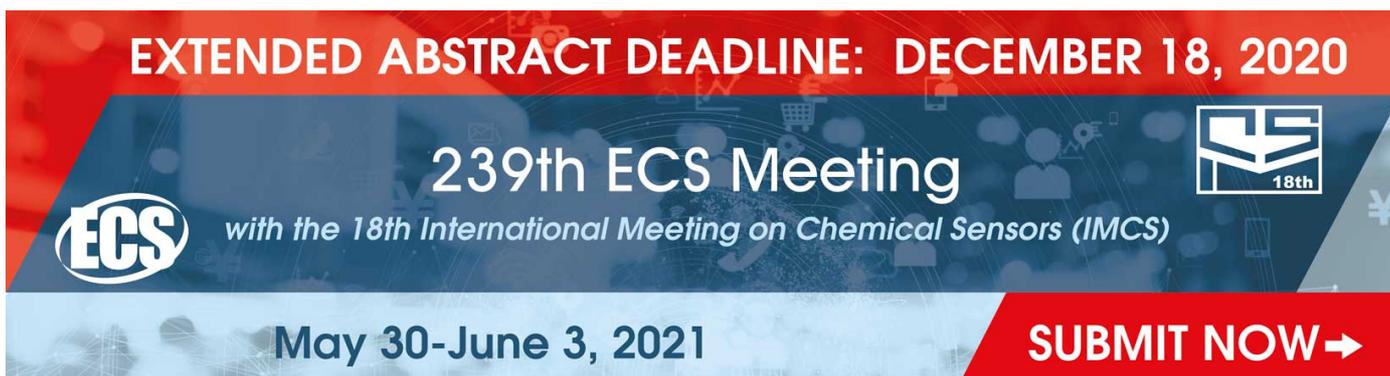


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District Heating De-Carbonisation in Belgrade. Multi-Year transition plan.

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Abstract. A large share of the city of Belgrade is heated by a District Heating network. Established in 1965, the network delivers 3.6 TWh to more than 20 million square meters of households industries and businesses, by means of a 1460km-long network. The system has been continuously upgraded and adapted to new technologies and already operates at relatively low temperature, with modernized substations. However, the delivered heat is still produced mainly by means of carbon intensive technologies. Conscious of the need to de-carbonise the city, a multi-year transition plan was established, where large investments have been secured, comprising greater interconnection levels, installation of large solar thermal plants and waste incineration plants, and the conversion of a power plant into CHP, among others. In this paper, the criteria for the selection of the technologies, the identification of enabling investments, interaction with stakeholders, securing of financing, and status of the plan are presented. After the execution of the de-carbonisation roadmap, it is expected that the DH system will reduce its carbon intensity by 50%.

1. Introduction

District heating (DH) systems are one of the most energy efficient heating systems in urban environments, with proven reliability over the last decades. DHs are therefore identified as key systems to achieve the de-carbonization of heating energy in European Cities (D. Connolly et al, 2014).

DHs have traditionally been designed to be operated in a hierarchized way, with central energy production facilities delivering heat to a variety of distributed consumption locations. In some countries, DHs are linked to intense use of Combined Heat and Power (CHP) and Heat pump technologies. In those cases, the use of highly efficient fuel-based heat production processes (either by direct use of fossil fuels or the use of an electricity mix with relevant present of fossil fuels), with unprecedented performance levels, means that improvements in efficiency levels will only have minimal impact in the route to DH de-carbonisation.

Renewable and waste heat sources are therefore foreseen as de-carbonized heat sources and the way to guarantee competitive energy costs with limited influence of fossil fuel supply price volatility. Along the last decade large solar thermal systems have already been successfully connected to DH networks



under commercial operation in several EU locations (SDHplus project). Hence, in order to allow for a transition to more efficient cities at a cost-effective approach, extensive R&D on low carbon DHs with distributed sources is required (Harrestrup & Svendsen, 2014). DH operation temperature needs to be reduced in order to increase the integration and performance of renewable systems and operation criteria needs to be adopted for the introduction of weather-dependent, distributed heat sources such as solar systems. The DH strategy for the city of Belgrade (Serbia) is focused on the development and demonstration of these concepts. Conscious of the need to de-carbonise the city, a multi-year transition plan was established, where large investments have been secured, comprising greater interconnection levels, installation of large solar thermal plants and waste incineration plants, and the conversion of a power plant into CHP, among others.

This strategy to de-carbonise the Belgrade DH will take this network to the level of Nordic systems, where the presence of CHP, waste energy and similar low carbon strategies is high, as in Stockholm, where around 90 percent of greater Stockholm is supplied by a DH with a production based 90% on renewable or recovered energy. The size of the Belgrade DH, one of the biggest of Europe with >12PJ heat sales only compared to few DHs networks such as Copenhagen's (>30PJ heat sales) or Stockholm's DHs (>25PJ heat sales), makes its de-carbonisation highly relevant and challenging, requiring advanced technologies to reach the goals.

In this paper, the present status of the network, the criteria for the selection of the technologies, the identification of enabling investments, interaction with stakeholders, securing of financing, and status of the plan are presented.

This work is aligned with the following Sustainable Development Goals (SDG):

- SDG 7_AFFORDABLE AND CLEAN ENERGY: through the increase in energy efficiency of the main DH in Belgrade and the integration of renewable energies (RES) into this system.
- SDG 11_SUSTAINABLE CITIES AND COMMUNITIES: through the decarbonization of the main city in Serbia by providing a low carbon heating at urban level.
- SDG 12_RESPONSIBLE CONSUMPTION AND PRODUCTION: the city of Belgrade has been modernized to enable automatic measurement of delivered heat energy and thus the realization of pay by consumption for residential objects, resulting in more responsible and aware consumers.
- SDG 13_CLIMATE ACTION: by supporting the city's views and expanding to more municipalities in the short-medium term.

2. History of Belgrade DH

The history of DH in Belgrade started in 1961 with the first heat plant of Novi Beograd. Later in 1965 the first combined thermal power and heat plant opened in Belgrade, being still today the most significant single heat source. 1965 was also the year defined as the official start of the Belgrade power plants public company (in serbian "Beogradske elektrane", also know from his acronym BE). BE seeks to provide a public service that supplies the consumers with heat energy in a safe, competitive and ecologically acceptable way.

Between 1965 and 1987 a number of heat plants were opened, accounting still today as the largest share of BE capacity. Konjarnik, Vozdovac, Cerak and Dunav (this one the first heat plant to supply the old city center), are among these heat plants, increasing each of them their capacity in line with the expansion of its distribution network and growth in the number of its users.

Originally with steam as heat carrier, this DH has evolved through the last decades into a system at lower temperature, delivering pressurized water at about 80°C to consumers with an operative temperature of 120°C at the inlet of the primary side of the DH. In contrast, in Nordic countries DH developed rapidly in the nineties into areas with lower heat density, requiring more efficient distribution networks. Supply temperatures were reduced even further. In these systems, heat is supplied at 60-70°C, supported by modern building codes in those regions, where new radiator systems are sized for operation at 60°C/30°C.

From 1988, the plan for the city of Belgrade was for a united district heating in the city through the development and expansion of the network and the shutting down of old individual boilers. 557 boilers were shut down until 1996, and more than 1,200 were shut down until 2015. By 2010, the numbers of apartments connected were 300,000.

From 2000 to 2015 more than 8,000 substations were modernized and fitted with required equipment to enable automatic operation, measurement of delivered heat energy and thus the realization of pay by consumption for residential objects. In 2010 the biggest boiler in the BE system was opened in TO Novi Beograd.

3. Capacity of the DH

The Belgrade DH relies on 61 heat sources (14 heat plants and 47 individual boilers) with a total capacity of 2,819 MW. This installed power has an annual production of 3,600 GWh of heat energy.

Regarding the distribution network, the total length of the network is 730 km, connecting 8,686 substations, adding up a total of 1,460 km with the return line. The main fuel used is natural gas, accounting for an 89% of the total. As for today, RES only account for 0.38% of produced energy, being the total fossil fuels consumed sum up to 14.1 billion Serbian Dinars in the heating season 2014/15.

The total heating area of BE constantly expands at a rate of 411,278 new m² on average annually to a total of 21,882,862 m² in February 2016. The share on different uses is:

- 81% of residential area meaning approximately 305,000 households.
- 19% commercial area, approximately 15,500 users in the commercial sector.

A visual representation of the above can be observed in the following picture, where 11 of 14 existing BE heat plants are shown together with their capacities:

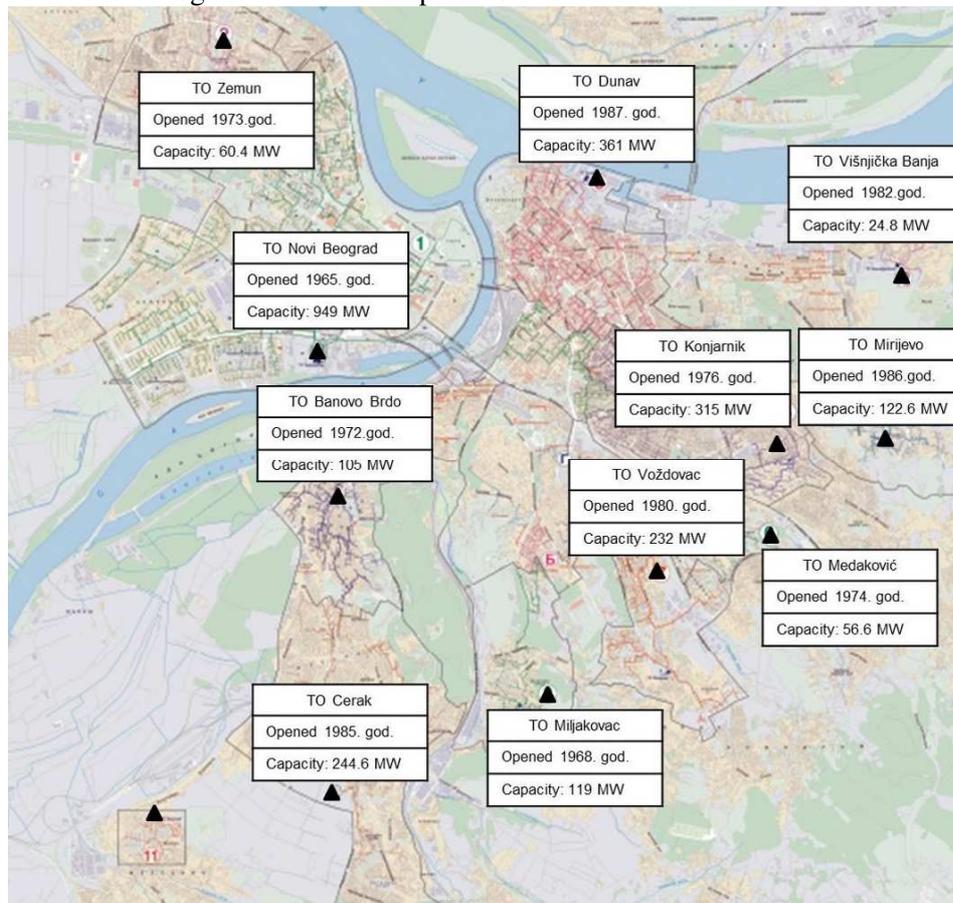


Figure 1: Capacity and location of the main central plants of the Belgrade DH (Source: BE Management and Deloitte analysis).

4. General energetic plan

According to the views of the City's representatives and BE's interests, the system of district heating (SDH) will be expanded to more municipalities in the short-medium term, being planned by 2025. City's representatives are considering the possibilities of one joint company at City level, which would have as its activity district heating management on the entire City's territory.

Currently, about 50% of all households in Belgrade are connected to the DH of BE, which provides sufficient possibility for the SDH expansion. By 2025 the goal is to have at least 360,000 households connected to the SDH, meaning an annual growth rate of 1.7%. Also, with the construction of a large number of new residential and office objects an increase in the expected potential consumption is expected.

4.1. Interventions

The main interventions according to the *Energetics development strategy of Belgrade until 2030* are the following:

1. Introduction of district cooling technologies and improvement of the current SDH to the level of fourth generation district heating and cooling, with an increase in the use of cogeneration energy (which can account for up to 60% of annual produced energy in BE) and RES (which can reach the level of 15%) as well as the systematic heat pipeline network replacement. This would increase the SDH efficiency, reduction of the degree of primary energy utilization, smaller heat production cost and smaller heat losses.
2. Deployment of the heat pipeline known as "TENT-A: Obrenovac – TO Novi Beograd", to connect the largest power plant in Serbia with the DH. This power plant is located on the right bank of the river Sava, approximately 40 km upstream from Downtown Belgrade, near the city municipality of Obrenovac and generates around 17.263 GWh annually, covering almost half of Serbia's needs for electricity. This intervention is in line with EU regulation, including the connection of existing heating areas into a single heating system of Belgrade, with possible development of heat storages as an integrative part of the system. In figure 2 it can be observed the magnitude of the intervention.

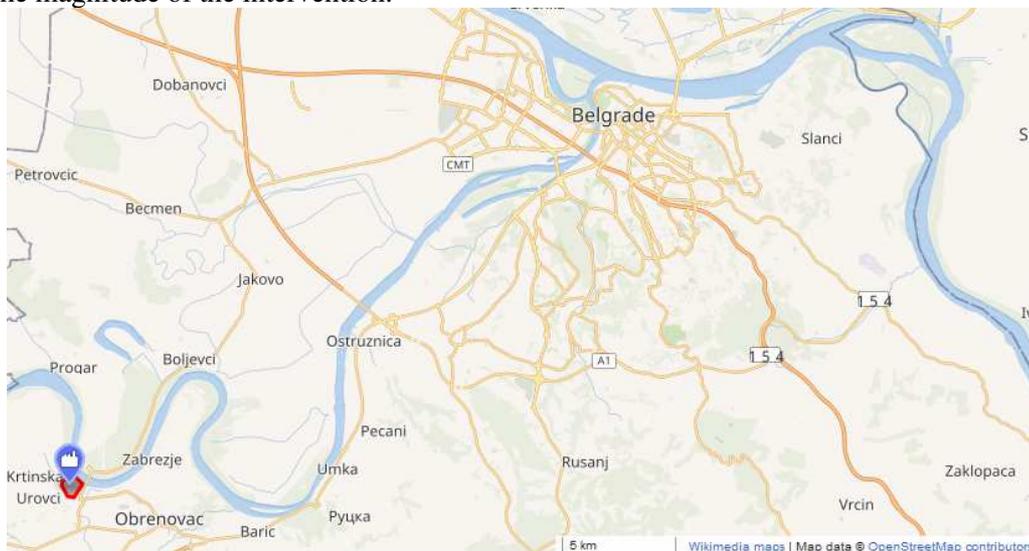


Figure 2: Map of Belgrade area, where it can be observed the distance that the TENT-A pipeline will cover (plan in progress).

3. Lower water temperature in the distribution system.
4. As large as possible coverage of City with SDH.
5. Users' change from electricity to SDH for heating
6. Large deployment of ITC to manage the SDH.

7. Implementation of cleaner energy sources, such as geothermal energy, cogeneration facilities on biomass or solar panels.

4.2. Budget and target dates

The conversion of a DH network is a complex process, which needs to be performed stepwise in order to guarantee continuous space heating (SH) and domestic hot water (DHW) services. Although relatively long SH service interruption in summertime is possible, DHW is required all-year-round. Thus, network conversions need to be carefully scheduled. The following main dates are foreseen as follows:

- Diversification of heat sources and network interconnection with 3,000,000 m² of newly connected heated household and commercial areas by 2025.
- Reduce energy losses by 20% by 2025 in comparison to 2025.
- Shutting down of boiler stations in the SDH system of BE by 2021.
- Large deployment of ITC to manage the SDH will be done gradually.

The budget of the interventions can be summarized as following:

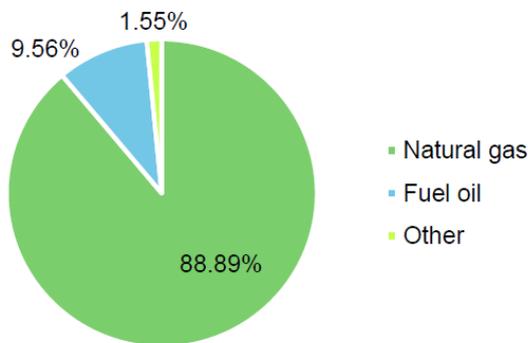
Table 1. Main interventions with the investment and the deadline associated.

Intervention	Investment (€)	Planned term
Diversification of heat sources with higher capacity for expansion of the DH served areas	165 M	2020
Decrease on distribution losses until 20% reduction.	50 M	2025
Network interconnection	30 M	2025
Installation of economizers on big boilers	6 M	2025
Development of small capacity cogenerations	6 M	2025
Shutting down of old individual boilers	30 M	2021
RES installation and integration into the DH	[350-650] €/kW	2025
Development of the district cooling	[500-1000] €/kW	2020
Implementation of cleaner energy sources, such as cogeneration facilities on biomass	~650 €/kW for small capacity cogeneration facilities	2025
Implementation of cleaner energy sources, such as solar panels	~350 €/kW for solar energy facilities with seasonal heat storage	2025

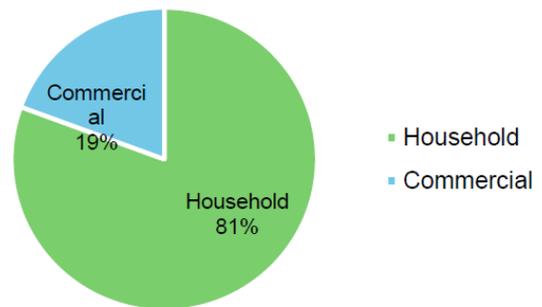
4.3. Energetic and environmental impact

Energy produced in yearly balance relies especially in natural gas, with 89% of the total heat energy produced, followed by oil fuel. Renewable energy sources are still not relevant on the mix, with only 0.38% of the total.

This energy produced supplies energy to approximately 49% of all households and business facilities in the municipalities in which BE offers its services, accounting for more than 50% of the DH on the energy mix of the city. This demand of fuels meant 14.1 billion RSD for the 2014/15 heating season.

Production of heat energy by fuel type (Heating season 2014/2015)

Source: BE Management

Users by heated area type, February 2016

Source: BE Management

Figure 3: Mix of the different energy carriers on the DH.

Regarding the TENT-A intervention, a capacity of 600 MW will be included in the DH. The whole set of interventions planned will have a significantly reduction of natural gas consumption, with savings on CO₂ emissions to approximately 50%.

5. Impact of the DH network to meet the SGDs

The DH De-Carbonisation Multi-Year transition plan here presented for the city of Belgrade has a large contribution to meet the SGDs.

The main goals addressed by this plan are:

- **7.1 By 2030, ensure universal access to affordable, reliable and modern energy services:** this goal is addressed with the improvement of the current SDH to the level of fourth generation district heating and cooling.
- **7.2 By 2030, increase substantially the share of renewable energy in the global energy mix:** by fuel diversification with biomass and solar, even though they represent small capacity heat sources.
- **7.3 By 2030, double the global rate of improvement in energy efficiency:** addressed by lowering water temperature in the distribution system.
- **11.B By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels:** by an increase on resource efficiency and mitigation of climate change thanks to the whole set of interventions with an estimated savings on CO₂ emissions to approximately 50%.
- **12.2 By 2030, achieve the sustainable management and efficient use of natural resources:** by similar facts as described above.
- **13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning:** by supporting the city's views and expanding to more municipalities in the short-medium term.

6. Conclusions

The present article summarizes the renovation plans for the District Heating network of the city of Belgrade. The paper includes the criteria for the selection of the technologies, the identification of enabling investments, interaction with stakeholders, securing of financing, and status of the plan.

This DH, established in 1965, delivers today over 3.5 TWh to more than 20M m², being the main heating source for the city. Therefore, the upgrade and improvement on the technologies used has a great impact over the carbon balance of the city.

The plans for the improvement of the DH take into account the importance on the operation at low temperature. The reduction on the temperature of the DH not only reduces the energy demand, but also allows the integration of renewable energies such as large solar thermal plants and waste incineration plants.

After the execution of the de-carbonisation roadmap, it is expected that the DH system will reduce its carbon intensity by 50%.

References

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- [2] D. Connolly et al. / Energy Policy 65 (2014) 475–489.
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