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# DECARBONIZATION OF SERBIAN DISTRICT HEATING SECTOR – THE ANALYSIS OF SCENARIOS

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**Abstract:** This paper examines the decarbonization of Serbia's district heating (DH) sector, which currently relies predominantly on fossil fuels, with renewable energy sources (RES) accounting for only 2.2% of heat production in 2023. Guided by Serbia's Energy Strategy and National Energy and Climate Plan, two development pathways are analyzed: the Basic and the Advanced Scenario. The Basic Scenario anticipates gradual integration of biomass, heat pumps, and solar energy, leading to a 54.3% RES share and a 49% reduction in greenhouse gas emissions by 2050. The Advanced Scenario assumes stronger policy and financial support, enabling earlier adoption of biomethane, hydrogen, and electric boilers, achieving a 76.6% RES share and a 74% emission reduction by 2050. Required investments are estimated to be between 1.1 and €1.6 billion. The study emphasizes the need for coherent policy, technological innovation, and targeted financing to ensure a sustainable, low-carbon DH sector in Serbia.

**Key words**: district heating, decarbonization, renewable energy sources

## 1. INTRODUCTION

The Serbian district heating (DH) sector consists of 60 district heating systems in the same number of cities. District cooling service is not currently present on the energy market. Serbia's DH sector faces significant challenges, including outdated infrastructure, a high dependency on fossil fuels (especially natural gas), and low integration of renewable energy sources (RESs). The share of biomass, as the only RES used, in the heat production energy mix was about 2.2% in 2023 [1]. A

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consequence of heat production exclusively based on combustion processes is relatively high emissions of greenhouse gases (GHGs) and urban air pollution.

Two adopted national strategic documents define Serbian energy policy - Integrated National Energy and Climate Plan of the Republic of Serbia for the period 2030 with projections up to 2050 (NECP) [2] and Energy Sector Development Strategy of the Republic of Serbia up to 2040 with Projections up to 2050 (Strategy) [3]. Both documents envisage a range of policy measures related to the decarbonization of the DH sector.

Following these documents and in accordance with their presented optimal scenario of Serbian energy system development, Basic scenario of DH sector development was modeled and presented in this paper. The presentation includes summary of expected policy measures, projections of changes in the structure of heat production, as well as related GHG emissions. The second scenario analyzed is the Advanced Scenario, which is more ambitious compared to the Basic Scenario and assumes the implementation of the additional energy policy measures and instruments. In relation to the Basic Scenario, after 2035, more intensive use of biomethane, hydrogen, electricity from renewable energy sources (RES), heat pumps, and solar energy is anticipated.

The production capacities in both scenarios, as well as the indicated investment values (that should be understood as indicative figures) are determined based on the implementation of ongoing programs ReDeWeb (Novi Sad, Niš, Kragujevac, Kraljevo, Bečej, Vršac, Pančevo, Kruševac, Novi Pazar) [4], KFW (Majdanpek, Prijepolje, Novi Pazar, Vranje, Niš) [5], and Air quality (Niš, Zaječar, Valjevo, Smederevo) [6].

## 2. BASIC SCENARIO

### 2.1. Proposed policy measures and instruments

The main pillar of the new energy policy in DH sector proposed in the Strategy is the enactment of the Law on Heating and Cooling (alternative name: Law on Thermal Energy) as a general regulation for the district heating and cooling sector. For the adoption and support of the implementation of this

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law, as well as for the implementation of other measures and activities that this approach to the decarbonization of the sector entails, it is necessary to strengthen the personnel and organizational capacities of institutions at all levels (national, local government unit (LGU), district heating system (DHS)).

Another key element necessary for the Basic Scenario is the adoption of specific decarbonization goals for the DH sector up to 2040. Goals are set for each DHS separately and at the level of the entire sector. These goals will become an integral part of the official document "Development Program for the Production and Use of Thermal Energy," which must be done in accordance with the provisions of the Law on Energy (Article 8v) [7].

For the district heating sector to be decarbonized, measures regarding the financial and economic rehabilitation of companies engaged in the production, distribution, and supply of thermal energy must be undertaken. Only then can the incentive measure provide for in the Basic Approach, based on the Law on the Use of RES (Articles 70-74), be applied [8].

Experiance of the most developed European countries in the field of district heating and cooling (e.g. Nordic countries) indicate that a coordinated planning system is necessary for the successful decarbonization of the heating and cooling system [9]. These countries have harmonized systems of local urban planning and local energy planning for the development of district heating and cooling systems. That is why the development of policies also foresees the obligation of local self-governments to simultaneously and harmonized revise plans for the improvement of local district heating services and make an amendment of local urban planning regulations [10].

This approach also includes the revision of the Decree on Establishing the Methodology for Determining the End-consumer's Price of Heat Supply and the adoption of regulations on the quality of wood chips. It is being done with the practical parts of this package of political measures that overcome some of the problems observed so far in the decarbonization of the district heating and cooling sector.

### 2.2. Structure of heat production and GHG emissions

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The basic scenario was developed taking into account the development of the district heating system as presented in the Energy Development Strategy, with the additional introduction of biomethane, direct use of renewable electricity and hydrogen (through blending with natural gas), as well as waste heat generated in the electrolysis process. In principle, this scenario corresponds to the implementation of the set of energy policy measures presented in the Basic Approach.

The projection of changes in the structure of heat energy production for the Basic Scenario is shown in Figure 1. The introduction of renewable energy sources into the energy mix results in a reduction in fossil fuel consumption. By 2040, the use of coal and petroleum derivatives in district heating systems is expected to cease. Meanwhile the share of natural gas, which was 75% in 2023, is projected to decline to around 50% by 2040 and about 33% by 2050. The decrease in the share of natural gas between 2040 and 2050 is due to the use of traditional renewable energy sources, as well as the introduction of biomethane, hydrogen, and electricity from renewable sources into the energy mix of the district heating system.

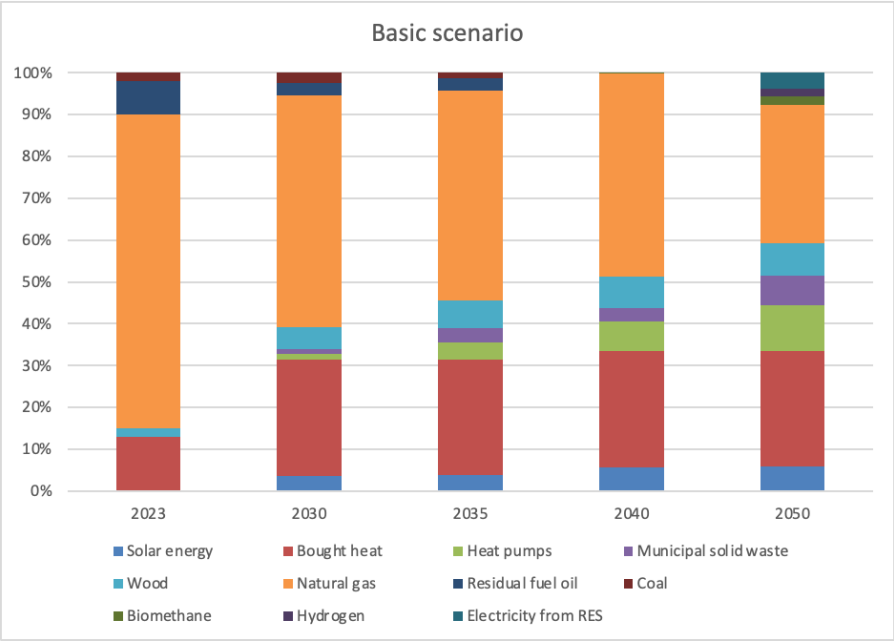


Figure 1: Structure of heat production in DHS, Basic scenario

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A detailed overview of the expected changes in heat energy production from renewable energy sources and waste heat in district heating systems for the Basic Scenario until 2050 is presented in Table 1. Until 2035, the focus is on the introduction of biomass and heat pumps into the energy mix, along with the construction of solar thermal plants in Novi Sad and waste incineration plants in Belgrade and Novi Sad. After that, the commercialization and wider use of hydrogen and biomethane (currently financially unfavorable for use) are expected. The anticipated increase in electricity production from solar and wind power plants will also create space for greater use of green electricity for heat energy production [11]. In this way, the share of heat energy production from renewable energy sources will increase from the current 2.2% to 24.9% in 2025, and to 54.3% in 2050 (Figure 2).

Table 1: Energy produced from RES by sources, Basic Scenario, MWh

| RES | Period | Biomass | Heat pump | Solar | Municipality waste | Biomethane | Hydrogen | Electric boilers |
|---|---|---|---|---|---|---|---|---|
| Contribution | 2025-2030 | 446,955 | 119,113 | 321,135 | - | - | - | - |
| | 2031-2035 | 64,972 | 221,032 | - | 178,869 | - | - | - |
| | 2036-2040 | 92,206 | 254,204 | - | - | 18,400 | - | 5,200 |
| | 2040-2050 | - | 300,000 | 160,568 | | 155,625 | 155,625 | 311,250 |
| Total in 2050 | | 604,133 | 894,349 | 481,703 | 178,869 | 174,025 | 155,625 | 316,450 |

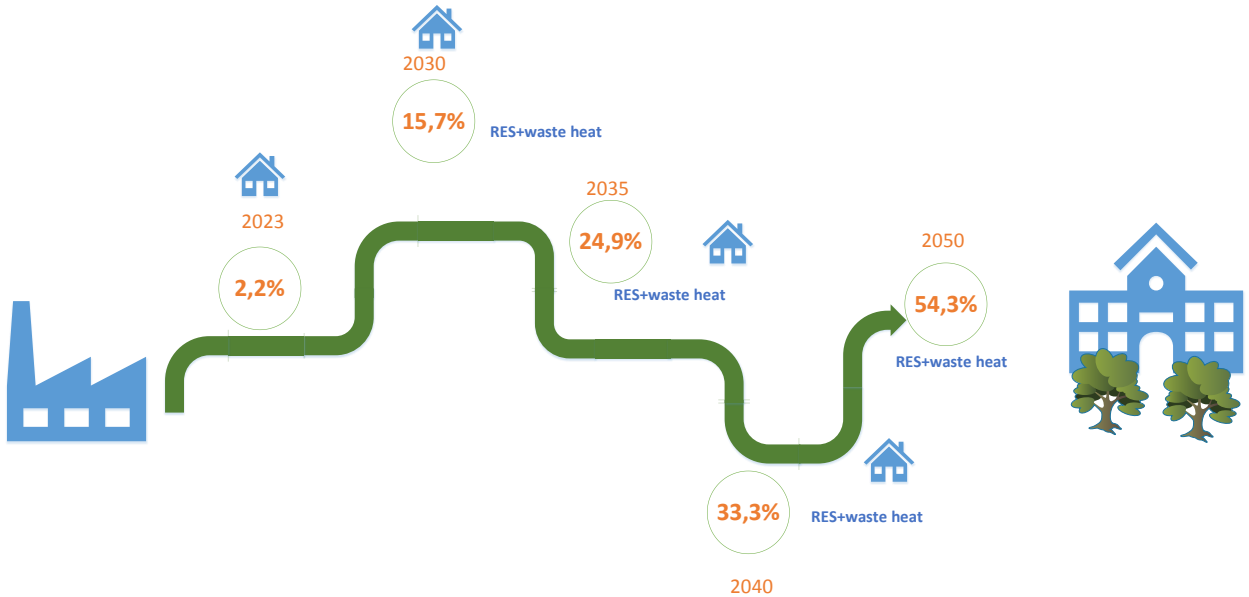


Figure 2: Expected share of RES in heat production in DHSs, Basic Scenario

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Such a change in the energy mix for heat energy production will result in a reduction in GHG emissions. The projections of GHG emissions and emission factors for the period up to 2050 are presented in Table 2. Compared to 2023, CO2eqv emissions from the DHS are expected to decrease by about 13% by 2035 and by an additional 36% by 2050. During the same period, the emission factor—specific emissions from district heating—will decrease from 0.231 kg CO2eqv to 0.1 kg CO2eqv per kWh of produced heat energy. Compared to 2023, when the emission factor for carbon dioxide was 0.230 kg/kWh, the expected value for 2050 is 0.097 kg/kWh, which is 42% of the initial value.

Table 2: GHG emissions, Basic Scenario

| Emissions | 2023 | 2030 | 2035 | 2040 | 2050 |
|---|---|---|---|---|---|
| CO2, (1,000 t) | 1,163.33 | 1,184.81 | 1,000.50 | 866.23 | 577.96 |
| CH4, t | 39.07 | 94.84 | 126.26 | 129.74 | 165.13 |
| N2O, t | 5.42 | 85.63 | 71.18 | 72.34 | 52.14 |
| CO2ekv, (1,000 t) | 1,165,87 | 1,250.98 | 1,018.73 | 884.38 | 595.53 |
| kg CO2/kWh | 0.230 | 0.192 | 0.169 | 0.142 | 0.097 |
| kg CO2eqv/kWh | 0.231 | 0.195 | 0.172 | 0.146 | 0.100 |

## 3. ADVANCED SCENARIO

### 3.1. Proposed policy measures and instruments

The second considered scenario is Advanced Scenario, which is more ambitious compared to the Basic Scenario and assumes the full implementation of the energy policy measures and instruments proposed in the Advanced Approach. The Advanced Approach includes:

- Further opening of the sector to new participants and the development of specific legislation that will facilitate and encourage this process [12],
- Development of new financial mechanisms to encourage heat production from renewable energy sources (RES) and the use of waste heat [13], and
- Encouragement of the use of those renewable energy sources that are still not commercially viable but are necessary to achieve full decarbonization of the sector [14].

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The advanced approach is not a set of separate and independent policies compared to the Basic approach. It is a set of measures and policies that can be implemented simultaneously with the Basic approach and help achieve the energy policy goals of decarbonizing the district heating sector more quickly and completely.

### 3.2. Structure of heat production and GHG emissions

Until 2035, there is no difference between the Basic and Advanced scenarios. This assumption has been adopted based on the relatively short, considered period (10 years) and very ambitious goals and plans, the implementation of which is foreseen by 2035. In relation to the Basic Scenario, after 2035, more intensive use of biomethane, hydrogen, electricity from RES, heat pumps, and solar energy is anticipated. The structure of energy sources used for heat energy production until 2050 is shown in Figure 3.

In 2050, the only fossil fuel used will be natural gas, and its share in the produced heat energy will be 16.9%. The use of natural gas is linked to peak demand periods and the largest district heating systems, whose decarbonization represents the greatest technological challenge [15]. The share of renewable energy sources in 2050 will be 55.6%, while the share of purchased heat will be 27.5%.

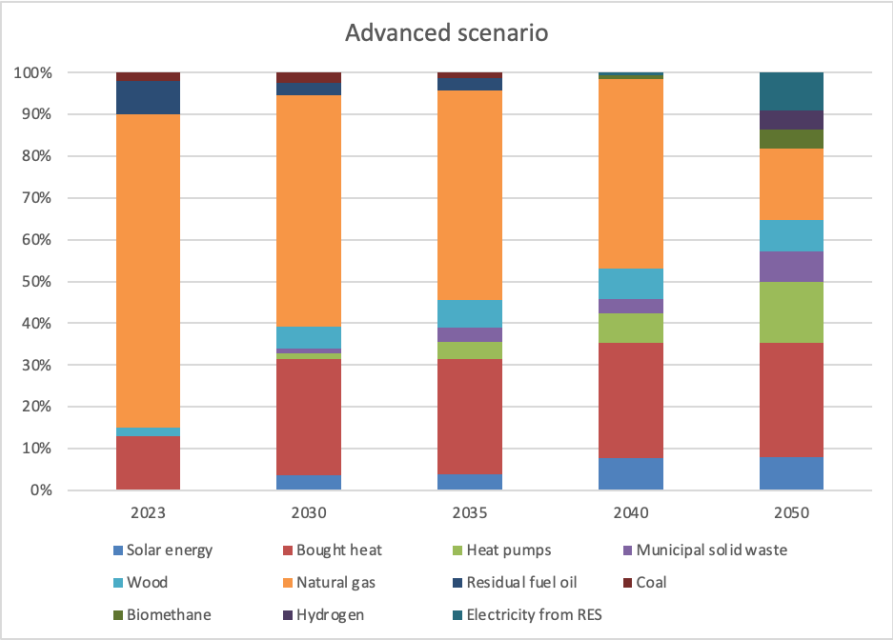


Figure 3: Structure of heat production in DHS, Advanced Scenario

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The detailed structure of energy production in district heating systems using RES, according to the Advanced Scenario, is shown in Table 3. Compared to the Basic Scenario, the most significant change is the more intensive use of hydrogen, biomethane, and electricity from RES. The Advanced Scenario results in the share of heat energy production from RES increasing from the current 2.2% to 37.6% in 2040 and 76.6% in 2050 (Figure 4).

Table 3: Energy produced from RES by Source, Advanced Scenario, MWh

| RES | Period | Biomass | Heat pump | Solar | Municipality waste | Biomethane | Hydrogen | Electric boilers |
|---|---|---|---|---|---|---|---|---|
| Contribution | 2025-2030 | 446,955 | 119,113 | 321,135 | - | - | - | - |
| | 2031-2035 | 64,972 | 221,032 | - | 178,869 | - | - | - |
| | 2036-2040 | 92,206 | 254,204 | - | - | 18,400 | - | 5,200 |
| | 2040-2050 | - | 600,000 | 321,136 | | 355,100 | 373,500 | 741,800 |
| Total in 2050 | | 604,133 | 1,194,349 | 642,271 | 178.869 | 373.500 | 373.500 | 747,000 |

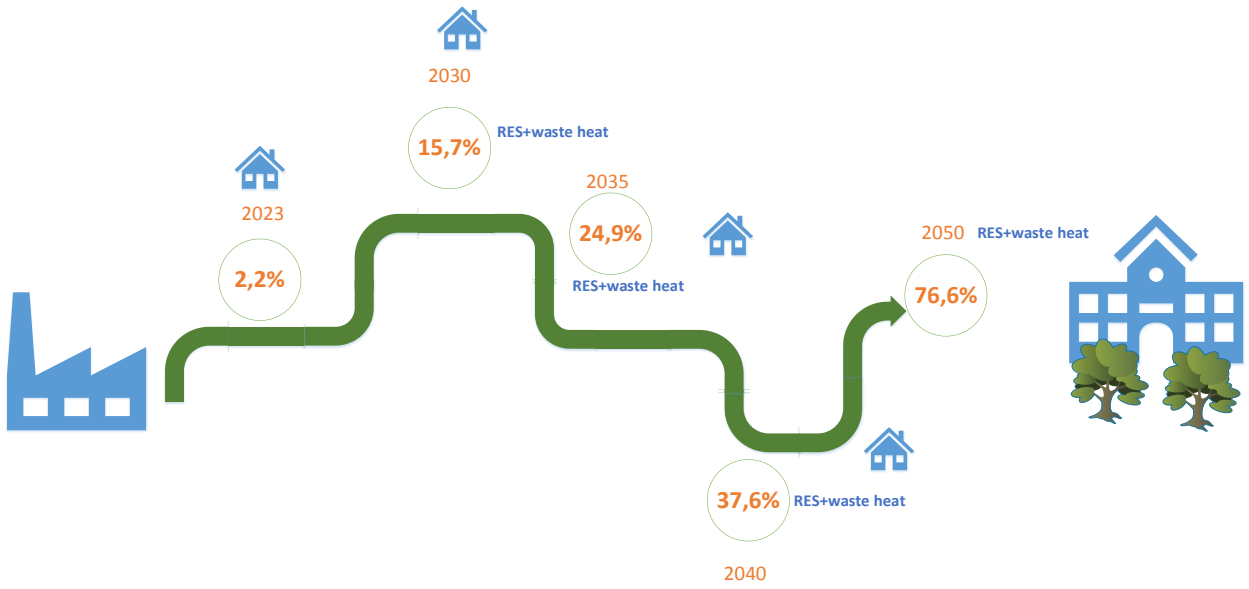


Figure 4: Expected share of RES in heat production, Advanced Scenario

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The projections of GHGs and emission factors according to the Advanced Scenario are shown in Table 4. The expected value of the emission factor in 2050 in the advanced decarbonization scenario is 0.05 kg $CO_2$/kWh, which is less than a quarter of the current value.

Table 4: GHG emissions and emission factors, Advanced Scenario

| Emissions | 2023. | 2030. | 2035. | 2040. | 2050. |
|---|---|---|---|---|---|
| CO2, (1,000 t) | 1,163.33 | 1,184.81 | 1,000.50 | 832.10 | 294.78 |
| CH4, t | 39.07 | 94.84 | 126.26 | 129.13 | 160.08 |
| N2O, t | 5.42 | 85.63 | 71.18 | 69.90 | 32.44 |
| CO2ekv, (1,000 t) | 1,165,87 | 1,250.98 | 1,018.73 | 854.67 | 307.96 |
| kg $CO_2$/kWh | 0,230 | 0.192 | 0.169 | 0.133 | 0.050 |
| kg$CO_2$eqv/kWh | 0,231 | 0.195 | 0.172 | 0.136 | 0.052 |

## 4. INVESTMENTS IN DECARBONIZATION PROJECTS

Future investments in the sector aimed at decarbonizing district heating and cooling are detailed in the previous sections. In this section, we present an overview of the planned investments across four observed periods (2025-30, 2031-35, 2036-40, and 2040-50), along with their effects, measured in MW of installed capacity and amounts, in millions of EUR (€). Two scenarios are outlined: basic and advanced, highlighting differences in the last two periods (2036-50).

The basic scenario until 2040 is identical to Scenario S from the adopted Energy Sector Development Strategy of the Republic of Serbia [3]. After 2040, it becomes more advanced in terms of decarbonization, as it introduces hydrogen, biomethane, and electricity used through electric boilers into the energy mix. The advanced scenario envisions the installation of additional solar thermal plants, as well as the use of biomethane and electric boilers starting from 2035.

Table 5: Recapitulation of investments in DH decarbonization projects

| Period | Basic scenario | | | Advanced scenario | | |
|---|---|---|---|---|---|---|
| | No of projects | MW | Mil.EUR | No of projects | MW | Mil.EUR |
| 2025-2030 | 23 | 424.8 | 228.75 | 23 | 424.8 | 228.75 |
| 2031-2035 | 10 | 264.9 | 378.78 | 10 | 264.9 | 378.78 |
| 2036-2040 | 10 | 297.2 | 201.21 | 10 | 656.4 | 324.16 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 2040-2050 | >3 | 844.8 | 293.53 | >3 | 1,490.0 | 650.87 |
| Total | 46 | 1,831.7 | 1,102.27 | 46 | 2,836.1 | 1,582.56 |

Common to both scenarios is the expectation that total investments by 2035 should amount to €606 million and bring an additional 700 MW of capacity. The basic scenario foresees that by 2050, an additional 1.8 GW will be installed through 46 investment projects, with investments totaling around €1.1 billion. The advanced scenario predicts higher investments in the periods 2036–2040 and 2040–2050, which will result in a total installed capacity of 2.8 GW in facilities using RES and an increase in investments to €1.6 billion. The advanced scenario particularly emphasizes investments in new technologies, such as biomethane and hydrogen.

## 5. CONCLUSION

Decarbonization of DH systems must be systematically structured and carefully planned. To ensure a move to a sustainable heating sector it is essential to act on:

- Demand side to increase energy efficiency to lower overall demand,
- Supply-side to replace fossil fuels with more sustainable, carbon-neutral energy sources.

Available measures for decarbonization can be grouped into categories:

- Replacing fossil fuels with RESs and waste heat,
- Electrification of heat supply by increased utilization of heat pumps and electric boilers (that would utilize electricity produced from RESs),
- Introduction of green hydrogen,
- Increasing use of high efficiency combined heat and power (CHP) generation.

This paper analyzed two possible scenarios of DH systems decarbonization in Serbia. The share of RES and waste utilization in both scenarios significantly increase, in comparison to 2.5% in 2023. It was shown that by implementing dedicated policy of decarbonization, the share of RES and waste heat could reach 15.7% in 2030, and depending on scenarios, between 33.3% and 37.6% in 2040, and 54.3% and 76.6% in 2050. At the same time, the reduction of GHG emissions should be in the range from 24% to 27% in 2040, and even 51% to 75% in 2050.

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There is no doubt that significant funds are needed to implement the decarbonization of the DH sector. The rough estimation shows that necessary investments are between €1.1 and €1.6 billion by 2050. However, these figures should be additionally verified. The essence is that each DH system should be treated individually, and each decarbonization project should be covered by a corresponding feasibility study.

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