Report on actions in the follower cases

upgrade DH

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(numbers in superscript refer to the project partners on page 3)

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Abbreviations

Amba	Andelsselskaber Med Begrænset Ansvar (Limited liability cooperatives)
BiH	Bosnia and Herzegovina
BMS	Building Management System
BPE	Best Practice Example
CHP	Combined Heat and Power
DH	District Heating
DHC	District Heating and Cooling
DHS	District Heating Systems
DHW	Domestic Hot Water
DK	Denmark
IRR	Internal Rate of Return
KWKG	Kraft-Wärme-Kopplungsgesetz (The German Heat and Power Cogeneration Act)
NL	the Netherlands
NPV	Net Present Value
O&M	Operation and Maintenance
PBP	Payback Period
RES	Renewable Energy Sources
TES	Thermal Energy Storage

1 Introduction

The overall objective of the Upgrade DH project, funded by the EU's Horizon2020 programme, was to improve the performance of inefficient district heating networks in Europe by supporting selected demonstration cases for upgrading, which can be replicated in Europe. The Upgrade DH project supported the upgrading and retrofitting process of DH systems in different climate regions of Europe, covering various countries. The target countries of the Upgrade DH project are: Bosnia-Herzegovina, Denmark, Croatia, Germany, Italy, Lithuania, Poland, and The Netherlands. In each of the target countries, the upgrading process is initiated at concrete DH systems of the so-called Upgrade DH demonstration cases (demo cases) (Figure 1). The gained knowledge and experiences were further replicated to other European countries and DH systems in order to leverage the impact.

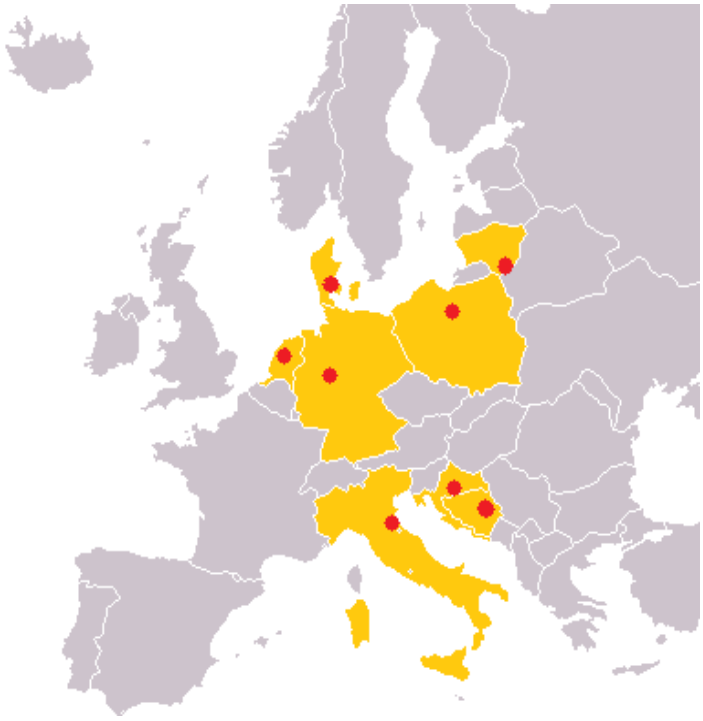

Figure 1: Upgrade DH target countries and demo cases

In order to outreach the experiences and results gained in the Upgrade DH project, replication cases were supported, besides the demo cases. This action consisted of continuous involvement, cooperation and information sharing with the follower cases. Replication cases were provided priority access to project results, were invited to Upgrade DH events and benefitted from direct expert support for the upgrading of their DH system by the Upgrade DH expert partners.

In total, 8 replication cases (networks/cities) were selected based on most promising upgrading potentials: Høje Taastrup (Denmark), Kakanj (Bosnia and Herzegovina), Karlovac (Croatia), Mehren (Eifel, Germany), Næstved (Denmark), Sarajevo (Bosnia and Herzegovina), Širvintai (Lithuania) and Verona (Italy).

The present report summarises all activities conducted in the framework of expert support for replication cases interested in retrofitting DH networks and impact achieved.

2 Overview of the replication cases

Table 2: Overview of the Upgrade DH replication cases

City / network (country)	Responsible UpgradeDH partner	No. of connected substations / heat users / heating area [m^2]	Length of the DH system [km]	Current annual heat supply [GWh]	Estimated heat losses	Current heat generation mix	Owner	Relevant demo case
Høje-Taastrup Municipality (Denmark)	COWI	6.820 connected heat users	236 km	295 GWh	17%	60% CO2-neutral energy sources	Høje Taastrup Fjernvarme amba Owned by the customers (amba)	Middelfart, DK Puremerend, NL
DH Kakanj (Bosnia and Herzegovina)	EPBiH	39 substations 240.000 m^2	Hot water pipeline: 22 km Warm water pipeline: 128 km	60 GWh	25%	coal	JP 'Grijanje' d.o.o. Kakanj (public company)	Tuzla, BiH
Karlovac DH (Croatia)	UNIZAG FSB	8094 heat users	21 km	66.3 GWh heat supplied	11%	natural gas/oil	municipality	Sisak, HR
Mehren (Eifel, Germany)	AGFW	3 industry customers	0.7 km	≈ 20 GWh (2019)		Biomass	Bioenergie Vulkaneifel GmbH	n/a
Næstved (Denmark)	COWI	5,141	108 km Main pipes / 77 km Service pipes	234 GWh	18%	98% heat from waste incineration	Næstved Fjernvarme A/S (public company)	Middelfart, DK

DH Sarajevo (Bosnia and Herzegovina)	EPBiH	198 substations 51.317 heated apartments 2.763 heated premises	83 km	Total installed capacity 502 MW Total thermal engaged capacity 333 MW		natural gas	'KJKP Toplane-Sarajevo' d.o.o. Sarajevo (public company)	Sisak, HR Marburg, DE
DH "Sirvintu siluma" (Širvintos District Municipality, Lithuania)	LDHA	108 substations, 2164 users, 156177 m^2	13 km	29.9 GWh in 2017	15%	wood biomass	Širvintos District Municipality	Salcininkai, LT
Verona (Italy)	OPTIT	1414 substations 1414 buildings (20.000 apartments) 12.262.868 m3	127 km (double pipes)	220 MWt (50 MWt from CHP, 5 MWt from heating pump, 165 MWt from boiler); 320 GWht (gross value); 275 GWh (net value)	14%	Natural gas 65% of heat from cogeneration 5% from boiler	AGSM Verona spa	Marburg, DE Ferrara & Bologna, IT

3 Actions in the follower cases

The following sections describe activities conducted in the framework of expert support for replication cases, including current situation and challenges, participation in the Upgrade DH events, direct expert support and impact achieved.

3.1 Høje Taastrup (Denmark)

Høje Taastrup Fjernvarme a.m.b.a. (Hereafter: Høje Taastrup DH) is the district heating company located in Høje-Taastrup Municipality. It is a public company owned partly by the Municipality and partly by the customers.

Høje Taastrup DH is characterized by a total network length of about 240 km pipes and supplies approximately 7,000 buildings for a total heated area of 3,200,000 m².

Høje Taastrup DH is connected to a large district heating transmission and distribution network called VEKS, which supplies large part of the Greater Copenhagen area. The largest part of the heat delivered by Høje Taastrup DH is supplied by VEKS, which receives heat from CHP plants and waste incineration plants. In Høje Taastrup, six boilers are installed mainly to supply the peak demand. Lastly, up to 15% of the heat is produced locally from solar heating and from the co-production of heating and cooling with several large heat pump installations. In 2017, the total heat sold by Høje Taastrup DH was approximately 295 GWh, with a heat loss of approximately 17% compared to the delivered (sold) heat.

Høje Taastrup DH continuously works on keeping the network updated, focusing among the others, on lowering the flow and return temperature to reduce the heat loss, the renovation of the outdated pipes and the optimization of co-production of heating and cooling. Furthermore, Høje Taastrup DH keeps a continuous dialogue with the customers, offering subscription scheme and service scheme for the district heating units installed at the users. In general, thanks to the continuous work done by the DH company, the network has already good performances, even though different neighbourhoods need to be renovated and updated. An example of district that need to be upgraded is Taastrup Have, which is located on the east from the center of Høje Taastrup.

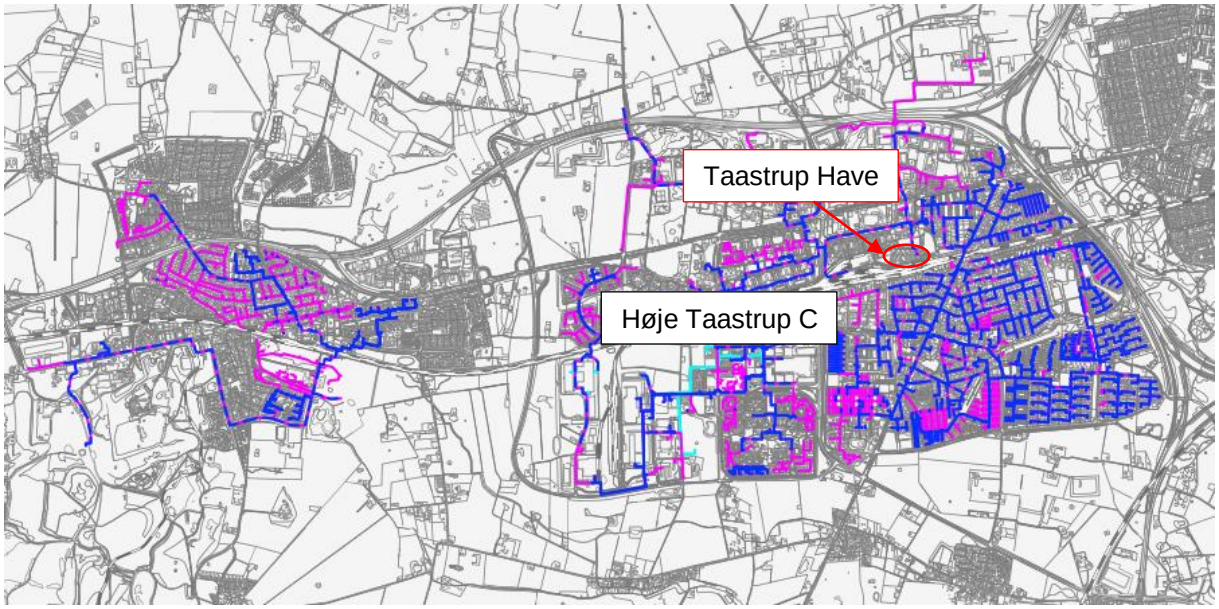

Figure 3. Overview of Høje Taastrup district heating network

3.1.1 Participation in the Upgrade DH events

Table 2. Participation of Høje Taastrup DH company in Upgrade DH events

Event (date, place)	Event description	Who participated	Outcomes following participation
Innovation Workshop and Study Tour 8-10 Oct. 2019	Following the Upgrade DH progress meeting held in Copenhagen on the 8th of October 2019, a workshop study tour was organized in collaboration between Upgrade DH and COOL DH consortiums.	Upgrade DH partners and COOL DH partners.	During the second day of the study tour, Høje Taastrup DH presented the company and all the characteristics of the network. Afterwards, the demo site related to COOL DH project was presented and visited as well as a nearby solar panel plants, which directly supply the district heating network. The presentation and the site visit gave the possibility to discuss and share inputs and ideas about the network and further upgrade potentials.

3.1.2 Direct expert support for the upgrading of DH system

Høje Taastrup DH has a good and continuous collaboration with the consulting company COWI. Upgrade DH project gave another possibility for collaboration with the definition of areas where it is possible to optimize the performance of the network.

Taastrup Have is a residential district composed by 352 apartments for a total heated area of 20,094 m² divided in 15 blocks built around 1965. The main DH supply is in Block O, where the main heat exchanger is located. Afterwards, an internal network delivers heat to the other buildings. There are in total eight technical rooms in eight different blocks each equipped with a domestic hot water tank. The eight technical rooms also supply the remaining buildings through the internal network. The space heating system is equipped with mixing loops in each block. The radiators in the buildings are from the sixties, which were normally designed for supply/return temperatures at 80/60°C. In general, the technical installation at Taastrup Have are quite outdated and not ready for lower supply temperature. Høje Taastrup District Heating has measured the average return temperature from the district to be between 45°C and 46°C in the period 2017-2019.

To lower the supply temperature to 70-75°C in winter as well as the return temperature, which is expected to reach 41°C, the technical installation in the neighbourhood need to be upgraded. Some upgrading measures are suggested in the following bullet points:

- Direct connection from DH network to each block, with the implementation of a technical room in every block.
- New water tanks and DH heat exchanger in every block.
- Radiator replacement (where not ready for low temperature supply).
- New thermostatic valves with sensor for the radiators.
- Reduction of DHW pipes and circulation pipes in the ground.
- Eventual reduction of building management system (BMS) subscription.

Based on previous experience, it is expected that the changes in the technical installations are not enough to ensure a lower return temperature, but the renovation of the building envelope must be considered as well. As first step, the replacement of the old windows and the insulation of the roof might be considered.

3.1.3 Impact of the Upgrade DH support

As it was mentioned in the previous paragraph the residential area Taastrup Have needs an upgrading of the heating system. The following analysis was conducted to evaluate the different solutions that can be implemented, such as:

- New heating system in the building, with new heat exchanger, buffer tanks and new piping system in the boiler rooms, implemented in all the 15 blocks.
- New DH network with direct connection of each block.

- Two new radiators per apartment with new thermostatic valves.

Table shows the investment costs for the upgrading measures. The boiler rooms are going to be renovated where already existing, while new heating systems will be established were, they were not implemented, so there will be in total 15 new boiler rooms.

A new DH network is expected to be established, which will directly supply each building from the public DH system, instead of having a local 4 pipe heating network. In that way, the housing association will not be responsible for the maintenance and upcoming major overhaul of the present local (internal) distribution network and will not pay for the internal heat loss. The cost is set as negative since the implementation of the network is seen as an avoided expense, which is considered as a main driver. In fact, it is expected to be done by Høje Taastrup DH company, which is interested in the investment, as it helps the total system temperature level in DH system to be lowered also outside this specific served area of Taastrup Have. The finance is secured as the earnings from the heat sale is reinvested in the continued network upgrading. If the network is not renovated by the DH company, it is going to result as an expense. And as it is at present, it will be a burden for the building association, since the network is old and has high maintenance costs. With the proposed solution it will instead be shared in the cooperative of the owners/users of the DH company.

Lastly, it is assumed that 1-2 radiators per apartment must be changed to allow the lower supply temperature and reduce the return temperature. New thermostatic valves are also expected to be installed, which will ensure a better heat supply to the apartments and a lower return temperature.

Table 3. Investment cost for the upgrading measures (for the housing association)

Upgrade measures	
New heating system in buildings	604.839 EUR
New DH network	-256.586 EUR
New radiators and thermostatic valves	473.118 EUR
Contingencies (additional 10%)	82.137 EUR
Total investment	***903.508 EUR***

Table shows the savings that can be achieved with the implementation of the upgrading measures. The actual high return temperature results in an extra fee that the building association must pay. The tariff is based the average return temperature (degrees above the reference temperature) and the heat consumption (MWh). For lower return temperature than the reference one, the housing association will on the contrary receive a bonus. It was calculated that the upgrading measures can lead to a reduction of 6°C of the return temperature.

An extra saving will be achieved thanks to the new thermostatic valves, which will allow the optimization of the energy use with an expected energy saving on the heating demand of approximately 3%.

The removal of the internal DHW circulation pipes will result in lower heat loss payed by the housing association. The reduced heat losses are optimistic since the actual condition of the internal pipes in not known. Lastly, the new configuration of the DH network, with the new boiler rooms in each building will reduce the heat losses from the network paid by the building association.

Extra savings will be achieved thanks to the new equipment installed which allows to achieve a better efficiency in terms of electricity use and lower O&M costs.

Table 4. Annual savings achieved with the implementation of the upgrading measures

Savings

Lower return temperature	14.026 EUR
New thermostatic valves	2.801 EUR
Removed DHW circulation pipes	1.554 EUR
No heat losses from DH network	6.507 EUR
Electricity savings from main pumps	4.032 EUR
Savings in O&M	10.081 EUR
Control system savings	4.704 EUR
Total savings	***43.706 EUR***

A quick evaluation of the investment showed that the simple payback time is about 21 years, which is in line with the expected lifetime of the new equipment. Looking at the investment, it appears that for low interest rates, the investment results convenient for the housing association, especially it may be considered that the required investment is already available from previous savings on the planned maintenance account with negative interest, so that a bank loan is not required. Supplementary finance can be provided by guaranteed loans for housing associations is presently available at interest rate of about 2%.

Table 5. Overview of the economic results of the upgrading measures

Interest rate	0%	2%	4%
NPV	407.667 EUR	73.870 EUR	-142.063 EUR
IRR	2,6%		
PBP	20,7		

In terms of environmental impact, it is possible to calculate the avoided CO_2 emission achieved with the upgrading measures. The CO_2 emission factor for the year 2020 presented by the DH heating company is equal to 54.5 kg/MWh. The reduced heat loss from circulation assumed equal to 27.5 MWh/year leads to a yearly reduction approximately equal to 1500 kg/year.

In the same way, the introduction of new valves can lead to a heat demand reduction about 3%, with the consequent CO_2 reduction of 2700 kg/year.

Regarding the implementation of the new DH network, it is estimated a minimum reduction of 545 kg/year. The calculation is based on the simulation of the heat loss from the actual network using Series 1 DH pipes. It is expected that due to the condition of the actual network the heat loss is higher.

3.2 Javno Preduzeće Grijanje d.o.o. Kakanj (Bosnia and Herzegovina)

Javno preduzeće Grijanje d.o.o. Kakanj (hereafter: JP Grijanje Kakanj) is a public company founded in 1986, which deals with distribution of heat energy. Thermal energy is being produced by a combined heat and power facility in Kakanj, owned and operated by JP Elektroprivreda BiH d.d. – Sarajevo.

Average annual heat consumption is ca. 60.000 MWh which covers about 240.000 m^2 of heating space. The heat energy distribution is done via 39 substations which are located in the Kakanj city. The hot water pipeline is 22.000 m long and the length of the warm water pipeline is ca. 128.000 m. Estimated heat losses are 25%.

JP Grijanje Kakanj underlines the need to increase the efficiency of many existing district heating networks, and thus, to improve the image of heat supply by district heating. Since the objective of the Upgrade DH project is, amongst others, to improve the performance of district heating networks in Europe by supporting selected demo cases which can be replicated on other systems as well, JP Grijanje Kakanj expressed its interest in being a follower case by its Letter of Support for the H2020 Upgrade DH project from the 17th of May, 2019.

3.2.1 Participation in the Upgrade DH events

Table 6: Participation of JP Grijanje Kakanj experts in Upgrade DH events

Event (date, place)	Event description	Who participated	Outcomes following participation
2nd Progress Meeting (12th of April 2019. - Sarajevo)	Within the 2nd Progress Meeting, the 3rd day was organised as an open for external participants event where the district heating sector in Bosnia and Herzegovina has been presented and where BiH's follower cases where given the opportunity to present their systems and challenges faced.	Upgrade DH partners, some external participants and 3 experts from JP Grijanje Kakanj: Mirnes Bajtarević Senad Bajrić Izudin Hrusto	Presentation of the JP Grijanje Kakanj company and district heating system by its experts to the Upgrade DH partners and other external participants present. Discussion on identified challenges. Getting to know Upgrade DH partners and obtaining contacts for possible future cooperation.
DH knowledge sharing Expert Workshop in Bosnia and Herzegovina (12th of July 2021. - Sarajevo)	Overview of district heating sector in BiH - status, perspectives and roadmap for decarbonisation. DHC activities and plans of Tuzla City (demo case), Sarajevo City and Kakanj City (Replication case), Livno City (BPE). Upgrade DH approach and methodology. Upgrading measures for Tuzla City. Presentation of draft National Action Plan for upgrade DHS in Bosnia.	33 participants representing Tuzla distribution utility and EPBiH power utility as demo case, replication cases Sarajevo and Kakanj, Best practice example from Bosnia, International organizations, DH equipment producers, consultancy companies, university, etc.	The following bullets summarize the main outcomes of the discussions and the participating organisations: 1. Energy transition of heat sector is an ultimate. 2. Support of politicians for heat sector transition is essential. 3. Thermal energy law is urgent. 4. Establishment of DH companies association is needed. 5. Formation of the local working group for the DHC network retrofitting projects is essential. 6. Integration of RES modules into DHC networks is ultimate. 7. Possibilities for high-efficient co-generation and utilization of industry waste heat by heat pumps should be investigated in detail.

3.2.2 Direct expert support for the upgrading of DH system

Besides the direct expert support, general support for upgrading of the replication case DH system was provided through some other means as well. Details are provided in Table 7.

Table 7: Support for upgrading of the DH system

Action (date, place)	Description	Beneficiaries	Outcomes
E-mail information on *Catalogue on Best practice instruments and tools for diagnosing and retrofitting of DH networks* publishing and electronic version delivery thereof. E-mail information on *Catalogue on Best practice examples on upgrading projects* publishing and electronic version delivery thereof. (23th of April 2019, Sarajevo)	Upon *Catalogue on Best practice instruments and tools for diagnosing and retrofitting of DH networks* and *Catalogue on Best practice examples on upgrading projects* release, an e-mail information has been provided to the replication case representatives. Within this e-mail, colleagues were provided with electronic versions of the two materials for their further use and distribution amongst their colleagues. Colleagues were informed about the PLANHEAT final event @ Euroheat & Power Congress taking place in May, 2019.	Senad Bajrić	Provision of information on best practice instruments and tools as well as best practice examples and possibilities to initiate further improvements and contribute to benefits in the DH system area.
E-mail information on *Upgrade DH Handbook* publishing. Distribution of the electronic version of the Handbook in Bosnian language. (29th of May 2019, Sarajevo)	Upon *Upgrade DH Handbook* release, an e-mail information has been provided to the replication case representatives. Within this e-mail, colleagues were provided with an electronic version of the Handbook for their further use and distribution amongst their colleagues.	Senad Bajrić	Provision of information on district heating topics and possibilities to initiate further improvements and contribute to benefits in the DH system area.
International Trade Fair on Renewables and Energy Efficiency – RENEXPO BiH (23rd of October 2019, Sarajevo)	The trade fair and congress RENEXPO BiH is the biggest international platform for renewable energies and energy efficiency in the Western Balkan speaking area. Everyone, from experts to beginners, can gather information and discuss the innovation and future potential of water, the regenerative energy source - innovative, ecological, sustainable.	Izudin Hrusto	The meeting at the Renexpo BiH conference was used to inform the representatives of Grijanje d.o.o. Kakanj about the status of the project, implemented and upcoming activities, as well as future EPBiH meetings and replication cases in the Upgrade DH project.
Biannual expert meeting on district heating topics 2019 (07th of November 2019, Tuzla)	Expert meeting on district heating topics held in Tuzla. Distribution of Upgrade DH flyers Distribution of Upgrade DH Handbooks	Senad Bajrić	Provision of the Handbook printouts and information on experience exchange possibilities.

Action (date, place)	Description	Beneficiaries	Outcomes
Meeting in EPBiH premises: Deep Geothermal EAVOR (09th June 2021, Sarajevo)	Deep Geothermal EAVOR for DH systems – Presentation of Technology and discussion on interest for cooperation and Project development with demo case Tuzla and Replication cases Sarajevo and Kakaj.	Senad Bajrić	Demo case and Replication cases will provide: 1. Estimation of temp. gradient (oC / 100 m) for any well for which there is data on the location (or nearby), where it can also be data of shallower wells eg from 500 m or 1000 m or similar. Colleagues from AGFW and EAVOR will then do temperature gradient estimation calculations at greater depths (3000-5000 m). 2. Assessment of the morphological-geological structure at a depth of 3000-5000 m, where there should be no so-called geological faults, ie faults / interruptions at these locations (geologists will know what it is about). These two sets of data need to be provided for the following generally nominated sites: - a. Bukinje, b. site owned by Distribution utility Tuzla, (Distribution utility Tuzla, Kreka, RGF Uni Tz), - b. Ilidza (Sarajevo Heating Plant) - c. Kakanj (Heating Kakanj)

3.2.3 Impact of the Upgrade DH support

JP Grijanje Kakanj benefited from the discussions about replacement of distribution network, since they have launched a project of replacement of old distribution network which started in the meantime and is currently in progress.

Furthermore, all the material from Upgrade DH, which was shared with the JP Grijanje Kakanj, as well as meetings organized within Upgrade DH project, were useful for them. Particularly project of deep geothermal presented to EPBiH by AGFW, and then presented to Bosnian replication cases, was interesting to JP Grijanje Kakanj, which might lead to the launch of investigation on this measure in JP Grijanje Kakanj as well.

Other benefits can be summarised as follows:

- Capacity building;
- Systematic approach to the upgrade opportunities of district heating networks;
- Increased knowledge of the district heating upgrading opportunities;
- Realistic assessment of potential upgrade measures;
- Technical recommendations to improve operation;
- Evaluation of influences caused by individual measures to support prioritization for most efficient operation;
- Close contact to DH branch, DH association and experts for all relevant upgrading opportunities, including contacts to experienced DH planning companies;
- Initiating planning process for multiple necessary technical adaptations and improvements.

3.3 Gradska Toplana Karlovac (Croatia)

Gradska Toplana Karlovac is a municipality owned district heating system located in the city of Karlovac in central Croatia. It covers the heat demand of 7833 end users and is responsible for the production, distribution and the supply of heat. It supplies 66.3 GWh of heat to its end users through 21 km of pipes (trench length). The main production units consist of the natural gas and fuel oil heat only boilers.

One of the biggest problems with the district heating system of Karlovac is its old and outdated distribution system, which has significant heat losses due to bad insulation, but also very high water losses due to the obsolescence of the existing pipes. However, the company is currently working on an project, funded by European structural and investment funds, through which it will replace the majority of the distribution network in the city by the end of 2023.

3.3.1 Participation in the Upgrade DH events

From the beginning of the project, UNIZAG FSB was in contact with the responsible persons from Gradska Toplana Karlovac, in order to provide them with the latest results of the project and discuss possibilities of further help through Upgrade DH. The contact was mostly maintained by emails and phone calls. All the most relevant deliverables were first sent to Gradska Toplana Karlovac as a replication case in Croatia and they were invited to all of the Upgrade DH events in Croatia. UNIZAG FSB partners also met physically with Gradska Toplana Karlovac representatives on 2.9.2021. to discuss further possibilities and present the final results of the project, with the focus on the upgrading measures analysed for the FH system of Sisak. Gradska Toplana Karlovac representatives also agreed to participate at the final Upgrade DH conference in September.

Table 8: Participation of Gradska Toplana Karlovac experts in Upgrade DH events

Event (date, place)	Event description	Who participated	Outcomes following participation
DH knowledge sharing workshop (8.7.2021., Zagreb)	National DH knowledge sharing workshop, where the final results of the project have been presented to the relevant national stakeholders	Hrvoje Klobučar (managing director of Gradska Toplana Karlovac), Tomislav Pukšec (UNIZAG FSB), other relevant national stakeholders	National DH upgrading action plan was presented, among other relevant project results and the proposed measures have been discussed at an informal lunch with the managing director of Gradska Toplana Karlovac. One on one meeting with the representatives of Gradska Toplana Karlovac has been arranged for September
One on one meeting with the representatives of Gradska Toplana Karlovac (2.9.2021., Karlovac)	One on one meeting with the relevant stakeholders from Gradska Toplana Karlovac, mainly the managing director and the technical director	Hrvoje Klobučar (Gradska Toplana Karlovac), Inoslav Latković (Gradska Toplana Karlovac), Tomislav Pukšec (UNIZAG FSB)	Specifically the upgrading measures and the business plan for the DH Sisak have been presented in order to disseminate the benefits of making such upgrades to the system. Both the managing director and the technical director were very interested in the low rate of return for the thermal storage system. They were provided with the Upgrade DH brochure and technical handbook, for further information They were invited to the Final Upgrade DH Conference (and agreed to participate)

Event (date, place)	Event description	Who participated	Outcomes following participation
Final Upgrade DH conference (15.9.2021., online)	Final UpgradeDH conference, which was organised online	Hrvoje Klobučar (Gradska Toplana Karlovac)	As agreed in the previous meetings, the director of Gradska Toplana Karlovac participated at the final Upgrade DH conference in order to further increase the knowledge about different upgrading issues and network with other relevant stakeholders from all around Europe

3.3.2 Direct expert support for the upgrading of DH system

Gradska Toplana Karlovac contacted UNIZAG FSB very early into the project, interested in the project results. Hence, direct support was provided throughout the project lifetime by the experts of UNIZAG FSB. This was done mostly in the form of the email communication, especially due to the COVID 19 situation. All the relevant project material and deliverables/reports were first sent to the representatives of Gradska Toplana Karlovac and were discussed with the experts of UNIZAG FSB. The main issues which were discussed were the high water losses in the distribution network of DH Karlovac, as well as the old fossil fuel production units. Through the results of Upgrade DH, the management of Gradska Toplana Karlovac was introduced to the technical and economic potential of renewable energy sources for heat production, which will be useful for future planning of Karlovac DH. Furthermore, UNIZAG FSB experts provided information on the economics of distribution network replacement and additional info through the technical handbook. These were used by the management of Gradska Toplana Karlovac while preparing the distribution network replacement project, funded through European Structural and Investment funds.

3.3.3 Impact of the Upgrade DH support

Through the inclusion of Gradska Toplana Karlovac in the Upgrade DH project activities as a follower case, the management of Gradska Toplana Karlovac increased their knowledge of the district heating upgrading opportunities. They further benefited from the discussions about the distribution network replacement, since they were preparing a replacement project which started in the meantime and is currently in progress. All the material from Upgrade DH, which was shared with the management of Gradska Toplana Karlovac was useful for them, especially in terms of gaining insights into the potential upgrading measures in Karlovac DH. Particularly thermal storage integration, as a measure which was analysed in detail for Sisak DH and which proved to be specifically feasible, was interesting for the management, which might lead to the implementation of this measure in Karlovac DH as well.

3.4 Mehren (Eifel, Germany)

Mehren is a small town with round 1,400 inhabitants, located in the western part of Germany (Close to the boarder of Belgium and Luxemburg) in the federal state of Rheinland-Palatinate.

Figure 3: Location of Mehren (source: google maps)

Near Mehren (around 1 km outside) there is a small industry area with a few companies of different businesses. Planned by a few local businessmen the idea to build a biomass motor CHP plant was initiated and starts operation in 2009 (some impressions of the CHP in Figure). In addition to the current heat demand, future ambitious expansion plans of the industrial area were considered. The power plant is able to supply around 1.4 MW electrical power and 5 MW thermal power. For various reasons (e.g. financial crisis) an expansion of that area began to stagnate and the operation of the plant became more challenging than expected. Different companies with different levels of experience tried to operate the plant until an official receiver was called by the main investor. Within a year numerous maintenance and investments were made which ensured a basic operation of the power plant. After the basic supply for the connected customers could be ensured different inefficiencies of the system were detected. At this point AGFW offered support for responsible operators of the Mehren's MCHP plant and the opportunity to join the Upgrade DH project as Germany's follower case. The document for official participation in the project Upgrade DH was signed in September 2019.

Figure 4: Impressions from CHP Mehren

3.4.1 Participation in Upgrade DH events

Table 9: Overview on Upgrade DH event participation

Event (date, place)	Event description	Who participated	Outcomes following participation
3rd progress meeting of Upgrade DH (08.10.2019, Copenhagen, Denmark)	progress meeting of Upgrade DH expert consortia	Mr. Keller, Mr. Smeets PhD	first contact to international consortia with different experts
study tour (09. - 10.10.2019, Denmark)	study tour for target country stakeholders to best practice examples	Mr. Keller, Mr. Smeets PhD	excursion to best practice examples and coaching input for optimisation possibilities and solutions.

3.4.2 Additional Upgrade DH support

- Handbook – sent as hard copy and download link on website
- Regular updates to public project deliverables and webinars
- Individual coaching and calculations on
  - Relevant details on cogeneration law (KWKG)
  - Heat-exchanger boundary conditions
  - Technical issues of the DH system in general
  - Business cases and plans (also with stakeholders)

- Showing opportunities for switch from direct connected customers to a substation (see Figure)

- Meetings in Mehren
  - 02.09.2019 – Analysis of cogeneration law
  - 25.11.2019 – Business plans
  - 07.02.2020 – Technical optimisation
  - Since March 2020, the ongoing Corona situation prevented further on-site appointments. However, support was continued through various phone calls, mails and web meetings.
- Additional
  - Include Mehren in a national monitoring project to get valid high-quality data from the current situation

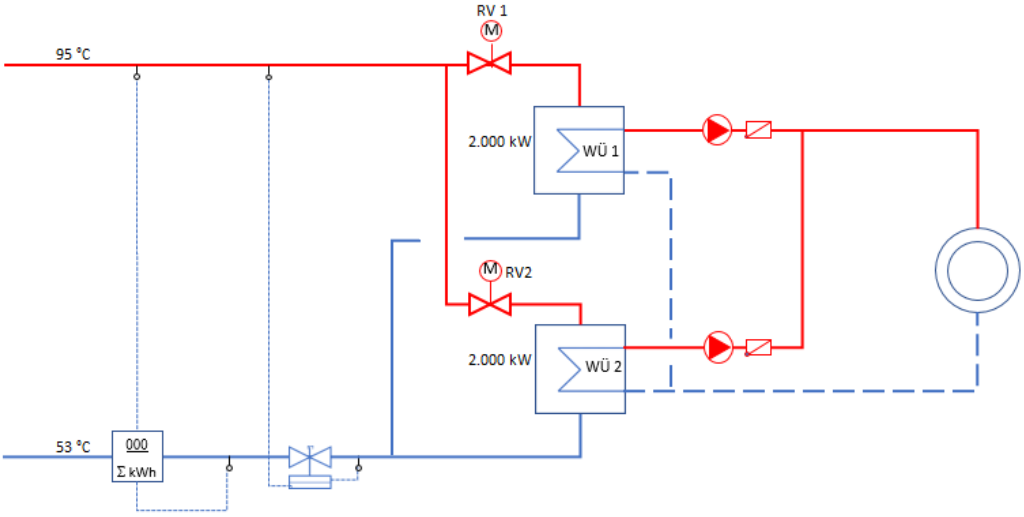

Figure 5: Exemplary substation for currently directly connected major customer

3.4.3 Direct expert support to upgrade the DH system

- Basic discussion on general optimisation opportunities;
- Contacts to relevant experts and institutions of the whole DH supply chain;
- Initial consultation on subsidies requirements and framework conditions with experts of AGFW e.V.;
- Supporting/ discussing monitoring activities for digital control of the DH system (see an example in Figure);
- Basic discussions on currently valid rules and standards;
- Analysis of technical issues for different expansion strategies;
- Technical analysis of customers with negative influences on the overall system;
- First technical rough analysis of the overall technical system on the heat side;
- Support the research for lost technical documentation of installed plant parts;
- Providing relevant basic information to potential cold-out-of-heat approaches.

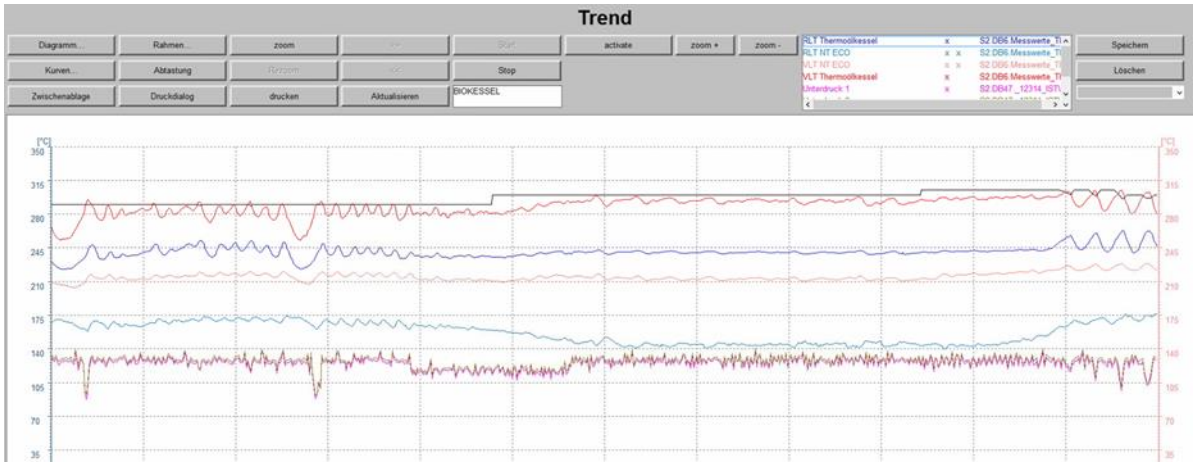

Figure 6: Screenshot of some monitoring data for discussion

3.4.4 Impact of the Upgrade DH support

- Better overall system understanding;
- Realistic estimation of potential upgrade measures;
- Technical recommendations to improve operation;
- Evaluation of influences caused by individual measures to support prioritization for most efficient operation;
- Close contact to DH branch, DH association and experts for all relevant upgrading opportunities during the next 5-10 years;
- Initiating planning process for multiple necessary technical adaptations and improvements – providing contacts to experienced DH planning companies.

3.5 Næstved (Denmark)

Næstved Fjernvarme a.m.b.a. (Hereafter: Næstved DH) is the district heating company located in Næstved Municipality. It is a public company partly owned by the Municipality and partly by the consumers.

The DH networks in Næstved covers around 50% of the heating demand in the entire municipality, while the city center is approximately 100% supplied by DH. For the future, the municipality aims continue developing and expand the DH network, reaching 90% of the total heat demand covered by DH within 2035.

In 2019, the total heat production amounted to 234 GWh, while the network heat loss was about 18% of the total production. Regarding the heat sources, the 98% of the heat comes from waste incineration and the remaining 2% is produced from natural gas.

The DH network in Næstved Municipality is already characterized by good performances. However, the DH company continues to update the network with high focus on the production but also on the distribution and the optimization of the heat consumption at the users. Furthermore, Næstved DH in the last years invested in the implementation of smart energy meters in the network, which can deliver a huge amount of data that can be used to optimize even more the heat supply as well as the maintenance of the network.

3.5.1 Participation in the Upgrade DH events

Table 10. Participation of Næstved DH company in Upgrade DH events

Event (date, place)	Event description	Who participated	Outcomes following participation
Innovation Workshop and Study Tour 8-10 Oct. 2019	Continuous collaboration between COWI and Næstved District Heating	COWI and Næstved District Heating	The continuous collaboration between COWI and Næstved District Heating is not only limited to the normal work related to the DH maintenance and expansion. The collaboration has focus also on the development of the heat loss calculation tool, which use the data from the smart meters installed in the network to evaluate the condition of the network and optimize the maintenance tasks.

3.5.2 Direct expert support for the upgrading of DH system

Næstved DH has started a collaboration with the consulting company COWI aiming to use the large amount of data available after the implementation of smart meters in the network.

The aim of the collaboration was to develop a new heat loss calculation tool, which could estimate the losses from the pipes in the network to understand where the pipes needed to be replaced. Through the combination of the Termis analysis and the measurements performed by the energy meters placed in the network, it is possible to evaluate the condition of the network, with focus on the service pipes. In particular, the analysis highlights the pipes that have higher heat losses. In this way, it is easier to allocate the resources for the renovation on the network. Figure presents the principle diagram of the heat loss calculation tool.

The combination between the Termis analysis and the measurements performed in the network helps the DH company to evaluate the condition of the network. In this way, it is easier to define the renovation of the network, efficiently allocating the money reserved for the renovation actions. The renovation of the network is no longer related to the experience of the employees or to not verified assumption, but it is based on measurement and analysis of the network.

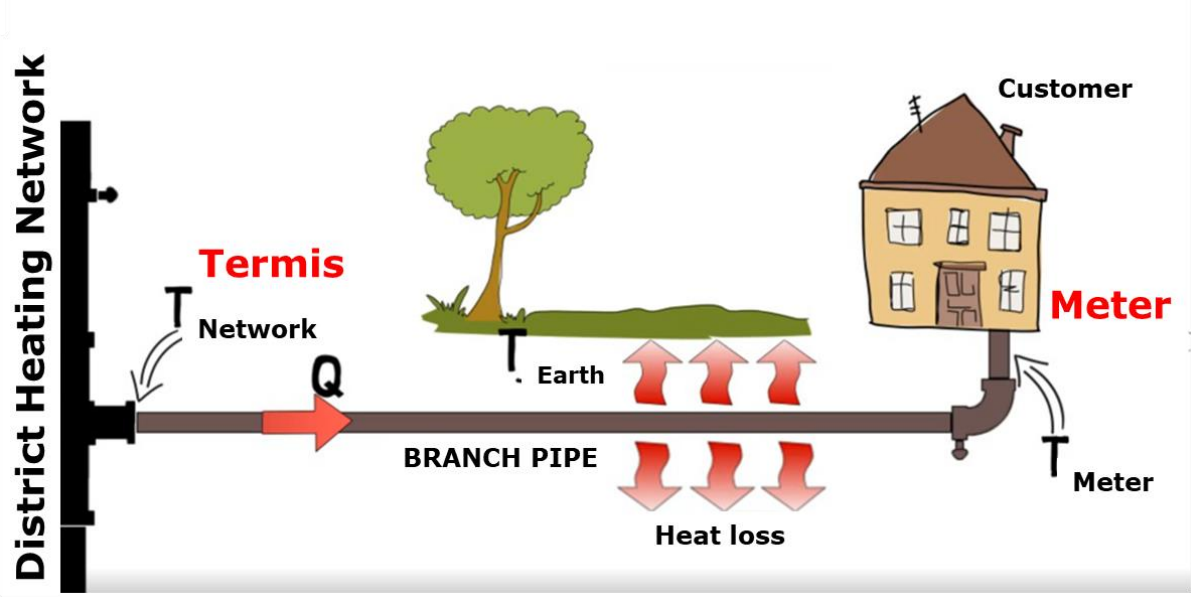

Figure 7. Principle diagram of the heat loss calculation tool

For the implementation of this project, Næstved DH company was nominated for the District Heating Price 2020 in Denmark. The following link shows a short video that explain the project and its contribution in the optimization of the DH network:

https://www.youtube.com/watch?v=NxWO2w2SG4s

3.5.3 Impact of the Upgrade DH support

The heat loss calculation tool has been tested for the first time during the winter 2020-2021. The data collected allowed to deliver some outputs during spring 2021. In fact, the tool was used to make a priority list of the service pipes that have the highest losses in the network. In this way, the maintenance tasks can be optimized.

Figure shows an example of the outputs from the heat loss calculation tool. The tool makes the ranking of the worse service pipes based on the average temperature drop. In this way, it is possible to optimize the replacement of the pipes starting for the worse ones, which lead to a better use of the available resources and in long terms also to a more optimized network.

Rank	Kundenr	T_Supply [ºC]	Flow [l/h]	Tf [ºC]	T_Drop [ºC]	T_Drop/m [ºC/m]	Pipe length [m]	City	Address	Nr	Litra	Pipe dimension	Me-dian	AVG(Tdrop/m)	Max(Tdrop/m)
1		82,4	103	73,9	8,5	1,3	6,8	Næstved				LO 22/66 PEX	1,8	1,8	2,5
2		80,2	107	72,9	7,2	1,3	5,4	Næstved				20+20/110	1,6	1,6	1,7
3		79,7	113	73,8	5,9	1,0	5,8	Næstved				26/90	1,5	1,7	3,4
4		75,9	107	68,4	7,5	1,4	5,4	Næstved				26/90	1,5	1,5	1,6
5		84,8	113	78,9	6,0	0,7	8,3	Næstved				ukendt	1,4	1,4	1,9
6		81,3	100	75,5	5,9	1,1	5,2	Næstved				20+20/110	1,4	1,4	2,1
7		82,4	100	74,7	7,7	1,2	6,5	Næstved				LO 22/66 PEX	1,4	1,4	1,6
8		82,4	108	75,8	6,6	1,1	5,7	Næstved				ukendt	1,4	1,3	1,4
9		84,2	122	79,5	4,7	0,7	6,4	Næstved				LO 22/66 PEX	1,3	1,5	2,6
10		82,5	126	57,8	24,7	1,2	21,4	Næstved				ukendt	1,3	1,3	1,4
11		80,0	119	75,9	4,1	0,8	5,0	Næstved				22/77	1,3	1,3	2,1
12		81,6	101	73,3	8,3	0,8	9,9	Næstved				ukendt	1,2	1,2	1,6
13		81,2	115	75,4	5,8	0,9	6,7	Næstved				20+20/110	1,2	1,2	1,5
14		78,6	113	71,8	6,8	0,8	8,2	Næstved				26/90	1,2	1,2	1,5
15		78,8	130	74,7	4,1	0,7	5,6	Næstved				AL 20/77 AluFlex	1,2	1,2	1,6
16		79,6	105	77,7	1,9	0,1	14,0	Næstved				LO 28/77 PEX	1,1	1,1	1,9
17		67,1	403	62,9	4,2	0,8	5,5	Næstved				26/90	1,1	1,1	1,5

Figure 8. Results from the heat loss calculation tool

Assuming a heat loss reduction of approximately 7 W/m from the service pipes and an average pipe length of 7.5 meters (double pipes) per customer, the potential heat loss reduction from the replacement of 20 pipes per year is approximately 9.2 MWh. This corresponds to a CO_2 reduction of about 1463 kg per year, based on the CO_2 emission factor in 2020 equal to 159 kg/MWh. The strong point of the heat loss calculation tool is that it avoids eventual extra costs for maintenance in case of failure of the pipes in worse conditions and at the same time the heat loss reduction is achieved earlier that without the tool.

3.6 KJKP Toplane – Sarajevo d.o.o. (Bosnia and Herzegovina)

KJKP Toplane – Sarajevo d.o.o. (hereafter: KJKP Toplane) is the Cantonal Public Utility Company for heat production and distribution in Sarajevo, founded in 1977. It is the largest district heating system in Bosnia and Herzegovina. The main fuel is natural gas, whereby alternative fuels are extra light and heavy fuel oil. Within KJKP Toplane, there is no cogeneration plant for combined heat and electricity production.

The total installed capacity of the plants is 521 MW and the total engaged thermal capacity is 378 MW. It consists of a large number of bigger and smaller area boiler plants (139) with independent distribution networks of total length of 84 km. The systems are with hot water or warm water with installed power ranging from 300 kW to 56 MW. The average annual heat production is ca. 430 GWh for 51.317 heated apartments and 2.763 heated business premises. The average system efficiency is 83%. Remote control and monitoring system is implemented at 40% of all plants and individual heat metering system is established for ca. 3.500 apartments and business premises.

KJKP Toplane underlines the need to increase the efficiency of many existing district heating networks, and thus, to improve the image of heat supply by district heating. Since the objective of the Upgrade DH project is, amongst others, to improve the performance of district heating networks in Europe by supporting selected demo cases which can be replicated on other systems as well, KJKP Toplane expressed its interest in being a follower case by its Letter of Support for the H2020 Upgrade DH project from the 29th of May, 2019.

3.6.1 Participation in the Upgrade DH events

Table 11: Participation of KJKP Toplane experts in Upgrade DH events

Event (date, place)	Event description	Who participated	Outcomes following participation
Small study tour during the 2nd Project Meeting to the District heating system Tuzla (11th of April 2019, Tuzla)	Within the 2nd Progress Meeting, a small study tour has been organised to visit and discuss issues at the district heating Tuzla system. Participants visited the CHP Tuzla of the company JP Elektroprivreda BiH and the district heating system installation and control centers of the company Centralno grijanje Tuzla.	Upgrade DH partners, some external participants and 5 experts from KJKP Toplane: Nirha Kozica Adnan Škulj Nejra Mulaosmanović-Tanjo Nihad Kurtalić Asmir Salihović	Possibility to see system components on site and discuss and exchange every-day working practice, problems and possible solutions implemented so far.
2nd Progress Meeting (12th of April 2019. - Sarajevo)	Within the 2nd Progress Meeting, the 3rd day was organised as an open for external participants event where the district heating sector in Bosnia and Herzegovina has been presented and where BiH's follower cases were given the opportunity to present their systems and challenges faced.	Upgrade DH partners, some external participants and 4 experts from KJKP Toplane: Adnan Škulj Nejra Mulaosmanović-Tanjo Nihad Kurtalić Asmir Salihović	Presentation of the KJKP Toplane company and district heating system by its experts to the Upgrade DH partners and other external participants present. Discussion on identified challenges. Getting to know Upgrade DH partners and obtaining contacts for possible future cooperation.

Event (date, place)	Event description	Who participated	Outcomes following participation
DH knowledge sharing Expert Workshop in Bosnia and Herzegovina (12th of July 2021. - Sarajevo)	Overview of district heating sector in BiH - status, perspectives and roadmap for decarbonisation. DHC activities and plans of Tuzla City (demo case), Sarajevo City and Kakanj City (Replication case), Livno City (BPE). Upgrade DH approach and methodology. Upgrading measures for Tuzla City. Presentation of draft National Action Plan for upgrade DHS in Bosnia.	33 participants from Tuzla distribution utility and EPBiH power utility as demo case, replication cases Sarajevo and Kakanj, Best practice example from Bosnia, International organizations, DH equipment producers, consultancy companies, university, etc.	The following bullets summarize the main outcomes of the discussions and the participating organisations: 1. Energy transition of heat sector is an ultimate. 2. Support of politicians for heat sector transition is essential. 3. Thermal energy law is urgent. 4. Establishment of DH companies association is needed. 5. Formation of the local working group for the DHC network retrofitting projects is essential. 6. Integration of RES modules into DHC networks is ultimate. 7. Possibilities for high-efficient co-generation and utilization of industry waste heat by heat pumps should be investigated in detail.

3.6.2 Direct expert support for the upgrading of DH system

Besides the direct expert support, general support for upgrading of the replication case DH system was provided through some other means as well. Details are provided in Table 12.

Table 12: Support for upgrading of the DH system

Event (date, place)	Event description	Who participated	Outcomes following participation
E-mail information on *Catalogue on Best practice instruments and tools for diagnosing and retrofitting of DH networks* publishing and electronic version delivery thereof. E-mail information on *Catalogue on Best practice examples on upgrading projects* publishing and electronic version delivery thereof. (23th of April 2019, Sarajevo)	Upon *Catalogue on Best practice instruments and tools for diagnosing and retrofitting of DH networks* and *Catalogue on Best practice examples on upgrading projects* release, an e-mail information has been provided to the replication case representatives. Within this e-mail, colleagues were provided with electronic versions of the two materials for their further use and distribution amongst their colleagues. Colleagues were informed about the PLANHEAT final event @ Euroheat & Power Congress taking place in May, 2019.	Admir Džubur	Provision of information on best practice instruments and tools as well as best practice examples and possibilities to initiate further improvements and contribute to benefits in the DH system area.

E-mail information on *Upgrade DH Handbook* publishing. Distribution of the electronic version of the Handbook in Bosnian language. (29th of May 2019, Sarajevo)	Upon *Upgrade DH Handbook* release, an e-mail information has been provided to the replication case representatives. Within this e-mail, colleagues were provided with an electronic version of the Handbook for their further use and distribution amongst their colleagues.	Admir Džubur	Provision of information on district heating topics and possibilities to initiate further improvements and contribute to benefits in the DH system area.
International Trade Fair on Renewables and Energy Efficiency – RENEXPO BiH (23rd of October 2019, Sarajevo)	The trade fair and congress RENEXPO BiH is the biggest international platform for renewable energies and energy efficiency in the Western Balkan speaking area. Everyone, from experts to beginners, can gather information and discuss the innovation and future potential of water, the regenerative energy source - innovative, ecological, sustainable.	Adnan Škulj	The meeting at the Renexpo BiH conference was used to inform the representatives of KJKP Toplane – Sarajevo d.o.o. j about the status of the project, implemented and upcoming activities, as well as future EPBiH meetings and replication cases in the Upgrade DH project.
Meeting in EPBiH premises: Deep Geothermal EAVOR (09th June 2021, Sarajevo)	Deep Geothermal EAVOR for DH systems – Presentation of Technology and discussion on interest for cooperation and Project development with demo case Tuzla and Replication cases Sarajevo and Kakaj.	Mirza Musić Siniša Jovanović	Demo case and Replication cases will provide: 1. Estimation of temp. gradient (oC / 100 m) for any well for which there is data on the location (or nearby), where it can also be data of shallower wells eg from 500 m or 1000 m or similar. Colleagues from AGFW and EAVOR will then do temperature gradient estimation calculations at greater depths (3000-5000 m). 2. Assessment of the morphological-geological structure at a depth of 3000-5000 m, where there should be no so-called geological faults, ie faults / interruptions at these locations (geologists will know what it is about). These two sets of data need to be provided for the following generally nominated sites: - a. Bukinje, b. site owned by Distribution utility Tuzla, (Distribution utility Tuzla, Kreka, RGF Uni Tz), - b. Ilidza (Sarajevo Heating Plant) - c. Kakanj (Heating Kakanj)

3.6.3 Impact of the Upgrade DH support

KJKP Toplane benefited from the discussions about introducing renewable resources into DHS, since they were preparing a project of integration of geothermal energy which started in the meantime and is currently in progress.

Furthermore, all the material from Upgrade DH, which was shared with the KJKP Toplane, as well as meetings organized within Upgrade DH project, were useful for them. Particularly project of deep geothermal presented to EPBiH by AGFW, and then presented to Bosnian follower cases, was interesting to KJKP Toplane, which might lead to the launch of investigation on this measure in KJKP Toplane as well.

Other benefits can be summarised as follows:

- Capacity building;
- Systematic approach to the upgrade opportunities of district heating networks;

- Increased the knowledge of the district heating upgrading opportunities;
- Realistic assessment of potential upgrade measures;
- Technical recommendations to improve operation;
- Evaluation of influences caused by individual measures to support prioritization for most efficient operation;
- Close contact to DH branch, DH association and experts for all relevant upgrading opportunities, including contacts to experienced DH planning companies;
- Initiating planning process for multiple necessary technical adaptations and improvements.

3.7 Sirvintu siluma (Lithuania)

Širvintos is a city in Vilnius County in the eastern part of Lithuania. According to 2020 data, the city has approximately 5500 inhabitants. It is the administrative center of the Širvintos district municipality.

Sirvintu siluma is a municipality owned company founded in 1983. From the beginning, the company is in charge of providing heat energy to households, state authorities and businesses in city and within district.

The company supplies heat to 129 buildings, most of which are multi-story households. The total length of operating networks is 13km. The total annual amount of heat generated in company's owned facilities is 27000 MWh. The heat loss in the network is nearly 15% percent and stands for 4000MWh. Beside new boiler installations, the company has 2 boilers ready for back up operation that date back to 1971. The company produces all of the heat using biomass boilers, using biomass which was bought from state biomass exchange market. Each year the company generates around 332 tons of ash.

The company faces similar problems as the Upgrade DH demo case – Salcininkai DH company. High technological heat loss occurs due to low usage capacity and oversized and old network, as well as low heat generation flexibility, especially in summer months. Therefore, the company is keen to upgrade its current infrastructure in order to increase efficiency and maintain a competing heating price in the city. Company's representatives are keen on Upgrade DH solutions in Salcininkai and look forward to replicate and learn from demo case solutions.

3.7.1 Participation in the Upgrade DH events

Table 13: Participation of Sirvintu siluma representatives in Upgrade DH events

Event (date, place)	Event description	Who participated	Outcomes following participation
Lithuanian knowledge sharing expert workshop (24 May 2021, online)	'Local expert workshop'' was organized in order to discuss Lithuanian demo case possibilities and other	Upgrade DH partners from Lithuania, most DH companies of Lithuania (including Sirvintos – replication case), External speakers concentrating on Salcininkai demo case solutions	Everyone was briefly introduced to Upgrade DH project and demo case – Salcininkai upgrading measures. External speakers concentrated on implementation of previously mentioned upgrading measures. Sirvintos DH representatives were active in the discussion since the familiar DH size and problems might be tackled by replicating the solutions that were applied in Salcininkai
Seminar on low temperature DH (07.03.2019, Vilnius, Lithuania)	Seminar "Gradual transition to low temperature DH network and integration of new energy sources"	most DH companies of Lithuania (including Sirvintos – replication case)	Multiple speakers who presented various DH problems and solutions attended the event. One of the speakers was Upgrade DH partner Optit (Stefano Morgione), who presented network optimization solutions and work in Upgrade DH and local demo case – Salcininkai DH system.

3.7.2 Direct expert support for the upgrading of DH system

Sirvintos DH company had a constant communication and support from LDHA throughout the whole project period. Upgrade DH project gave opportunities to communicate with different DH experts and representatives from various countries. Continuous access to knowledge of various DH sector fields in order to increase the overall performance of DH system was available.

Upgrade DH project Handbook released and printed in Lithuanian language was sent directly to Sirvintos DH system representatives.

The company constantly aimed to increase heat generation flexibility. Due to the ongoing renovation, the current heat generation equipment became oversized, which caused disfunction during summer months. This was one of the major similarities with the Upgrade DH demo-case Salcininkai problems, where immediate actions were necessary. During the project, Sirvintos representatives were active in order to install small biomass boiler so that its generation would be efficient even at the low heat demand periods throughout the year. Sirvintos DH operator is keen to keep DH price as stable as possible in order to sustain the status of the cheapest heating solution. Considering the fact that subsidy schemes ended a couple of years ago, the company involved LDHA, as a bigger player, to liaise with the responsible government institutions concerning similar support mechanisms as in the past.

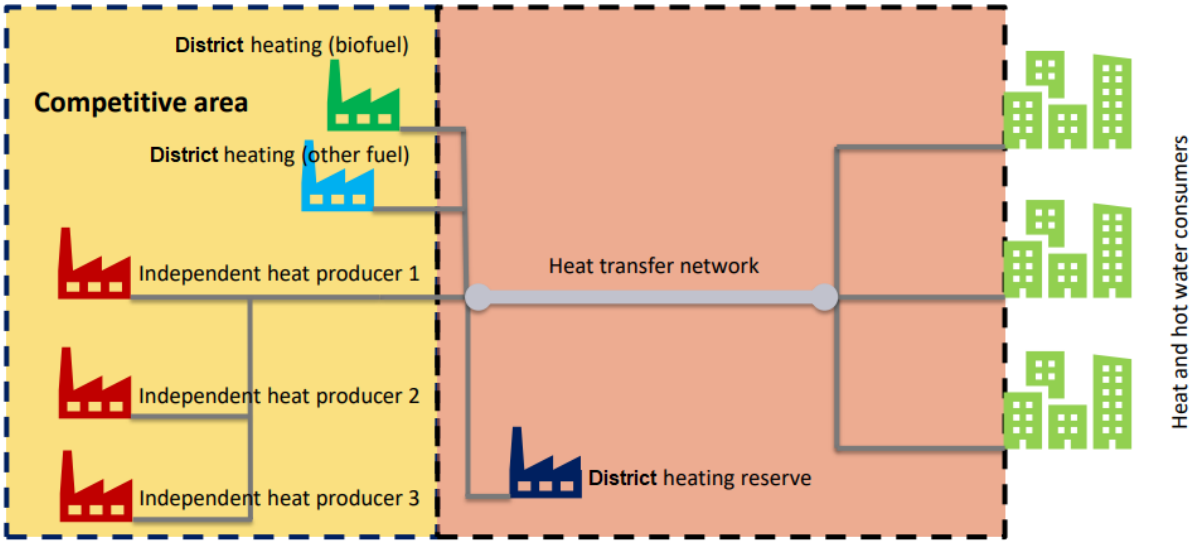

Figure 9. Illustration of heat production competition

Additionally, in order to support the upgrading of the replication case – Sirvintos DH system, LDHA invited representatives to participate in various DH events concerning relevant topics.

Table 14: Online events with the participation of Sirvintos DH system

Event date	Event description	Participants
2021 September 20	Training seminar "Topical issues of personal (customer) service: management of diversity of channels and emotions"	DH companies, DH experts from government organizations and universities based on the relevance of the event topic.
2021 September 13	Expert remote webinar on the topic of corrosion of biomass boilers	
2021 September 6	Expert remote webinar on pipe solutions for the DH sector	
2021 August 30	Expert remote meeting on preparations for 2021/2022 heating season, the purchase of biomass and its rising prices	
2021 August 23	Training seminar "Tax and accounting innovations and practical recommendations"	
2021 August 16	Training seminar “Pollution Tax and Control Innovations in 2021. The latest environmental requirements for business "	

2021 July 19	Expert remote webinar on biofuel boiler and cogeneration power plant efficiency issues.	
2021 July 12	Expert remote webinar, during which the representatives of the Lithuanian heat pump manufacturer IGLU TECH presented their products, services, innovations relevant to heat suppliers.	
2021 June 14	Expert webinar on conditions for design and installation of low temperature DH networks.	
2021 May 17	Webinar on opportunities and obstacles to reduce the operating temperatures of current DH systems	
2021 March 8	Expert meeting “Data scanning, monitoring and management. Accounting of collected data and automation of payments"	
2021 January 25	Expert meeting of experts on the quality of biofuels, problems in the operation of biofuel boilers, on the loss of heat during storage of biofuels	
2021 January 11	Expert Meeting on Trade Electricity Balancing Services	
2021 January 4	Expert meeting on the status of water treatment in DH networks	
2020 December 21	Expert remote meeting on Cogeneration issues, presentation of ORC technology	

3.7.3 Impact of the Upgrade DH support

Sirvintos DH company ’’Širvintų šiluma’’ received access to various expert meetings in which new DH trends in heat production, distribution and consumption were widely discussed. Results of the Upgrade DH project activities were available throughout all project implementation period, therefore the company gained knowledge of upgrading opportunities analyzed in all demo-cases and events that went in parallel to the project actions. The company particularly was interested in Salcininkai demo-case solution for network optimization which results and the system installed were presented and discussed during the knowledge sharing expert workshop.

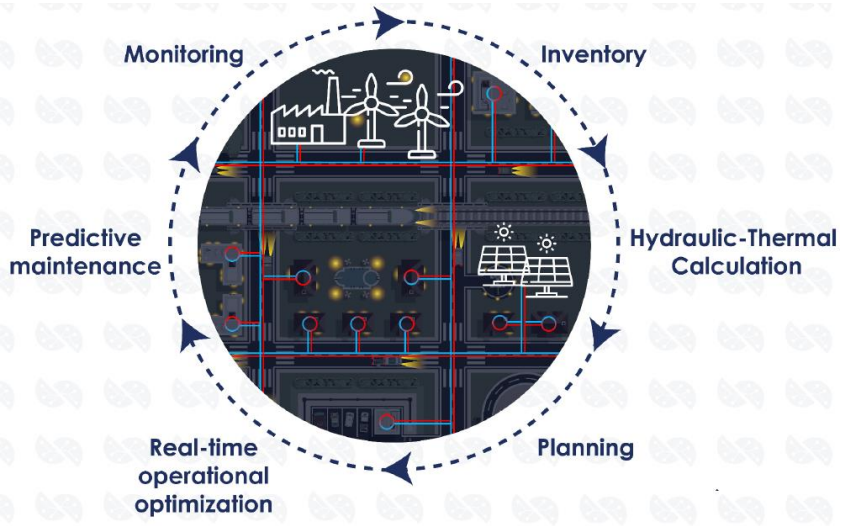

Figure 10: Digitalization of the DH system

Sirvintos DH company is keen to install same or similar solutions in order to track complete work of the system:

- Monitoring
- Inventory
- Forecast of the heat consumption
- Hydraulic-thermal calculation
- Network planning
- Real-time operational optimization
- Predictive maintenance.

This would help the company progress towards low temperature heat network operation, reduce heat loss, increase pump efficiency, reduce CO2 emissions and maintenance costs.

3.8 Verona (Italy)

Verona is a small city located in the north of Italy with approx. 260,000 inhabitants. A portion of the city is served by a district heating and cooling network with total length of 282 km managed by the local utility AGSM Verona.

The system energy demand is covered by a series of distributed generation assets formed by:

- 1 cogeneration facility with thermal capacity of 39 MW_{th} and electric production capacity of 11 $MW_{el.}$ The plant is formed by 5 CHP engines connected to 5 different small heat pumps and 3 large natural gas boilers
- 1 boiler station with total thermal capacity of 3 MW_{th} made of 3 natural gas boilers

Furthermore, the network is directly connected to a local steelmaking facility which provides excess process heat through a series of heat exchangers for a total power 4.4 MW_{th}.

A solar thermal field is also under construction, following a previous feasibility analysis with Solites as one of the key expert partners.

The integration of the excess heat from the steel factory has positive implications, reducing the amount of runtime for the least efficient boilers on the grid. On the other hand, it has increased the complexity in managing the generation assets given the volatility of the heat generation coming from the factory.

Figure 9: Verona location

3.8.1 Participation in the Upgrade DH events

Table 14: Overview of AGSM Upgrade DH participation

Event (date, place)	Event description	Who participated	Outcomes following participation
2nd October 2020, virtual conference	AIRU / Upgrade DH Conference on "the future of DHC in Italy"	Ivan Zambaldo; Marco Cazzanelli	Better awareness of potential of DHC development in Italy, based on Politecnico of Milan and Politecnico of Turin's study, higher recognition of Upgrade DH's role in support of a national action plan, first hand recognition of regulatory and some politicians' positions on DHC future development
15th July 2021, virtual meeting	Presentation to AIRU members digital approaches to optimise energy production	Paolo Zuccato (head of DHC Ops in controlled company (AIM Vicenza)	The option to proceed with a feasibility analysis for the plant in Vicenza is being considered
15th September 2021, virtual event	Final Dissemination Workshop of Upgrade DH "Towards efficient District Heating and Cooling in Europe"	Ivan Zambaldo Federico Vigato	Know-how increase, updates on the developments in Italy following the large AIRU / Upgrade DH conference, recover the study tours that could not be followed on 16th June 2021

3.8.2 Direct expert support for the upgrading of DH system

AGSM, during the study performed with Optit's support, was looking for solutions to reduce the negative implications of being connected to the steel factory, mostly coming from the uncertainty of heat production, and at the same time exploit the full potential of the energy source.

To qualify the problem and understand better the situation, Optit offered to model the energy production system, including the external heat coming from the factory, into its own optimization application. AGSM provided Optit all the data regarding the machines and the historical timeseries to configure and model the system. The objective was then to run a series of scenarios evaluating how to optimize the relationship between the steel factory heat production and the distributed assets on the grid.

At the same time, an analysis was also carried out evaluating the impact of introducing a thermal storage system in two different locations on the network. The introduction of the storages was modelled into the tool with the support of another consortium partner, Solites. The proposed storage location was identified at the steel factory location close to the heat exchangers acting as buffer between the volatile production of waste heat and the DH network. Second location was identified within the boundaries of the large cogeneration facility of "Centro Città". Even in this second case the storage was supposed to act as a buffer between the thermal generation of the various engine, decoupling de-facto production and demand therefore reducing the risk involved with system volatility, and the DH network.

Table 15: Two main scenarios evaluated with AGSM Verona to reduce impact of volatility in waste heat production

	CASE A	CASE B
Description	Addition of a TES with a capacity of 20 MWh at the "Centro Città" site	Addition of a TES with a capacity of 10 MWh between the steel plant and the district heating network as buffer for the peak waste heat supply

Results obtained with Optimization tool	Max. TES capacity used: 10 MWh	Max. TES capacity used: 2 MWh
Thermal storage capacity	175 m³	35 m³

Solites offered its support as expert in thermal energy storage applications during the design and the selection of the best technology to be considered. In a short memorandum for AGSM it was concluded, that for both options the storages would be relatively small for a DH application, with 175 m^3 and 35 m^3 water equivalent. For this kind of application a state of the art short term buffer storage designed as steel tank was suggested. Solites suggested to also consider the long term sustainability and operation concept for the plant in the planning of upgrading measures and moving towards a medium term energy storage system. This includes looking for possibilities to increase the size and feasibility of the thermal storage by considering for example the integration of other highly volatile waste heat sources or the integration of renewable heat sources such as solar thermal in the district heating system. But that would require larger investment from AGSM and therefore further considerations.

A report was developed and provided to AGSM highlighting all the options, the state of the art and similar applications throughout Europe.

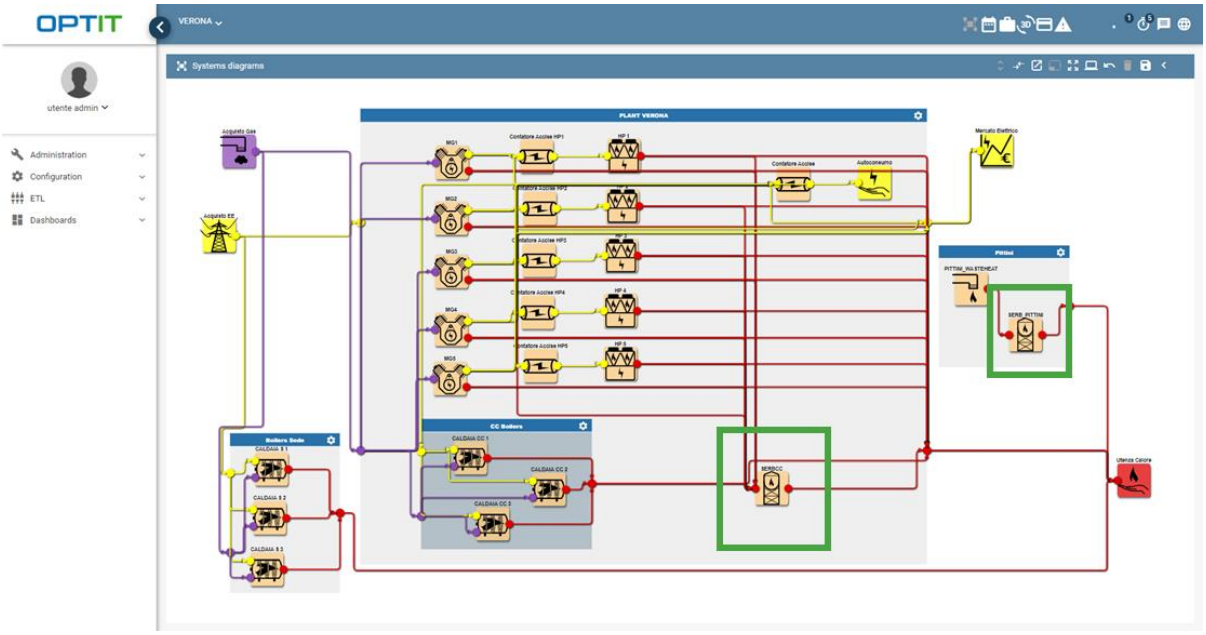

Figure 10: Thermal energy storage integration within Optit's modelling platform

Optit, after configuring the plant, performed a series of optimization analysis both on the short term (from 1 day to 1 week) to long term (from 1 month to 1 year) comparing the model results with the historical data related to 2019. The amount of waste heat energy coming from the factory have been considered the same as the historical data not allowing the model to optimize production which would have given completely inaccurate results.

Further analysis was performed to benchmark our forecasting models against the service used by AGSM to evaluate possible improvement also in demand forecasting and reduce even more the risk involved with the volatility of supply.

The results and conclusions are reported in the following paragraph.

3.8.3 Impact of the Upgrade DH support

The study performed by Optit showed that a small thermal storage system/buffer, either at the centro città plant or the steel plant, does not seem to bring significant economic advantage to the utility. The very detailed analysis performed with Optit's tool showed that the high flexibility of the machines at centro città plant (5 CHPs engines, 3 boiled and 5 heat pumps) was sufficient to reduce the impact of the volatility of heat production coming from the steel plant. The model suggested rather different combination of machines with respect to current policies, turning on and off engines and reducing boiler output, quite often in order to adapt the system to the waste heat production rather than save the excess energy into a thermal storage tank. Low electricity prices also played a big role in determining the advantage of having a thermal buffer to decouple demand and production. The analysis showed that selling the maximum amount of electricity into the market did not have the same advantage as providing flexibility in dealing with the waste heat plant. For instance, the velocity of turning on and off different engines, using different combination depending on availability, maintenance conditions and others, was more important than keeping the engine up and running all time just to sell electricity into the market. Of course, different pricing scenarios may result in different outcomes, yet the awareness of the inherent flexibility of the system is a strong case towards adoption of tools to improve operational planning.

Figure 11: Comparison between historical data and model results showing the different use of CHPs

From an economic perspective the studied showed that a more flexible use of the CHPs engines generates approx. 14% increase in the operative margin of the plant, equivalent to several hundred thousand €/year (the company asked to keep this amount confidential). This is due to multiple factors such as:

- Higher flexibility in the use of different CHPs engines
- Higher shutoff time of the engine particularly when electricity prices are very low
- Better use of the resources during the participation into the capacity market and during maintenance periods

Overall, the project helped AGSM understanding better the necessary steps to improve the operations and to reduce the implications related to a volatile heat production coming from a steel factory. Furthermore, the project gave a better idea on how to integrate different energy sources and thermal storage in the system.

4 Conclusions

As a result of Task 6.2 – Expert support for replication cases interested in retrofitting DH networks – representatives of the follower cases increased their knowledge of the district heating upgrading opportunities, benefitted from the discussions and newly created contacts, as well as technical recommendations from Upgrade DH experts.

8 replication cases (networks/cities) were supported in tackling their specific challenges:

- **Høje Taastrup** (Denmark). The residential area Taastrup Have needs an upgrading of the heating system. Upgrade DH project gave a possibility for expert collaboration with the definition of areas where it is possible to optimise the performance of the network.
- **Kakanj** (Bosnia and Herzegovina) benefited from the discussions about replacement of old distribution network and introduction of deep geothermal.
- In **Karlovac** (Croatia), through the results of Upgrade DH, the management of Gradska Toplana Karlovac were introduced to the technical and economic potential of renewable energy sources for heat production, the economics of distribution network replacement and thermal storage integration.
- The follower case **Mehren** (Eifel, Germany) benefited from discussions on general optimisation opportunities, consultation on subsidies requirements and framework conditions, support in monitoring activities for digital control of the DH system, technical analysis of different expansion strategies.
- **Næstved** (Denmark) has started a collaboration with the experts from Upgrade DH aiming to use the large amount of data available after the implementation of smart meters in the network. The aim of the collaboration was to develop a new heat loss calculation tool, which could estimate the losses from the pipes in the network to understand where the pipes needed to be replaced.
- Through the expert support of the Upgrade DH partners, **Sarajevo** (Bosnia and Herzegovina) benefited from the discussions about introducing renewable resources into district heating system.
- The DH company in **Širvintos** (Lithuania) is interested in Salcininkai demo-case solution for network optimization. This would help the company progress towards low temperature heat network operation, reduce heat loss, increase pump efficiency, reduce CO2 emissions and maintenance costs.
- **Verona** (Italy). The Upgrade DH expert support helped AGSM Verona understanding better the necessary steps to improve the operations and to reduce the implications related to a volatile heat production coming from a steel factory. Furthermore, the project gave a better idea on how to integrate different energy sources and thermal storage in the system.