated coal unit for district heating. After careful review of available solutions and their strengths and weaknesses, a transparent **decision preparation process** was provided in the study. It shows that **it is technically possible to fully replace local use of coal (for power and heat) with solar energy**. This solution will require massive improvements to the efficiency of heat use in buildings, the transformation of the heat grid into a low-temperature, fourth generation district heating grid with an important role played by heat pumps. It will require a high level of financial investment and the deep involvement of houseowners. It will most likely be economically feasible if a geological study, which is yet to be conducted, identifies sufficient subsurface storage capacities.

In order to react to these uncertainties, a **second option** was developed. It consists of an ambitious **energy efficiency programme** in combination with the construction of a **biomass cogeneration heat plant** in the area of the coal plant and substantial reconstruction of the heat grid. In this option, citizens and investors would have more time to deploy solar energy. First mover districts can quickly start replacing their high-temperature heat pipes with a low-temperature microgrid with heat exchangers, solar heat storage and local heat pumps. In the period of transition to either of these two options, the heat can be supplied from the existing unit 6 of the coal power plant. Continued firing of **coal in the planned new unit 7 (TPP7)** and **waste incineration** were analysed for comparison, but the results were negative both from the viewpoint of economics and of sustainable development.

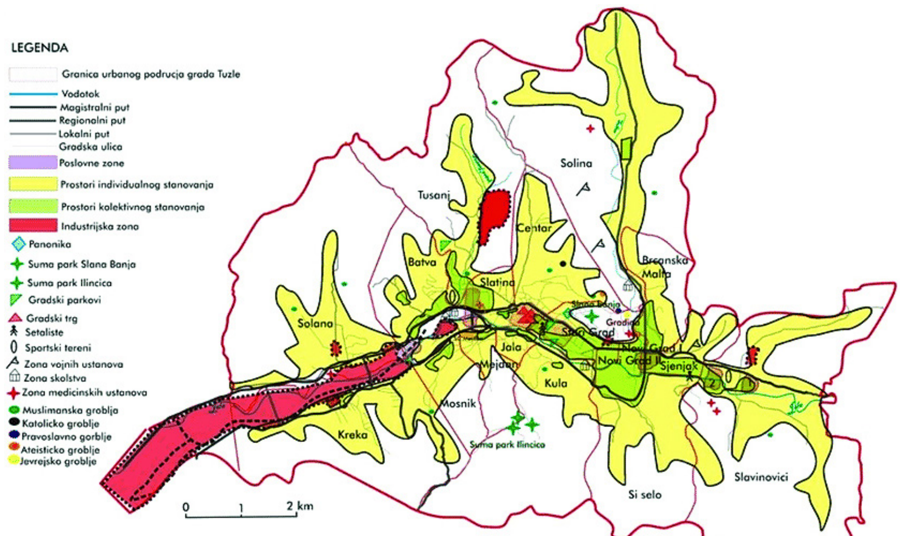
1. Current heating situation in Tuzla

1.1. Heating system (combined heat and power plant (CHP) Tuzla + area outside of the grid)

Tuzla is a city in the north-eastern part of Bosnia and Herzegovina (BiH). It is the seat of the Tuzla Canton and is the economic, scientific, cultural, educational, health and tourist centre of north-east Bosnia. The 2013 census identified a total of 110,979 inhabitants in the municipality, of which 80,575 were living within the city limits and 30,409 in the suburbs.

The following map shows the zone reserved for central functions (administration, retail) in green, residential zones in yellow, industrial zones in red, and some violet zones reserved for commercial activities other than industrial ones.

Figure 1: Overview of land use



Source: Bećirović and Kudumović Dostović[1]

1 Functional-spatial structure of the city Tuzla. Source: Topographic Map, Sheet Tuzla, 1977; Proposal of the Spatial Plan of the City of Tuzla 2010-2030, Institute for Urban Planning of the City of Tuzla, Tuzla, 2011; Field research conducted from October 2010 to March 2011 in the territory of the City of Tuzla, documentation available to local communities. Almira Bećirović and Fadila Kudumović Dostović, Basic features of modern functional-spatial structures of Tuzla city, *Acta Geographica Bosnia et Herzegovina 6*, no. 12, December 2019.

The settlement structure of the entire local administration unit of the city of Tuzla can be roughly subdivided into two types:

- the central part, characterised by a historic city core and dense residential block buildings mixed with retail and services
- residential quarters, characterised by small family houses built in mostly linear structures with a rather high settlement density on the outskirts

From the administrative viewpoint, the city of Tuzla is accordingly subdivided into the city area and the outskirt neighbourhoods ('other area outside the Tuzla city limits').

The population of Tuzla has been forecasted to grow moderately to 85,404 (+6 per cent) by 2030, and to 92,660 (+15 per cent) by 2050.[2]

Household size in Tuzla's residential buildings that are connected to district heating (2019) is 55 square metres and 3.1 persons per household,[3] which is below the Bosnian average of 3.41 persons per household (2013).

1.1.1 Heat production – CHP Tuzla

Tuzla has the largest district heating system in Bosnia and Herzegovina based on cogeneration. Heat is produced in units 3 and 4 of the coal-fired power plant, which also supplies heat to the town of Lukavac. The energy sources, lignite and brown coal, are supplied from the nearby Banovici-Kreka coal basin. Units 3 and 4 will have to be closed by 2023 according to BiH's pollution control commitments under the Energy Community Treaty.

The public energy supply company Elektroprivreda Bosne i Hercegovine (EP BiH), owner of the cogeneration facilities, plans to build a new 450 MW unit 7 which would replace units 3 and 4 of the existing plant. According to its environmental permit, the new Tuzla 7 unit will breach the binding emission limits set by the EU.[4] BiH is also in danger of sanctions from the Energy Community due to claims that the Tuzla 7 project received illegal state aid. The Energy Community Secretariat initiated a dispute settlement procedure in March 2019 against BiH.[5] In addition, as BiH is a candidate for potential EU membership, the European Commission regularly monitors the policy progress achieved in BiH.[6] The 2020 progress report states that in the area of energy, some of the measures introduced, including unit 7, represent a step in the wrong direction.

BiH needs a better solution than this infringement of international obligations and heavy impairment of the regional environment.

Currently, modernisation of the existing unit 6 is also under preparation. This unit could also supply heat through the revitalisation of the unit's turbine. This measure includes the installation of new equipment at unit 6. The reconstruction aims to extend the life of the turbine with increased efficiency, reliability and power capacity.

1.1.2 District heating system

The Tuzla district heating system is operated by **Centralno grijanje d.d. Tuzla** (CG), a company founded by the municipality of Tuzla.[7]

2 Worldometers.info, Bosnia and Herzegovina population, last accessed 17 June 2021.

3 Tuzla District Heating System, Tuzla, Bosnia and Herzegovina, *Global District Energy Climate Awards*, last accessed 16 July 2021.

4 CEE Bankwatch Network, Planned coal power plants in the Western Balkans versus EU pollution standards, June 2017.

5 Vladimir Spasić, Update: Site for coal project Tuzla ready as Energy Community hints at sanctions, *Balkan Green Energy News*, 28 October 2020.

6 European Commission, Bosnia and Herzegovina 2020 Report Accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – 2020 Communication on EU Enlargement Policy, 6 October 2020.

7 Upgrade DH, Tuzla, Bosnia and Herzegovina, last accessed 17 June 2021.

Since the deep grid reconstruction and modernisation of network pipes and heat substations in 2005,[8] the system has reached an annual **heat carrying capacity of 300,000 MWh_{th}**.[9] Instantaneous power grew to a net capacity of **220 MW_{th}**. Heat is delivered for room heating purposes only at a **flow temperature of 130°C and a return temperature of approximately 60°C**[10] (at a nominal pressure of up to 25 bar and at -17°C outdoor air temperature and steady fluid flow[11]). Drinking water is heated locally. In the past few years, the installed capacity has risen to **240 MW_{th}**. Under normal conditions, heat is delivered all day, including at night; but at times, heat demand cannot be fully covered.

The system is closed, meaning that all hot water delivered from the Tuzla power plant is returned to the plant after energy transfer at individual substations. The overall transmission network length has grown to **19.6 kilometres**, and the **total length of the distribution network** is **170 km**.[12] The diameter of the pipes range between DN 600 and DN 250.[13] Heat supply is in operation only during the heating season (about half of the year).

Around **80 per cent** of Tuzla's **heat consumers** are connected to the district heating grid. This very high share would allow for an outstandingly rapid switch from a high-emission town to a model town for clean heating with the switch to renewable, clean fuel. There are around **900 heating substations**. The total heating area is **1,732,660 m² of floor space with 23,200 customers (almost 90 per cent households and 10 per cent commercial customers)**.

The 2011 heat grid development plan foresaw the enlargement of the grid in several areas, most of them moderately to densely populated (shown in pink in the map below). Some of these areas were also planned for residential and commercial construction.

Figure 2: Map of district heating enlargement

Source: Upgrade DH[14]

8 Tuzla District Heating System, Tuzla, Bosnia and Herzegovina.

9 Ibid.

10 According to more recent information. In 2017, heat temperature was 145/75°C. Tuzla District Heating System, Tuzla, Bosnia and Herzegovina.

11 Upgrade DH, Tuzla, Bosnia and Herzegovina.

12 Ibid.

13 Ibid.

14 Ibid.

The annual heat consumption of a district heating-connected household in Tuzla – 116 MWh in 2020 and 2021 – is **much lower than the national average** of 295 MWh in 2019. This difference seems to be caused by a number of factors:

- combination with other heat sources in households; electrical heaters and wood stoves might be in use in apartments connected to the grid (43 per cent)
- limited peak capacity of district heating limiting heat sales on cold winter nights (5 per cent)
- limited time of district heating operation (6 months) (10 per cent)
- below-average household size in the city of Tuzla (10 per cent)
- a more efficient building stock (above-average share of multi-story residential blocks) (10 per cent) (NB: this is a comparison of useful heat not including losses at the heat source and during transport).

Tuzla District Energy System (2017)[15]	
Heat carrying capacity	300,000 MWh_{th} p.a.[16]
Flow/return temperature	130° / 60° C
Network length	19.6 km
Length of pipes installed	142.2 km
Users (households/public/commercial)	22,934 (20,979/156/1,799)
Floorspace heated (households/public/commercial)	1,718,787 (1,158,402/220,460/339,925) m^2
Throughput	2,340 m^3 - 2,800 m^3 per hour
Differential pressure	16.1 bar

The present heat grid was designed for 220 kW, and therefore its presently installed capacity of 240 kW sometimes causes hydraulic issues. The eastern part of Tuzla is characterised by a long heat transfer distance, and hydraulic issues therefore become apparent mostly in the eastern parts of the city. Pressure in the supply line is markedly higher than in the return line.

To solve these problems, the operating company investigated the possibility of installing big heat pumps at some important exchanger substations. Heat pumps should help to reach the needed temperature even at peak time, when the central source cannot deliver enough heat to these parts of the grid.

1.1.3 Pricing

In BiH, the **current price of thermal energy is not based on actual costs** and most district heating companies are subsidised by local governments. Decision-making is locally driven and differs substantially depending on the location. There is no independent regulatory authority, and the tariff methodology, calculation and approval is established at the canton and municipal levels. The prevailing form of billing for heat energy is a flat rate per square metre. In order to motivate and educate people to save energy, the introduction of a consumption-related pricing scheme with heat metering for each customer and thermostatic radiator valves in all heated rooms is necessary.

In Tuzla, **heat prices are low**, and such low prices are needed to avoid the energy poverty of a large proportion of the population. Most countries resolve such problems by a switch to cost-recovering market prices in conjunction with subsidies paid out to socially vulnerable groups.[17] It is often cheaper for the public

15 Tuzla District Heating System, Tuzla, Bosnia and Herzegovina.

16 Heating season 2020/21: 304 000 MWh, according to oral information provided by A. Husić, CG Tuzla

17 Majda Tesanović and Jasna Hivziefendić, 'Survey of Energy Poverty in Bosnia and Herzegovina', in *Advanced Technologies, Systems, and Applications IV -Proceedings of the International Symposium on Innovative and Interdisciplinary Applications of Advanced Technologies* (IAT 2019), 126-136.

to fund energy refurbishment than energy bills, and thus subsidising heat for everyone is an inefficient use of public funds. If a smart funding programme could address insulation, this could become the backbone of the modernisation of the entire heat system of Tuzla.

1.1.4 Energy efficiency of buildings connected to the grid

The retrofitting project launched in 2011 led to a system capacity of 2,300 m^3 per hour,[18] whereas the required flow to fulfil the heating demand of the connected homes, public and commercial buildings and other facilities is closer to 2,800 m^3 per hour. The shortcomings of the system were especially felt on winter mornings, when the inhabitants awoke to cold rooms. In order to maximise system efficiency, raise the level of end-user satisfaction and improve the stability of the system, the local heating company decided to gradually **modernise and replace most system components**, from substations to energy meters in individual homes.[19]

The following **goals** were set for the renovation:

- apply low-temperature district heating to existing and new buildings in the network
- distribute heat with minimum grid loss
- recycle heat from low-temperature sources and integrate renewables, e.g. solar and geothermal heat
- implement a smart energy system, balancing demand and supply at all times
- ensure suitable planning, cost and motivation structures to achieve a sustainable energy system[20]

Despite some success achieved, these goals have not been reached yet. To date, the supplied buildings are by far not as energy efficient as they should be because of low energy prices

1.1.5. Area outside the heating grid

The heat grid reaches all densely populated parts (and even many moderately densely populated quarters made up of one- or two-story family houses) of the city of Tuzla.

Some parts of Tuzla cannot be efficiently connected to the municipal heat grid. They are characterised by low settlement density, often unclear ownership rights, complicated altitude parameters and often also by some intersections of agricultural and forest land which would have to be crossed in order to reach the settlement. The predominant type of buildings there are small-size family houses. These areas consist of approximately 5,500 households.

There are also buildings which, for different reasons, were never connected to the heat grid although they are located close to it, and others which were connected but have stopped buying heat from the grid. The municipal heating company estimates[21] that at present, out of the 27,000 households located in the city of Tuzla,[22] approximately 6,000 households (14 per cent) are not taking any heat from the grid, either because they are out of the district heating zone or because they have stopped buying heat.

The remaining households in the city of Tuzla are customers of Centralno grijanje d.d. (86 per cent). They inhabit almost all the town's multi-story residential blocks, mostly characterised by a lower annual heat energy consumption than in family houses. One may therefore assume that **approximately 82 to 84 per cent of the final heat energy consumption** of Tuzla's private households comes from heat provided by the central heat grid. If the heat grid were to be extended, land for new residential development could also be connected to it.[23]

18 Danfoss, Renovation of a district heating network, Tuzla, Bosnia and Herzegovina, *Danfoss*, 25 November 2016.

19 Amer Karabegović, managing director of the Tuzla District heating company, in Danfoss, Case story - Ambitious renovation of Bosnia and Herzegovina's largest CHP district heating network, *Danfoss*, 2016.

20 Danfoss, Case story - Ambitious renovation of Bosnia and Herzegovina's largest CHP district heating network.

21 Information provided in March 2021 by A. Husić, Centralno grijanje d.d.

22 AdminStat, Maps, analysis and statistics about the resident population, accessed 10 March 2021.

23 The area in the south from Kula covering Đure Đakovića a Vukovarska, south of King Abdullah Bin Abdullah Mosque to Richmond Park College, including a development area and extending to the EP buildings and further to the west; area of Luke Mondzakovać; area near former Technograd north of Slavinoviči; area from the Tax Office to Krojicica, the western part north of the river Jala, Hudec; Batva; Dragadol; an area in the north near Dzemala Mandzica; Tušanj.

2. Analysis of the potential for alternative heating solutions

2.1. State of the art in heating

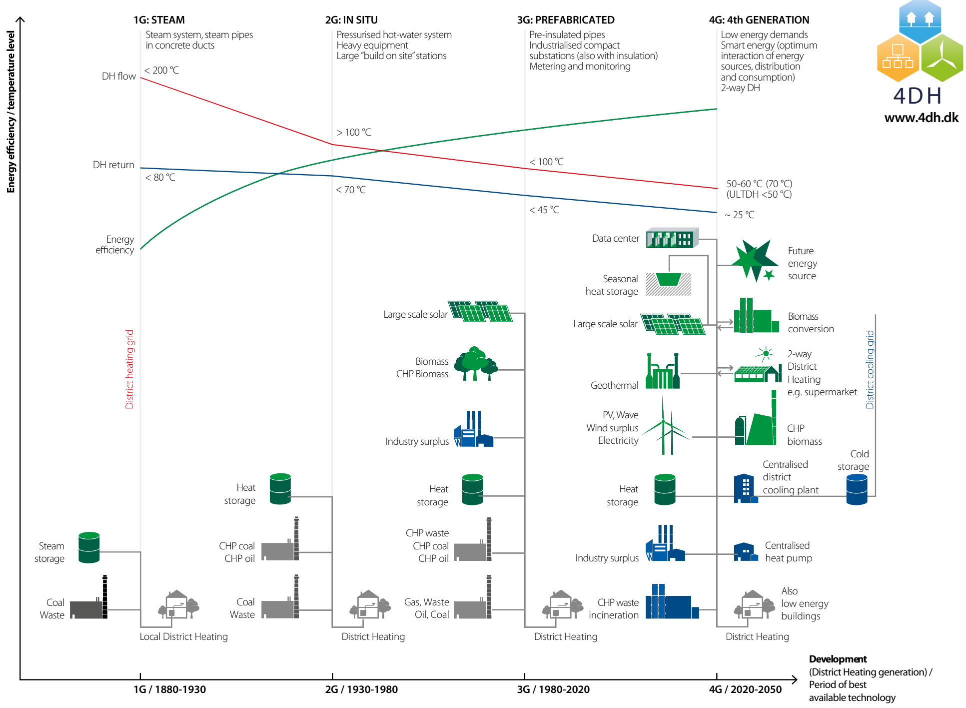
Despite the constantly decreasing heating density of urban settlements thanks to the growing quality of building shells, the total number, size and supply density of district heating networks have experienced strong growth in many central and eastern European countries. A main reason for this trend is the emergence of new technological solutions allowing for the storage of heat collected in summer and for the combination of district heating with district cooling. District heating is particularly favourable in climate zones with both cold winters and hot summers, and locations in which an efficient heat storage facility is available or can be built. Both criteria apply to Tuzla.

The currently available best technology for district heating systems is often characterised as **fourth generation district heating** (4GDH) in expert literature.

In order to be classified as fourth generation, a district heating system must meet the following requirements, according to a review by Lund et al. (2014)[24]:

- ability to supply low-temperature district heating for space heating and domestic hot water to existing buildings, energy-renovated existing buildings and new low-energy buildings
- ability to distribute heat in networks with low grid losses
- ability to recycle heat from low-temperature sources and integrate renewable heat sources such as solar and geothermal heat
- ability to be an integrated part of smart energy systems (i.e. integrated smart electricity, gas, fluid and thermal grids) including being an integrated part of fourth generation district heating systems
- ability to ensure suitable planning, cost and motivation structures for operation as well as for strategic investments related to the transformation into future sustainable energy systems

Figure 3: 4G district heating



Source: Thorsen, Lund, and Mathiesen[25]

24 Henrik Lund et al., '4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems', *Energy* 68 (2014): 1–11.

25 Jan Eric Thorsen, Henrik Lund, and Brian Vad. Mathiesen, 'Progression of District Heating – 1st to 4th generation', 2018. https://vbn.aau.dk/en/publications/progression-of-district-heating-1st-to-4th-generation-3

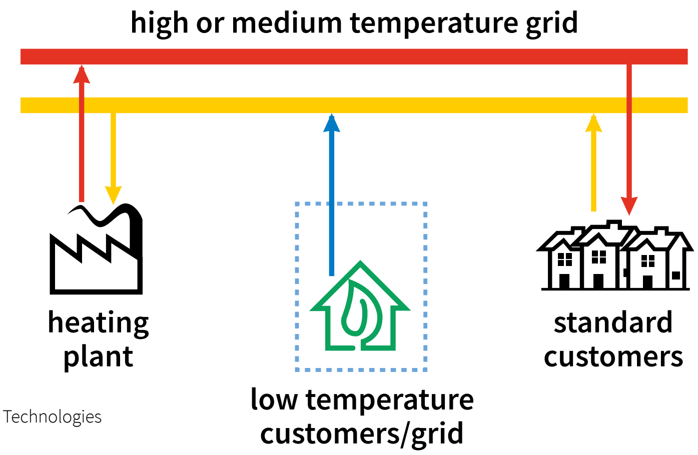
The current heating system in Tuzla is a **second generation** one. As a principle, one should always evaluate investment alternatives starting from the latest reliably available technology, falling back to earlier technological solutions only in well-justified cases, for instance if a location cannot secure the required level of technical maintenance expertise, which certainly is not applicable in this case.

A **fourth generation district heating** network necessarily is connected with the **highest possible building insulation standards**, to restrict the amount of heat needed, integrated with smart electric networks, to balance the demands on the electric grid by using the thermal mass of buildings to store heat and to **restrict demand for electricity** when there is supply pressure on the grid.

Low-temperature district heating

Low-temperature district heating, with flow temperatures below 65°C, is becoming more popular for customers with low heat needs. The advantage is that heat losses in the pipes are lowered and that polymer pipes can be used. Additionally, low temperatures offer much more favourable conditions for the integration of other low-temperature (or partially low-temperature) heat sources such as solar thermal installations, heat pumps or waste heat from industry. At a low temperature level, Legionella bacteria could be a problem. Thus, additional devices such as heat exchangers may be needed for hot water supply. Low-temperature systems can also be used as subsystems in high or medium temperature grids and can also include hot drinking water preparation into heat pump operation.[26]

Figure 4: Usage of return temperature for low-temperature customers/grids



Source: Güssing Energy Technologies (GET), leaflet, 2019

The return pipe can be used as the flow pipe for the low-temperature system. After using the heat, it can be returned to the return pipe. The advantages of low-temperature district heating are that the grid heat loss is lowered, which gives energy savings and lowers fuel costs. Low-temperature systems are **not considered more expensive to build** than conventional district heating. For example, in Austria there are low-temperature grids established with constant flow temperatures of 55°C during the whole year. Only buildings with low energy needs (floor heating or low-temperature radiators), in dense areas where no long distance pipes are needed, are connected.[27]

2.2 List of sustainable policy conceptions for fourth generation district heating locally available when considering legal restrictions such as nature conservation (technical potential)

Fourth generation district heating is too complex to treat as a single energy project, but it has the character of a municipal heat concept. It requires the will to comprehensively redesign urban heat policy. When a complex large infrastructure solution reaches the end of its life cycle, a window of opportunity appears.

26 Michael Kropp, Oliver Hörnle, Stefan Hess, Jeannette Wapler and Manuel Lämmle, Einfluss der Trinkwarmwasser-Systemvariante auf die Performance von Wärmepumpen in Mehrfamilienhäusern, ed. Albert-Ludwigs-Universität Freiburg, Institut für Nachhaltige Technische Systeme – INATECH and Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg, 2020, accessed 22 December 2020.

27 Gregor Goetzl, Geologische Bundesanstalt and AIT, DEGENT-NET Dezentrale geothermale Niedertemperatur-Wärmenetze in urbanen Gebieten, 2017, accessed 10 Nov 2020.

Most cities never reach this point, as they always operate infrastructure systems which have been gradually upgraded over time, and so the switch to fourth and fifth generation heat systems is mostly connected with the closure of a mine or the end of an older central heating system.

The phased end of coal firing in Tuzla, however, is a chance to redefine the city's entire energy infrastructure, using the existing power plant and the heat grid as valuable structures which can be given a new role. This location is the optimal place to implement a European model solution for an integrated, highly efficient, user-friendly and fossil-free energy system with a mid-term payback perspective. Apart from exceptional cases, such a system cannot be built on one energy resource alone.

The measures recommended for the heating sector can be subdivided into two parts:

- **the area reached by the central heat grid,** in which the suggested measures will cover the replacement of the heat source, the modernisation of the heat grid and its controlling and monitoring, as well as energy efficiency measures in the building stock.
- **the area not reached by the central heat grid,** in which the suggested measures will cover the building of independent microgrids, the modernisation of local heat sources and energy efficiency measures in the building stock.

2.2.1 Supply side

Heat supply from central coal-fired boilers should be replaced only by energy sources which are compatible with the international commitments Bosnia and Herzegovina has made. However, BiH has no consistent underlying strategy. On the one hand, it has signed the Green Agenda for the Western Balkans, committing to adopt the EU's climate law and therefore reach climate neutrality by 2050.[28] However, its second Nationally Determined Contribution is nowhere near this ambitious. BiH's unconditional greenhouse gas emissions reduction target for 2030 is 12.8 per cent compared to 2014, or 33.2 per cent compared to 1990. Its target for 2050 is 50.0 per cent compared to 2014, or 61.7 per cent compared to 1990.[29]

The gradual closing of the Tuzla heat plant creates a window of opportunity for a sustainable switch to renewable sources. The study therefore applies the principle that using fossil fuels is in no way an option for the future heat supply of Tuzla, as they are to be completely phased out in the coming years. In addition, when applying an integrated analysis covering the economy, climate policy, resource policy and protection of the environment, certain technologies and approaches, such as waste incineration, can in no way be recommended for Tuzla. It is a widely acknowledged principle in the field of resource economy that the priority should be given to waste reduction.

Based on the most recent state-of-the-art **technology, the following technologies are available for sustainable heat production in Tuzla:**

- solar heat
- heat storage in the salt mines
- geothermal and ambient heat for the operation of heat pumps
- biomass
- green electricity used for the operation of heat pumps and the heat grid, produced by photovoltaic panels, cogeneration plants running on renewable sources, and to a smaller extent, wind

28 Regional Cooperation Council, Sofia Declaration on the Green Agenda for the Western Balkans, 10 November 2020.

29 Nationally determined contribution of Bosnia and Herzegovina for the Period 2020-2030, *United Nations Climate Change*, April 2021.

A method such as a cost-benefit analysis should be used to select the most appropriate solution from among these approaches. Such a cost-benefit analysis should follow the rules laid down in the official EU guidance on cost-benefit methodology.[30]

2.2.2 SWOT analysis – comparison of alternatives potentially feasible for the area reached by the heat grid

1) Baseline case: coal-fired TPP7 with use of the existing coal-fired unit 6 until its completion

This option was included in the long list of options to allow for comparison, because decision makers will compare all more sustainable options with the scenario of the building of TPP7. For the political sector, the TPP7 option is easy to administrate, as there is one site, one permit procedure and one investor, and heat purchase contracts can treat heat generation almost as a 'turnkey' solution, whilst all other options require frequent and complex decision-making and patient explanation of reasoning. As TPP7 can start operation no earlier than 2025 and unit 4 has to go offline by the end of 2023, the investor would need to refurbish the existing unit 6 in any case.

2) Waste incineration + solar thermal + plus smaller separate biomass CHP + smaller solar power and heat generation with small heat storage and some decentralised heat-pumps + co-firing to ensure good combustion + building efficiency programme

This option was included in the long list as waste incineration is technically possible and well established.

Waste is generated continuously, while heat demand is seasonal, which will either require seasonal storage of waste or a combination with a second energy carrier such as biomass.

The region cannot generate as much municipal waste as would be required to operate the existing heat grid of Tuzla. Once built, a waste incineration plant will need to keep the energy content of waste high, which is likely to jeopardise waste avoidance, reuse and recycling of energy-rich fractions. Once built, the plant operator will also be eager to keep heat demand high, which will not support the climate needed for efficiency measures. Moreover, waste incineration requires strict and costly pre-treatment and supervision of municipal waste in order to keep emissions within legal limits and to avoid any necessity of fossil co-firing because of temporarily low energy content.

Municipal waste and locally harvested biomass alone cannot fully cover the heat needs of Tuzla, and long-distance waste import must be avoided.

3) Biomass CHP + ambitious building efficiency programme + support for decentralised RES generation and heat pumps (short name: 'biomass')

A biomass power station alone without an energy efficiency plus renewables programme would not be a reasonable solution for Tuzla, as with rising energy costs energy efficiency will have to be improved over time. If large-scale efficiency measures start before the building of the biomass plant, a smaller total capacity can be built. Even in this case, some efficiency measures will take longer than the biomass plant will take to be completed; the measures will also reduce demand by approximately 10-20 per cent within a decade, which can be compensated for by grid enlargement.

A biomass scenario without any energy from waste or fossil sources is generally possible and therefore was included in the comparison. It would be rather demanding, however, to acquire enough biomass to continuously supply the Tuzla heat grid. Such high biomass demand would lead to a rise in biomass prices, would exert pressure on forest owners to overexploit regional forests, and might lead to a supply shortage of other biomass projects in the region. Most of all, there is a danger that long transport distances will spoil the climate and energy balance of a solution built on renewable sources.

30 European Commission, Joint Research Centre, Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level, 2015.

The distribution technology in this scenario is a third generation district heating system. It is nevertheless recommended to operate certain sections of the heat grid at a lower temperature and to build short-term (and, wherever possible, also seasonal) storage tanks (ice storage, water or brine storage). As disused power plants would be available, it would only be logical to build a biomass-fired combined heat and power plant there, making use of existing structures.

4) Solar thermal + seasonal subsurface storage + fourth generation district heating line + heat pumps + ambitious building efficiency plan (short name: 'fourth generation DH')

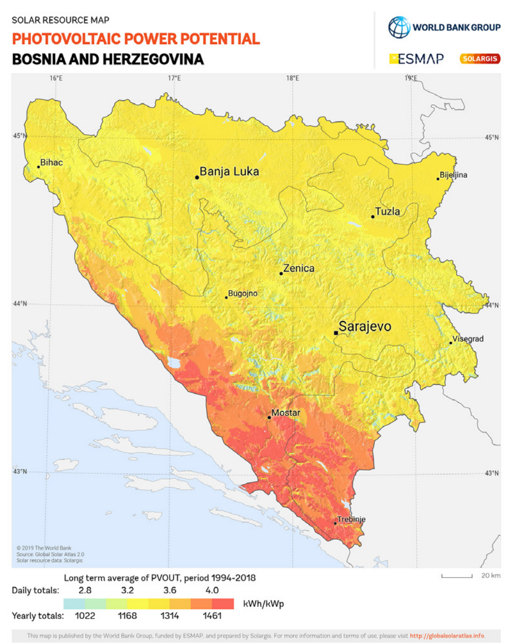
A solution based on the highest possible use of solar energy was also included in the list. The highest realistic solar energy potential is a scenario which does not foresee solar thermal panels at a major distance from the heat grid, and which does not foresee installations (in particular PV panels) in locations impeded by temporary shade between the late morning hours and the late afternoon. Moreover, it was assumed that valuable agricultural and horticultural land would not be used for large-scale solar installations.

According to this survey, annual solar irradiation in Tuzla is around 1,350 kWh per annum, which creates very good conditions for the efficient and profitable use of solar irradiation for energy conversion.

When **installing solar thermal panels** on rooftops wherever it is reasonable, the total estimated generation of the solar thermal portfolio in Tuzla could reach up to 310,000 m^2 (187,000 GW$_{ht}$ per year) with 106 GWh produced on rooftops, and in the existing power plant area another 81 GWh could potentially be produced.

Should houseowners be reluctant to install solar thermal panels, the city can increase the share of other renewable sources, build a central big solar thermal installation on a brownfield with good solar exposition, or deploy a user-friendly turnkey solution for house owners: for example, the heat supplier CG might rent rooftop space and build and operate installations for a period of 10 to 20 years, before ownership of the installation is transferred to the houseowner.

Figure 5: PV power potential, Bosnia and Herzegovina



Source: Global Solar Atlas[32]

The most suitable locally available renewable source for electricity generation is photovoltaics (PV). Favourable solar irradiation, space for panel installation available at low cost, and low levelised costs of energy (LCOE)[31] support this recommendation. The PV potential for Tuzla according to Solargis is approximately 1,100 kWh/kWp.

If a certain part of the power foreseen for heat pumps is produced not by PV but by wind-turbines, this would not strongly affect the overall evaluation of the option. A mix of solar and wind leads to a steadier electricity supply timeline (adding night hours, for instance) and might therefore be reasonable.

The aim should be to produce as much additional electricity from renewable sources annually as the operation of the heat grid, including heat pumps and electric heating of domestic drinking water, will require.

31 The levelised costs of energy (LCOE) are calculated as the ratio between all the discounted costs over the lifetime of an electricity generating plant divided by a discounted sum of the actual energy amounts delivered. Chun Sing Lai and Malcolm D. McCulloch, 'Levelized cost of electricity for solar photovoltaic and electrical energy storage', *Applied Energy* 190 (2017): 191-203.

32 Global Solar Atlas, Bosnia and Herzegovina, accessed 20 July 2021.

Even if both resources are intensely exploited, very ambitious efforts to achieve the lowest possible annual heat demand, low peak demand and low flow temperature will be necessary. The solar scenario is inseparably connected with a highly ambitious efficiency strategy. All new construction and building refurbishment would have to comply with or come close to the standards of passive architecture, and all possibilities to locally produce and store heat and power would have to be used.

The estimated potential for solar thermal energy is shown below. As the exact borders of the city quarters were not available, locations are described by dominant street or location names of the respective quarters.

Table 2: Potential for solar thermal and PV installation on rooftops and present and future brownfields

Areas in the city of Tuzla	ha	GWh/a	TJ/a
TPP7	12	72	259
Existing units 1-6	1.5	9	32
Block Husinskih rudara–Mitra trifunića uča, east of Petrol miladije–Soli uča	1.2	7	26
Jala-Bosne Srebrene (incl. bus station)–Univerzitetska	0.8	5	17
Roofs above private DH supplied houses with sunny orientation	14	84	302
NRW, Francuz	0.07	0	2
Eastern Tuzla Muzeum	0.03	0	1
Solina	0.12	1	3
Klinika Aleksa Santića	0.24	1	5
Put križani	0.16	1	3
Dramar Centar near Jala	0.02	0	0
Klinički centar Put Gradina	0.06	0	1
Konzum Family Centar plus further objects	0.05	0	1
Singularija-Tržnica Tuzla	0.19	1	4
SPKC Mejdan Bosne Srebrene	0.72	4	16
Total hectares on roofs + at the power plant site	**31.16**	**187**	**673**

Source: Author's own research

The roofs of private houses with a sunny orientation outside of the limits of the district heating zone could theoretically produce considerable quantities of solar heat but would pay off less well as there would be excess heat in summer which might not be fully utilised. An additional harvest of 38 GWh_t per annum could be generated by these off-grid rooftops.

In addition, it was assumed that the following PV installations could be built:

- 0.3 hectares of solar anti-noise barriers north of the motorway M4 Šički Brod
- 0.5 hectares of PV installations on parking lots
- 7 hectares of ground-mounted solar thermal panels or PV in Durići northeast of the Termoelektrana

PV would bring an annual electricity yield of **approximately 90 GWh**. Heat pumps with an average coefficient of power of 3.5 could produce an annual net output of 315 GWht, which translates to 1,134 TJ/a.

Thus, it is possible to **cover the heat and cooling needs of Tuzla from solar thermal panels on rooftops, and on some brownfield and noise protection walls, by covering the mentioned roofs and areas with panels** (205 GWh in the district-heated area + 5 GWh outside).

Whilst such measures would not yield attractive payback for house owners under the present conditions in BiH (low heat prices), seasonal storage should be foreseen to improve payback. A net storage capacity of approximately 50 per cent of the annual demand would be required to allow heat supply throughout the winter supported by heat pumps. The required gross storage capacity including storage losses would be a maximum of 125 to 135 GWh (needed each year in September). Seasonal storage cannot be financed from revenue achieved by storage, but will have to be heavily funded. **As seasonal storage in former salt mine caverns and shafts would be highly innovative and would have an excellent climate balance, it is realistic to assume that there would be funding available for this option in the framework of European coal exit plans.**

Heat storage in brine in disused salt-mines

Salt is an excellent heat storage medium. One cubic metre (m^3) of salt can store as much heat as approximately 10 m^3 of water. Caverns remaining after salt mining are voluminous, which often attracts the attention of energy companies seeking pump storage opportunities.

The Tuzla salt mine

The mono-mineral rock salt found at the deposit Tetima is made of halite and anhydrite mixed with marl belt, while the bay of salt in Tuzla is polymineral and contains a considerable amount of thenardite (Na^2SO^4) and rare minerals.[33] Salt mining in Tuzla employs approximately 200 workers and is a profitable business.[34] The extraction of rock salt from the Tetima deposit is performed by controlled leaching in underground chambers positioned deeply in the salt deposit.[35] The length of the saltwater pipeline is 2.4 kilometres.[36]

The Tuzla mining caverns have been exposed to subsidence since the 1950s. The latest precision measurement has shown that recent anti-subsidence measures were successful, except for in the north and northeast portions of the Pannonica Lake where the rate of subsidence was −1 to −4 cm/year during the period from October 2014 to May 2019.[37]

33 Amir Sušić, Amir Baraković and Snežana Komatina, 'Genesis of Tuzla salt basin', *Geophysical Research Abstracts 19*, EGU2017-17835, (2017).

34 Emina Rizvić, 'Salt Mine Tuzla expanded its Capacities', *Sarajevo Times*, 1 October 2016.

35 Almir Šabović, Sanel Nuhanović, Adnan Hodžić and Adnan Nalić, 'Problems of hermeticality of wells for leaching in "Tetima" massif and repairing construction in case of unhermetical column pipes 9 ⅝', *Archives for Technical Sciences* 1 no. 10:73 (June 2014).

36 Emina Rizvić, 'Salt Mine Tuzla expanded its Capacities'.

37 I.N.S. Parwata, N. Shimizu, B. Grujić et al., 'Monitoring the Subsidence Induced by Salt Mining in Tuzla, Bosnia and Herzegovina by SBAS-DInSAR Method'. *Rock Mechanics and Rock Engineering* 53: 5155–5175 (August 2020).

Energy storage potential of the Tuzla salt mine

The regular filling/emptying, heating/cooling or pressure increase/reduction of salt mines and their nearby aquifers can increase subsidence risk. With large parts of the mine located in or near inhabited areas, there would be a high risk of increased geological instability if the storage facility were built in a classical manner. But there is also a potential synergy: the former salt mines still cause damage to buildings by continued subsidence each year, and they bear a certain disaster risk.

Given that land prices in Tuzla are constantly increasing, there is a need for the geological stabilisation of the area. **On the other hand, stabilised caverns are needed for subsurface energy storage. It is therefore worth analysing the feasibility of a dual-use project combining sub-surface energy storage and ground level stabilisation. A heat storage facility in the local salt-mines could use brine as a highly suitable storage medium.** Its location right within the boundaries of Tuzla would allow for short heat transport distances.

The study should consider storage of heat in brine for extraction via a heat exchanger, and according to the season also direct extraction of brine of a suitable heat to an energy network.

Potential for subsurface gas storage in Tuzla indicates potential suitability for compressed air storage

In 2007, the Faculty of Mining, Geology and Civil Engineering studied potential sites for the storage of energy in Bosnia and Herzegovina. Out of a total of 30 mining sites investigated, the Tetima deposit near Tuzla turned out to be the most favourable location for underground gas storage (UGS).[38] One may assume it might also be suitable for compressed air storage, but with the mine located in a densely populated area, compressed air storage would have a considerable risk potential and would **require thorough geological research.**

Heat pumps

Heat pumps are increasingly used for room heating and cooling. They can absorb heat from a colder medium and transport it to a warmer one. They can utilise heat from waste heat sources, ground- and surface water, sewage water, geothermal water, ambient air, flue-gas and other locally available heat media. They require electricity input, but thanks to heat extraction from a medium, they produce heat much more efficiently than any electrical resistance heater.

Heat pumps are suitable under the following conditions:

- availability of a **heat medium** which cannot directly satisfy customer demands because of its low temperature level
- use in an input-output temperature range which allows a **high performance coefficient**[39]
- need for **heating and cooling energy in turns**: under certain conditions, a bidirectional heat pump can serve for air conditioning purposes as well
- availability of **renewable electricity** that is not too expensive for most of the operation time

It often is a good solution to allocate several heat pumps in a **cascade structure**.

In Tuzla, **ambient-air heat pumps** would be a good option wherever small, decentralised heat pumps will be needed.

38 Božo Tomić, Amir Sušić, Midhat Katanić and Sanel Nuhanović, 'Ležište kamene soli ''Tetima'', skladište tekućih i plinovitih ugljikovodika - sažetak istraživačke studije', *Zbornik radova RGGF Tuzla* 1 no. 33: 89-98 (2007).

39 Ratio between electrical power input and heat (or cooling) power output disregarding the input of the heat medium.

Big heat pumps in the MW range can either pre-heat water which is then heated up using heat from a big boiler or they can be used to heat up water received in the district heating grid (mid-pipe). This latter option will also be used for industrial customers who need a certain heat level which regularly exceeds the flow temperature at their part of the grid.

They work in single-family home neighbourhoods as well as in perimeter block developments and high-rise buildings. They emit noise, so in many cases 'silent' ambient air heat pumps will have to be installed despite their higher price.

Near the river Jala, there are certain locations where **groundwater** can probably be used as a heat source for small houses and perimeter block developments (not for more densely inhabited settlements). For the same type of buildings, ground probes can be an alternative. Ground collectors will be suitable for heat extraction only in exceptional cases.[40] The question of whether **heat extraction from the river Jala itself** is an option has to be investigated in an ecological analysis.

Heat pumps cannot only satisfy the heating needs of a single household; big heat pumps are also available and can be used for the heating of entire neighbourhoods and quarters.

Additional considerations in this scenario

In order to further contribute to payback, it was assumed that this option would include a **power-to-heat or power-to-heat-to-power component**. With just moderate additional investment, high revenue can be generated from buying electricity when it is cheapest, using it for heat-pump operation, storing produced heat underground if it should exceed current demand, using it later when heat demand exceeds solar harvest, and/or selling it as green electricity at times of high electricity prices on the European market.

In such a scenario it is good to have at least a **smaller biomass CHP** included in the grid so that its power generation unit can be used for high-price electricity production in peak times.

The following section presents the SWOT (strengths, weaknesses, opportunities and threats) characteristics of the above-described four options for the central heat supply of Tuzla.

40 More information (based on investigations in Germany) is available in: Stefan Hess, Raphael Vollmer, Jeannette Wapler, Martin Kleinstück, Constanze Bongs and Hans-Martin Henning, 'Ambient Heat Source Availability for Low-Ex Heating of Multi-Family Buildings', ed.: Albert-Ludwigs-Universität Freiburg and Fraunhofer-Institute for Solar Energy Systems, 2019.

Table 3: SWOT of options

	Strengths	Weaknesses	Opportunities	Threats
New coal-fired CHP plant TPP 7 together with minor support measures for local, decentralised RES and efficiency projects	+ investment costs	- LCOE - air pollution - slag/soil pollution - no incentives for innovative businesses - not EU compatible - no synergies supporting efficiency measures in the building stock	+ investors' liquidity remains untouched and can be used for other purposes, business opportunity for ailing coal industry	- significantly increased mortality and morbidity, emigration for health concerns - premature closing of plant because of increasingly strict environmental regulations - risk of bad payback if eco-tax implemented
Waste incineration + solar thermal + plus separate biomass CHP + smaller solar power and heat generation with small heat storage and some decentralised heat-pumps + co-firing to ensure good combustion + building efficiency programme	+ negative price of raw material	- must not replace regional efforts for waste reduction (saving use of resources, reuse) and recycling (residual waste has a low heating value) - health risk for workers and nearby dwellers - requires safe disposal of toxic fly ash and filter residues for which BiH does not have facilities	+ better than landfilling in some aspects (ground water, land use)	- jeopardises efforts for separation, recycling, reuse and reduction of waste - perpetuates a wasteful resource economy
Biomass-fired CHP replacing coal-firing; extensive energy efficiency programme **+ some support for decentralised RES generation**	+ carbon-neutrality is possible under certain circumstances + support for value-added chains	- particulate matter emission, ash	+ setting up of processing and logistics chains will support biomass heating all across the region incentive for short-rotation coppice use on set-aside land	- shortage of biomass nearby, long transport routes - particulate matter emissions - danger of supply shortage for local users elsewhere
Upgrade to 4G district heating with maximum solar thermal and PV installations, heat pumps, wind power, short-term and seasonal storage **+ ambitious building efficiency plan**	+ good LCOE in the best case + value-added chains – creation of highly qualified jobs with high export potential	- high investment costs (complex technology, licence costs for intellectual property)	+ pilot for the Balkan region	- risk of technical issues due to high complexity, risk of lack of qualified staff - danger of cost increase due to unexpected problems

Source: Author's own compilation

3. Recommended solutions

3.1 Fourth generation heating

In the subsequent analysis, the various alternatives were reduced to a short list of options which deserve further consideration in Tuzla based on their technical, economic and ecological potential. The following decision criteria were applied:

- consideration of CAPEX
- consideration of OPEX
- acceptance
- safety and security
- resource efficiency
- impact on the environment and climate

Each criteria was awarded a score ranging from triple minus (indicating highly unfavourable aspects of a project) to triple plus (the most optimal aspects of a project).

Table 4: Reduction of long list of options to a short list

	CAPEX	OPEX	Acceptance	Safety & security	Resource efficiency	Environment/ climate	Total
New coal-fired CHP plant TPP 7	-	- - -	-	- -	- -	- - -	-12
Waste incineration + RES programme	+	-	- - -	- -	- -	o	-3
Biomass-fired CHP replacing coal-firing; extensive energy efficiency programme + decentralised solar/heat pump programme	+	+ + +	+	- - -	+	+	+5
Upgrade to 4G district heating– solar thermal and PV installations, heat pumps, wind power, short-term and seasonal storage	++	+	+ + +	o	+ +	+++	+11

Two of the options remain relevant after their basic appropriateness for application in Tuzla has been roughly assessed. Out of these two options, **the advantage based on all criteria goes to option four – upgrade to an urban fourth generation heating system.**

It is possible to produce **all heating and cooling required for Tuzla exclusively from regionally available renewable sources**, but such a strategy will require the substantial engagement of all stakeholders involved:

- The present **energy input** for heating must be reduced by at least 50 per cent and the cooling energy need may grow moderately despite the growing market demand for air conditioning devices. Due to the low heat price, the thermal efficiency of the majority of the city's buildings is rather low, and therefore it is technically possible to achieve this cut. This measure will only be possible with the support of a massive funding campaign.

- **Solar thermal energy** would have to be exploited wherever technically possible and reasonable, in particular on the majority of flat rooftops and roofs with a south, south-east or south-west orientation not affected by shade around noon and in the early afternoon. It will also be necessary to build a large solar thermal or PV plant on the site prepared for TPP7, once a decision is taken to abandon this investment.
- In addition, a significant amount of **PV installations** would have to be built. PV and solar thermal on rooftops and urban brownfields alone will not suffice to produce all of the required energy. It will therefore be necessary to also exploit solar energy whenever noise protection walls are built, on other brownfield sites with no development plans, and on other barren land.
- It is likely that broad participation of houseowners will not be achieved. In such a case, **wind turbines** on hilltops would have to be built in order to produce the electricity required for heat pumps. They could be included in a power-to-heat-to-power concept in order to improve their economic performance.
- A small **biomass heat plant** could be built, preferably on the area of the existing coal plant, making use of the railroad connection, storage facilities and possibly parts of the CHP plant. If solar energy will be fully exploited, sustainably produced biomass from a catchment area of 30 to 35 kilometres around Tuzla will be sufficient. The less solar energy produced, the wider the radius of this catchment area will need to be.
- **Heat pumps** will have to play an important role in a district heating network which operates on low temperatures, but also for the area not connected to the network. It is assumed that the majority of these heat pumps will draw energy from ambient air, together with ground water and shallow geothermal heat wherever sites will allow this.

3.2 Measures for the area not reached by the heat grid

In the area that the heat grid does not reach, there are various **possibilities for improvement**:

- **microgrids:** Microgrids mostly cover one street, a group of residential blocks or the direct surroundings of a public building. The starting point for the planning of a microgrid is often the necessity to build or exchange a sewage line and/or road surface. Such an investment opens up a window of opportunity to install a small heat grid at comparably low cost. In many locations, it can be a good solution to operate a microgrid for some time, and to connect it to the main district heating grid at a later stage once energy demand in the grid diminishes as a consequence of efficiency measures and climate change.
- **energy refurbishment of buildings:** The principle that the best moment for energy efficiency measures is when the domestic heat source is exchanged should be respected. As efficiency measures aim at significant reduction of heat demand, a new heat source can be much smaller, more efficient and cheaper if its dimension is tailored to the building's energy demand after refurbishment. Energy efficiency measures should achieve high or even very high energy input savings. Once a façade or windows are refurbished, it is neither economically nor resource efficient to have the object refurbished a second time within the following two decades. In most cases, energy savings of approximately 50 per cent or more should be achieved. Measures should build on an analysis of the weak points of the buildings (e.g. an energy audit or thermographic capturing). Measures should allow for the operation of the building without air conditioning in summer.
- **exchange of the domestic heat source:** Small amounts of funding can enable the replacement of an old oil, coal, briquette or gas boiler with an efficient biomass boiler, where sustainable sources of biomass are available. Where low-temperature heating is an option and summer cooling is needed, heat pumps should be encouraged.

The city of Tuzla has introduced a funding scheme for clean heating measures in an effort to reduce air pollution. There is a very limited budget – the amount spent in 2020 was around BAM 600 000 and the planned amount for 2021 is BAM 1 000 000.[41] Through this scheme, the installation of heat pumps can be supported, and in units equipped with heat pumps, other energy efficiency measures can also be funded. Pellet heating and audits can be subsidised as well.[42]

A programme for the replacement of fossil-fuel-based boilers with heat pumps or efficient biomass boilers may be kept up for several years, and should be followed by a ban on the installation of new fossil fuel boilers. If this solution is communicated openly, acceptance would likely be high. Consumers will have enough time to replace their boiler with a funded biomass boiler or a heat pump. Public funding should be restricted to efficient sources using renewable energy sources and to heat pump technology applying strict rules on ecological minimum standards. Suitable heat sources are firewood from forest management, pruning residues, wood pellets, woodchips and wood and grass briquettes. Furthermore, in order to meet these standards the boilers must use low-emission boiler technology. Solar thermal panels should be used for hot water preparation wherever possible, rather than relying only on biomass. They can also be used for room heating in spring and fall. A city planning a funding scheme for local biomass boilers should support the building of biomass logistics chains in parallel. The availability of good biomass should not be a bottleneck in the transition phase: a sufficient, clean and reliable supply of pellets, wood and wood chips must be ensured continuously. The current municipal funding programme for heat pumps is a positive measure that should continue; however, the use of ambient air as the heat medium and electricity from the grid as currently supplied (with a high share of fossil fuels) must be addressed in order to make heat pumps truly efficient and ecological in the long run.

3.3 Energy efficiency measures (network + buildings)

It is widely known that prior to any investment in new heat sources and distribution systems, heat demand should be reduced through **efficiency measures**. In Tuzla, this applies even more, because:

- The heat grid is overburdened already (in particular in the eastern part of the city), and therefore efficiency measures should start as soon as possible.
- Efficiency measures allow the reduction of flow temperature without requiring wider pipe diameters.
- With current heat consumption at approximately 200 kWh/m^2, [43] the current efficiency of residential heating is low; it is evident that with many houseowners lacking financial liquidity, there is a backlog of efficiency measures necessary for good building maintenance.

Current **low heat prices** in Tuzla do not stimulate energy efficiency measures. The raising of the heat price, however, is not the only possible measure to motivate houseowners to invest in energy efficiency, and moreover, it would have several adverse effects:

- It would lead to energy poverty among elderly and socially weak citizens.
- It would motivate many energy customers to install electric heating devices in their homes or even cancel their district heat contracts and install another heat source. As a consequence, Centralno grijanje might run into economic problems despite higher prices. Once a houseowner has bought a new heat source, they can hardly be motivated to partake in energy efficiency initiatives, because their investment has not paid off yet.
- It would gradually shift real estate demand from the densely built-up parts of the city in the district heat supply area to the outskirts and suburbs, which is not desirable from the viewpoint of city planning.
- It would lead to even higher air pollution, and it is much harder to reduce air pollution from individual small-scale sources than from central power stations.

41 'Planirana sredstva u Budžetu Grada Tuzle za 2021.godinu oko 61,2 miliona KM', posted by RTV7 Tuzla, 30 January 2021.

42 Vladimir Spasić, 'Bosnia's Tuzla to allocate EUR 184,000 to reduce air pollution', *Balkan Green Energy News*, 15 June 2020.

43 Oesterreichische Entwicklungsbank AG, Energy Efficiency Finance II, Task 1 Energy Efficiency Potential, Country report: Bosnia and Herzegovina, 18, 2015.

A strategy to introduce a **heat subsidy scheme** in parallel with increasing heat prices would resolve the first problem but not the other three negative consequences of increased prices. The strategy should therefore also comprise soft loan funding for energy efficiency measures as a third element. Socially weak households threatened by energy poverty could be offered the funding of a part of their heating costs together with a soft loan for energy efficiency as a package. This two-pillar strategy (energy bill funding in connection with a soft loan) would contribute to a reduction of air pollution.

It is not easy, however, to design a strategy to keep citizens from installing local heating devices in rooms connected to district heating. For new construction and deep reconstruction, the city could impose mandatory connection to the public heat-grid in streets with district heat supply (to the degree that the grid will not be overburdened). For existing buildings which are not deeply refurbished, an obligation to connect to the heat grid is not reasonable. To a certain degree it should be possible to appeal to citizens’ ambition to protect the environment and climate, but other measures are not very realistic.

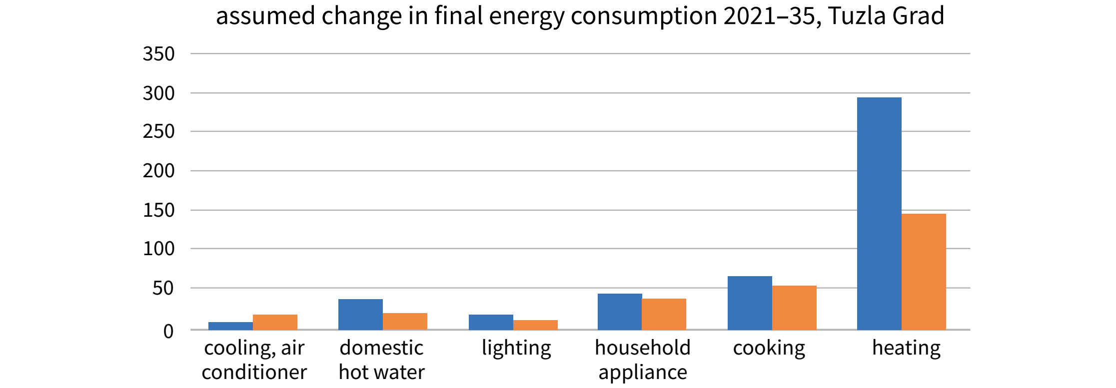
3.1.1 Rough estimation of the energy saving potential in heating and cooling (refurbishment of buildings, boilers, pricing systems and distribution grids)

Energy efficiency of buildings

The majority of citizens of Tuzla dwell either in large (often high-rise) apartment blocks or in small family houses. Unlike most European cities, the category of medium-sized apartment houses inhabited by 3 to 20 households is low. Family houses are often self-built, and construction is of varying quality. With respect to thermal efficiency, it is a strength of these houses that they are built close to each other – often directly connected to the neighbouring building. The surface-volume ratio is rather good. Most of these houses have a good potential for energy efficiency measures. Frequently, the upper ceiling lacks an insulation layer, for instance. Adding it can pay off quickly by a reduced heating energy bill. Outdated boiler technology, a lack of façade insulation and inefficient window panes are additional frequent shortcomings. The majority of the big apartment complexes are suitable for complex energy efficiency measures. Bosnia’s delay with respect to the insulation of residential quarters has a potential upside. In central and eastern Europe and parts of south-eastern Europe, many residential quarters were refurbished between 1995 and 2015 in an unambitious way, by inserting moderately efficient windows and doors, insulating facades with thin layers of polystyrene and neglecting summer heat problems. Learning from this experience, all these shortcomings can now be avoided. Thermal insulation of residential quarters should aim at a total reduction of 40 to 60 per cent of heating energy demand.

For the period until 2030, there are no quantified objectives yet, but plans will need to be more ambitious than they have been thus far. Ambitious efficiency measures are inevitable if Tuzla choses to implement a heat system based on renewable energy sources. For the purpose of the study, the targets in Figure 6 were estimated to be financially reasonable.

Figure 6: Potential for efficiency measures in the residential sector in Tuzla, 2021-2035



Source: Author’s own compilation

The above estimate builds on:

- the expectation that **more efficient** boilers, stoves, lighting systems, and other electric **devices** expected to enter the market in the upcoming years will be bought, replacing inefficient devices
- the assumption of **rising energy prices** in conjunction with increased citizen **awareness** with respect to energy saving, on the official economic growth forecast
- the introduction of precise **consumption metering**
- a **climate change** prognosis

It was assumed that final energy spent for air conditioning will double by 2035, and that in all the other categories, efficiency will increase: consumption for heating and hot water preparation is estimated to decrease to 50 per cent,[44] lighting to 60 per cent, cooking to 80 per cent, and consumption of other electric appliances to 90 per cent of the value assumed for 2021. The value for 2021 stems from trend extrapolation based on available statistical figures for 2002 and 2012.

Overall energy consumption in households is estimated to decrease to **61 per cent of the current value by 2035**.

For **non-residential buildings**, the efficiency potential was estimated only for their heating, air conditioning and hot drinking water demand. The further development of energy consumption for industrial processes could not be estimated due to a lack of available robust trend estimations.

It was assumed that from 2021 to 2035, the heating, air conditioning and hot water preparation demand of **public buildings** will decrease to **40 per cent** (from 18 to 7 GWh), considering the substantial backlog in building efficiency investment accumulated and assuming that in the upcoming years, BiH will commit to existing EU standards in this field. For **commercial and industrial** heating, drinking water preparation and air conditioning, a reduction from 39.8 to 28 GWh (i.e. to **70 per cent** of the present value) was assumed.

For the **local heat distribution grid**, a reduction of losses to a target value of 6 per cent was assumed.

Prosumer involvement potential

Legislative and financial incentives that would stimulate a local prosumer[45] culture are still missing. Public bodies have just started encouraging domestic renewable production (heat pumps). Nevertheless, there are many citizens who have already installed domestic solar thermal or PV panels; their problem is that there is no user-friendly possibility to sell surplus energy in the neighbourhood. For this reason, the number of early adopters is very low.[46] Such existing examples, if multiplied, integrated into a heat grid and accompanied by a seasonal heat storage facility, can be the backbone of a sustainable grid for heating and cooling.

3.3.2 Heat distribution network improvements – efficiency improvement potential of distribution of heating/cooling energy

Hydraulic optimisation of district heating via expert coaching

The eastern part of the city of Tuzla (in which around 60 per cent of the total demand is concentrated) has an insufficient available pressure difference, currently representing the main technical issue for the development of Tuzla's district heating system. Therefore, the challenge consists in determining how to

44 Except for the business sector, which will reduce consumption to 85 per cent of the value of consumption in 2021 because of expected economic growth and a more limited savings potential

45 A 'prosumer' is a 'producer-consumer' – this term is used for households both buying energy from the grid and selling self-produced energy to the local grid or microgrid.

46 For example, in a very small private pilot project, Tuzla citizen Reuf Altumbabić has demonstrated that such solutions are workable under domestic conditions. He installed a 17 kWp PV system which runs a 17 kWe heat pump. A heat exchanger resolves the transfer of produced heat to domestic heating and cooling. The owner found public enterprises reluctant to cooperate; he thinks they perceive prosumers as competitors. Altumbabić found out that his investment will be repaid within five years of its installation. Energetika.ba/N1, 'Domišljati Tuzlak prodaje struju', *Energetika.ba*, accessed 16 July 2021.

best improve the distribution and regulation system, also taking into account the projected additional load to be connected in the future. EP BiH and AGFW (the independent German Energy Efficiency Association for heating, cooling and CHP) have collaborated on an analysis of the current scenario, identifying various possible actions:

- Refurbishment of the main pipeline
- Supply temperature reduction
- Installation of temperature limiters at the users
- Installation of variable speed drive (VSD) pumps for the main network distribution

The implementation of such measures will enable a greater capacity to be available at the plant, enabling a better regulation flexibility while at the same time reducing primary energy demand and greenhouse gas emissions.

Installation of thermostatic valves at the users, coupled with the change to consumption-based billing

Currently, the vast majority of users are subject to surface-based billing (instead of kWh-based billing), so that only 15 per cent of flats within the Tuzla district heating system are equipped with thermostatic valves. This is a significant source of inefficiency in the system. Therefore, a pilot campaign of thermostatic valve installation has been carried out, as well as a communication and information campaign, in order to promote and assist a gradual change towards consumption-based billing.

The analysis will produce the following outcomes:

- field test benchmarking current regulation capability and consumption patterns with and without the thermostatic valves at the users
- sensitivity analysis on the technical and economic impacts of different regulation and payment schemes

Replacement of inefficient circulation pumps[47]

In order to improve the system's efficiency, a quick win strategy is to replace inefficient circulation pumps, producing significant benefits both in terms of increasing the network energy efficiency and reducing emissions and operating costs. For demand-response measures, see Cortés et al.[48]

Rough estimation of necessity of investment into power and heat grids

Deliberations about the investment required to upgrade the local heat grid should take place as soon as there is clarity about whether locally available underground storage capacities will allow for the switch to a fourth generation heat grid operating at low flow temperatures below 60°C.

The heat grid should be gradually transformed to a significantly lower operation temperature. In most cases, new pipes can be placed in the topographical position and depth of the previous ones. Lower temperature requires wider pipe diameters, but the reduced need for pipe insulation again reduces the diameter. Lower costs per linear meter of pipes are a major advantage of low-temperature heat grids.It should be analysed whether in some parts of the city, decentralised heat pumps will require reinforcement measures in the low-voltage electricity grid.

47 This upgrading measure and the following two were not developed specifically within Upgrade DH. They are the focus of other European projects (Horizon 2020 project 'BIOFIT') or internal activities at EP BiH and the Tuzla heat distribution utility, yet they are reported here to provide a complete picture of the full degree of retrofitting undertaken at the demo site.

48 Pau Cortés, Optimisation of district heating & cooling systems: D2.1: State-of-the-art, scenarios, requirements and KPI, Horizon 2020 project no. 649796, 28 February 2017.

4 Next steps needed in order to start implementing fourth generation heating in Tuzla

4.1 Regulatory and financial aspects, possible funding

Bosnia and Herzegovina should introduce a consistent climate and energy strategy. A clear national commitment would create security for foreign and domestic capital investment and for foreign and domestic funding institutions. The present strategy of expression of climate-related goals in parallel with energy consumption targets which foresee continued growth of emissions is inconsistent and cannot create the required trust.

A massive shift from coal to solar pays off quickly when the macroeconomic perspective is applied, because of the high costs caused by the pollutants and greenhouse gas emissions of coal-fired plants, because of high costs of coal mining and other external cost factors. Hence, most of the globally leading economies have introduced ambitious coal exit programmes. In the case of Tuzla, such a programme should at minimum consist of the following elements:

- requalification of staff formerly employed in the coal economy
- closing and demolition costs caused by mine closure and the closing of coal-fired plants
- investment costs for new power and heat supply solutions
- energy refurbishment costs needed to fully replace fossil heat with renewable heat

It would be recommended to create a funding scheme accessible for municipalities which commit to achieve a 50 per cent or higher reduction of energy demand for heating and cooling with the remaining demand covered solely by renewables. There would probably be a rather small number of municipalities which have the technical preconditions (subsurface storage possibilities, etc.) and the political will to participate in a programme with such an ambitious threshold, and so the programme would not have to foresee a budget for many cities and regions.

Investment decisions even if funded can be a barrier for many potential investors. To offer them a user-friendly alternative, a company ('single-purpose vehicle') should be founded which rents roof space and other areas suitable for solar thermal and PV installation and which then can plan, build and operate these installations. There can also be a possibility for houseowners to rent, lease or lease back such solar thermal or PV installations.

Currently, **subsidised heat prices** are too low to motivate customers to adopt energy saving behaviour and investments. It is suggested to gradually shift to market prices (applying a four to six year transition phase) in combination with social transfer payments for poor households in order to avoid energy poverty.

For **biomass exploitation**, there will have to be strict guidelines, an efficient monitoring system and an effective set of sanctions which will guarantee the sustainability of the biomass harvest without any overexploitation of forests.

In addition, administrative barriers related to the length and complexity of implementing heating projects need to be removed.[49]

4.2 Regulatory and financial aspects, possible funding

Need for change in urban planning, zoning and legislation. The switch from coal to a modern district heating grid is connected to urban development and planning in several ways: **zoning** for passive use of solar energy; **microclimate** measures to reduce summer heat by 1-2.5°C and mitigate cold winter

49 United States Agency for International Development, Energy Investment Activity (USAID-EIA), Draft report on the permitting regime and obstacles to investment in the energy infrastructure projects in BiH, December 2015.

phases – afforestation, green roofs and facades, waterbodies and bio-corridors; and an increase in settlement **density** in the built-up city area in conjunction with the limitation of urban sprawl. These are important for securing competitive costs of district heating in the mid-term.

Need for targeted expert training. The time needed for project preparation can be used to train **academic experts** in order to update and upgrade the qualification of local engineers. At the level of **technicians with secondary training**, there is also a need for staff qualification. As **citizens** should act as co-investors, produce rooftop-heat, build hot water-storage tanks and buy local heat pumps, there must be efforts to raise awareness about the necessity of solar-based heating and technical knowledge. The city of Tuzla should think about **ICLEI membership**, which offers access to relevant training resources.[50]

4.3 Suggestion for an organisational structure which can promote and manage the process

Experience shows that it is reasonable to build up a broad organisational structure at the very beginning of the planning process.

The city of Tuzla together with the local district heating company and a research partner could be the nucleus of such an emerging organisational structure.

The city of Tuzla should secure the ties to urban development policy, zoning, administration of municipal buildings and stakeholder dialogue.

Centralno grijanje d.d. is a key player for all novel solutions: they own the grid, are an experienced and well-accepted partner of heat customers, have accumulated considerable expertise and have proven their ability to upgrade the grid and services.

At present, a local research partner is not yet available, but the University of Tuzla could build on good expertise in engineering, construction, logistics, geology, process management and innovation management. A new research unit for district heating should be built up. Alternatively, a research and development spin-off could be founded, in which university staff should be well represented. The non-governmental sector should also be represented from the very start.

Other partners who should play a role in such a structure should be the Tuzla Canton administration, the salt mine, the regional power distribution company, any kind of relevant associations of houseowners, trading companies, tenants and SMEs, big heat producers/consumers, thematically relevant non-governmental organisations, banks, insurance companies, wood processors, forest owners, innovators and health services.

International financial institutions, in particular the EBRD and EIB, could play a key role in the financing of an ambitious sustainable heat supply solution for Tuzla.

Whilst the organisational structure should be as broad as possible, it should be open only for stakeholders who have publicly expressed commitment or at least serious interest in the envisaged novel heating system.

As to the organisation of the process of increasing the efficiency of the building stock in the city, there is good evidence-based research available, and any such activities undertaken should build on lessons learned in pilot cases.[51]

4.4 Recommendation for a basic scenario and next planning steps (with a rough timeline) needed to exploit the potential

As mentioned, it is important to involve all stakeholders at an early stage of planning to develop a needs-oriented solution and ensure acceptance. A concrete scheme including technical and organisational

50 ICLEI - Local governments for sustainability, What we do, accessed 16 July 2021.

51 Silke Schnaidt, Andreas Wagner, Akteure und Prozesse in der Gebäudesanierung & nichttechnische Rahmenbedingungen und Einflussfaktoren des Sanierungsprozesses, ed.: KIT-Forschungsuniversität in der Helmholtz- Gemeinschaft, Albert-Ludwigs-Universität Freiburg, Institut für Nachhaltige Technische Systeme (INATECH) and Fraunhofer-Institut für Solare Energiesysteme ISE, 2019.

measures based on a detailed diagnosis of the current situation should result from the planning phase. The following recommendations build on general recommendations found in the Upgrade DH handbook.[52] It will be very important not to develop new plans from current demand figures, but to anticipate expected changes and leave room for the possibility that the situation will develop differently. Possible changes could be related to the reduction of losses and improved distribution effectivity, investment prices and energy prices, retrofitting schemes, thermal demand, local microclimate, need for construction works on roads with a similar time horizon (which saves heat grid refurbishment costs), and customers lost because of low demand elasticity.

After the organisational structure (or at least a nucleus made up of the City, the heat supplier and a research unit) is established, **initial activities** should follow to complete the research missing in order to better quantify potentials. These should be:

- a **geological study** analysing the appropriateness of disused salt mines for energy storage purposes, roughly estimating its useful volume and necessary technical works. The **aims** of such research should be: analysis of geological stability, danger of subsidence, required measures to stabilise the ground level and water table, analysis of exact position (3D) and volume which can be used for storage purposes, possible location of intakes and outtakes, simulation of permeability of caverns, drifts and pits before and after construction measures, expected heat and cold storage capacity of brine.
- analysis of the **energy saving potential** of the most widely appearing building types, mapping of future demand for heat and cold (annual, monthly, peak-times) applying three to four scenarios.

The following two analyses should be tendered after the first analysis has yielded information on the possibility to exploit subsurface structures formerly used by the salt mine for storage of heat.

- **preliminary hydraulic simulation** of a fourth generation heat grid supplying the buildings supplied at present; identification of substations and other places along the grid at which heat pumps should be located; identification of a quarter which could serve as a pilot area
- preliminary estimation of **costs and benefits** of the suggested heat grid
- design of a locally applicable and legally feasible **combined funding scheme** for heating costs (to be applied in the event of a significant increase of the heat price) and for private energy investment (energy refurbishment of buildings, use of renewables, installation of heat pumps and storage) based on the above-mentioned analysis of the savings potential

In parallel, there should be negotiations with **international financial institutions and other potential funders** about possible support, negotiations with the **University of Tuzla** about capacity building (e.g. a competence centre or a spin-off) for district heating, and development of a local **energy plan** tailored to the needs of fourth generation district heating.

Additionally, an analysis of the waste heat potential should be conducted. Existing waste heat analyses often focus on waste heat of a high temperature level of 60°C or more only, but in fourth generation systems, low-temperature waste heat is of high value as well. An overview of current losses should be provided by drones equipped with thermal imaging. The scheme should include an open communication strategy and involve end consumers. Thermal retrofitting of connected objects and decentralised solar energy panel installation as well as heat pumps can be started without delay. A detailed monitoring solution should be in place from the very start of the operation period onwards. Experience from comparable cases shows that a project of the ambition and size of the one addressed in this study will need a mid-term time horizon of 10 to 12 years for implementation.

52 IDominik Rutz et al., *Upgrading the performance of district heating networks: Technical and non-technical approaches*, *Upgrade DH*, 2019.

Alternatively, a detailed planning, funding and tendering concept for a smaller city district can be speeded up in order to serve as a pilot investment. It is easier to win a big investment grant after having proven the city's abilities and the proper functioning of technical solutions in a pilot case. Companies can build up staff and technical capacities gradually, and lessons learned in the pilot case can be used to improve the planning of the main investment. Such a two-stage implementation approach, however, costs time and will delay the closing of the power plant for one (possibly up to three) years.

By mid-2022, geological research and pre-negotiations with owners and permit authorities should have matured to a degree that there can be a decision on whether to order planning work for year-round sub-surface energy storage in disused salt mines.

Table 6: Suggested timeline for further steps

	2021			2022				2023				2024	2025	2026	2027	2028	2029	2030
Geological survey																		
Public building refurbishment																		
Organisation building & info campaign																		
Decentralised RES																		
Funding scheme for private energy investment																		
Energy bill support for the poor																		
Decision on heat sources																		
Pre-feasibility																		
Feasibility study																		
Detailed planning; funding negotiations																		
Tendering																		
Pilot grid for 1 sector of town																		
Construction of grid, source and storage																		
Close down coal power plant																		
Evaluation																		

Tuzla faces a unique window of opportunity to gain a place among the cleanest and technologically smartest cities with respect to heat supply and air quality in southeast Europe

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